LONQUIST
FIELD SERVICE

September 13, 2024

From:

Nathaniel Byars, Lonquist & Co. LLC

Julie Shemeta, MEQ Geo Inc.

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

Please find attached the combined monthly deformation report for Sulphur Mines dome with results from the precision tiltmeters and GNSS stations for June and July and the cumulative InSAR monitoring to the end of July 2024.

Additional Notes:

- Due to an unsuccessful acquisition of the scheduled August 23, 2024 SNT satellite image, the report for the most recent August SNT dataset from August 11 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

Nathaniel Byars
Principal Engineer
Lonquist & Co. LLC

Julie Shemeta

Julie Shemeta
MEQ Geo Inc.

Attachment List

A. Tiltmeter/GNSS Data Report - August 2024
B. SNT InSAR report - August 11, 2024
C. TSX/PAZ InSAR report - August 29, 2024
D. Vertical & East-West 2D InSAR report - August 29, 2024

ATTACHMENT A

Tiltmeter/GNSS Data Report - August 2024

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FIELD SERVICE

September 13, 2024

Sergey Samsonov, PhD, InSAR Corporation

Nathaniel Byars, Lonquist & Co. LLC

Julie Shemeta, MEQ Geo Inc.

Re: Tiltmeter/GNSS Data Evaluation – August 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.

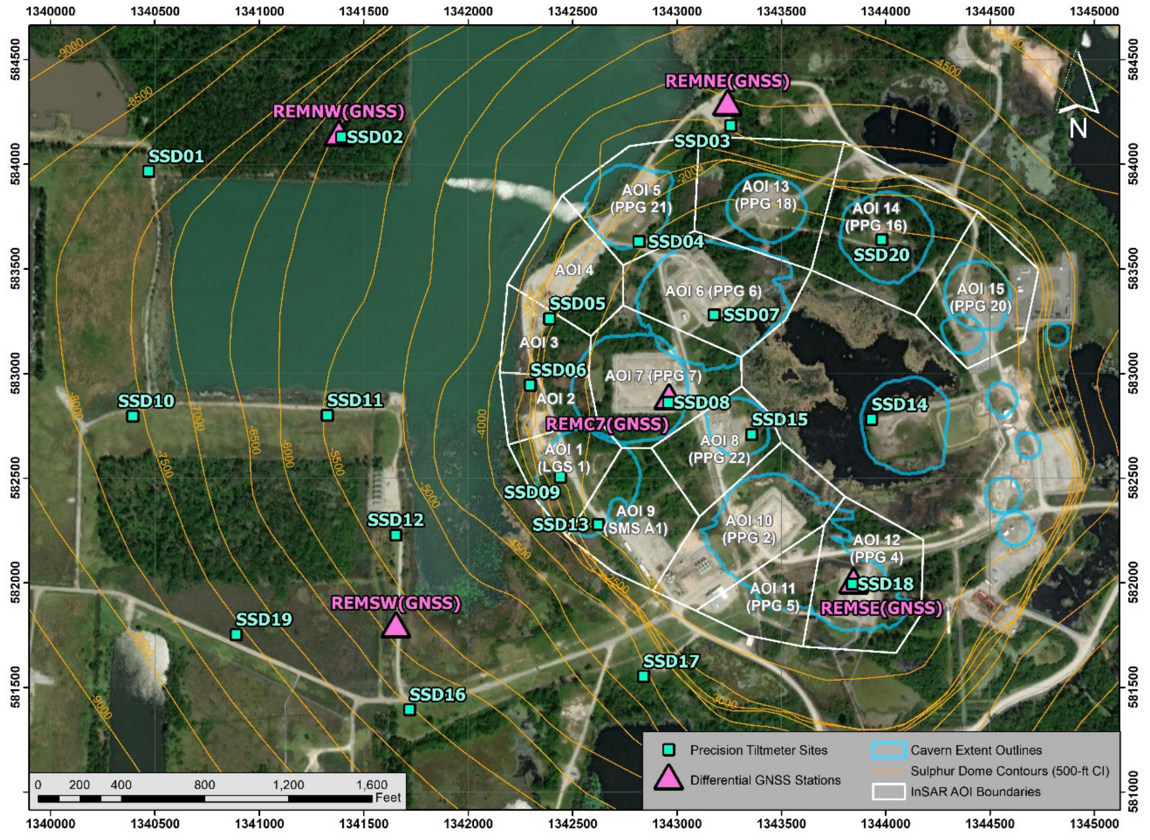


Figure 1. Map of the tiltmeter and GNSS network installed at Sulphur Mines dome. The cyan squares indicate the tiltmeter site locations. The GNSS stations are shown by pink triangles. The InSAR AOI boundaries are shown for reference. The surface projection of the various salt caverns is indicated by 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

Tiltmeter Analysis

Several months of tiltmeter data have been collected and analyzed from the Sulphur Mines Salt dome. A statistical approach was implemented to review the data from each tiltmeter station, and multiple plots were created to identify both long-term and short-term trends in the tilt data. This analysis will help us detect any abnormal deformation behavior related to Cavern 7 in the future. In this report, we present the tilt measurements observed during August 2024.

Tiltmeters are sensors that can measure subtle changes in ground slope in two directions: north-south and east-west. These sensors are highly sensitive and can detect small changes in tilt angle, as little as a fraction of a microradian. One microradian (equivalent to 0.00006 degrees) is approximately the tilt caused by placing a dime under one end of a beam that is one half-mile long (USGS Volcano Hazards Program). When monitoring the Sulphur Mines dome, each tiltmeter site is evaluated individually. Then all tiltmeters are assessed as a network to identify patterns in the data that suggest ground deformation related to subsurface movement near Cavern 7. These patterns are evaluated in relation to prior baseline readings and trends. Tiltmeters can also detect other local physical phenomena such as daily tidal changes and local weather, which may not be related to cavern deformation but can still affect the readings. Systematic daily variations in tilt values are visible at many sites. Precipitation also significantly affects tilt values. Thus, hourly precipitation time series observed at a nearby weather station (Choupique Bayou @ HWY 90) are also provided to help identify precipitation-related signals. The plots for each station are shown in Appendix 1 and described in detail below.

The long-term trend for each tiltmeter. The graphs in the top row display the raw tiltmeter signals (tilt values measured in microradians) observed at each monitoring station during the reported period for both the east-west and north-south directions. In the east-west direction (left graph), a positive tilt indicates the vertical displacement decreases in the east direction (i.e., tilt towards the east). In the north-south direction (right graph), a positive tilt indicates the vertical displacement decreases in the north direction (i.e., tilt towards the north). The red solid line on each graph shows the overall tilt trend, and the slope of the line indicates the annual tilt rate. The coefficient of determination (R2) for the linear model is labeled above the graphs. These values indicate the proportion of the variation in the dependent variable (tilt values) that is predictable from the independent variable (time), ranging from zero (low) to one (high).

Detrended tiltmeter for each component. The graphs in the second row are used to identify small changes in the tilt signals that could be hidden by the overall trend, the raw tiltmeter signals are adjusted (i.e., detrended) by removing the linear model from the raw tilt data. The detrended data is then shown with dashed lines representing the mean value, as well as 1, 2, and 3 standard deviations for that station computed during the reported period. This approach allows for a detailed examination of a station's tiltmeter readings that occurred over short time intervals, which can help to identify any unusual movement compared to what is typically observed at that station.

Precipitation data. The graphs in the third row show hourly precipitation (measured in inches) observed at the Choupique Bayou @ HWY 90 weather station. Both graphs are identical and plotted below the observed tiltmeter readings to simplify the detection of precipitation-related signals.

Daily tiltmeter motion maximum and minimum behavior. The graphs in the fourth row display the daily tilt ranges, calculated as the difference between the maximum and minimum daily tilt readings. The daily ranges are displayed along with the mean and 1, 2, and 3 standard deviation values for that station calculated during the reported period, which are indicated by dashed lines. This provides a quick way to identify any unusual movement compared to what is typically observed at that station.

Tilt direction distribution with respect to Cavern 7. The rose diagram in the fifth row shows how the daily tilt directions are distributed during the reported period. Tilt direction refers to the azimuth determined by the north-south and east-west tilt values for each day. These values are the average of multiple tilt measurements taken throughout the day. Additionally, the magenta line on the diagram indicates the direction to Cavern 7 for each station.

Estimated values. The fifth row also displays several estimated values, including the east-west and north-south annualized tilt rates with standard deviation, calculated during the reported period using linear regression analysis. It also includes the lateral distance of the tiltmeter station from the centroid of the Cavern 7 sonar, as well as the azimuth direction.

Summary of tiltmeter results for August 2024. At most sites, the tilt direction points towards Cavern 7, with a few exceptions at sites like SSD05, SSD15, and SSD18. We are investigating these sites for potential issues with their hardware. It's worth mentioning that the tiltmeter SSD05 was out of service for maintenance from mid-July to early August. The anomalous signal observed at this tiltmeter in early August is a result of the servicing.

We have noticed that anomalously large tilt signals are generally correlated with precipitation. However, the exact pattern is not clear at this time. Not all sites are equally and coherently affected, which might be due to local site conditions or irregular precipitation patterns in the area that cannot be accurately represented by measurements from a single weather station. Significant tilt variations caused by precipitation require manual interpretation, which limits the development of automated monitoring techniques. Additionally, we have observed a few small anomalies in the tiltmeter data that are not related to weather and appear to be linked to local, possibly shallow features in the near-surface, such as movement in the cap rock.

The modeling of ground deformation assuming a Mogi source located at a depth comparable to the depth of Cavern 7 suggests that subsidence with a maximum value of one inch would produce tilt values in the range of -20 to 20 microradians. However, such tilt is too small compared to the long-term tilt observed at some sites, so an advanced network analysis may be required to isolate it. We are continuing to test various computational techniques for identifying such signals when they occur, but first, we need to understand how to remove signals due to precipitation and other shallow processes. Thus, at this time, we are manually looking for trend changes in the tilt values consistently observed at several tiltmeter sites over a period lasting at least a few days.

Based on the tiltmeter data collected during the reported period, there is no consistent pattern of ground movement that suggests deep-sourced deformation and an immediate issue with Cavern 7.

GNSS Analysis

Several months of GNSS data have been collected and analyzed from the five stations positioned across the dome. GNSS data provides absolute measurements of ground position and is a reliable long-term measurement tool, but lacks precision in the short term. For this reason, the full data history starting at the beginning of June 2024 has been evaluated for this report. The plots for each GNSS station are shown in Appendix 2 and described below.

GNSS data measures the location of the GNSS station in space over time. To simplify, we subtract the initial location of the GNSS site from the time series, so the initial position starts at zero. The displacement of the GNSS station from its original position is then calculated by subtracting its current position from the initial position. The results show three displacement or deformation components in the north-south, east-west, and vertical directions. GNSS measurements are affected by atmospheric noise caused by ionospheric and tropospheric disturbances. When measured over a short period (days to a few months), the data appears noisy. Therefore, it is common to display only daily values estimated from measurements taken every few minutes. In the graphs, each daily measurement is represented by an error bar, which indicates the daily mean value and its standard deviation. To better observe the deformation signal in this noisy data, a linear trend computed using linear regression is added to the graphs. The slope of the linear trend represents the annualized deformation rate (measured in inches per year).

It's important to note that the time series of the three components of deformation shown in the graphs includes displacement due to local processes, which are of primary interest, as well as displacements due to tectonic plate motion, which is common to all sites. To focus on local deformation, the tectonic deformation rates estimated at a nearby GNSS station operational for several years (SAS4) are removed from the rates represented by the red line. These tectonic east-west, north-south, and vertical rates are -0.48, -0.02, and

-0.07 inches per year, respectively. The resulting deformation rates in a local reference frame are posted at the bottom of each figure.

GNSS deformation rates: The GNSS-derived deformation rates suggest that there is ongoing subsidence across the dome and potential horizontal motion directed toward Cavern 7. A component of this horizontal motion could be the result of historically recorded deformation toward the dome center. The low precision of the data does not allow for determining trend changes over a short period. The current precision also limits the ability to make reliable comparisons to historically measured subsidence and horizontal motion at the GNSS sites.

The missing July data at the northeast GNSS station (REMNE) was caused by an antenna failure. Data recording resumed in late July after the antenna was replaced. The horizontal motion at this site points to the west, while it is expected to be towards the south. The direction is expected to be corrected as more data is collected and precision improves.
The abnormally fast vertical motion at the NW GNSS station observed in mid-July due to work near the site has stabilized, and data from mid-July to the end of August appears to be quite 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.

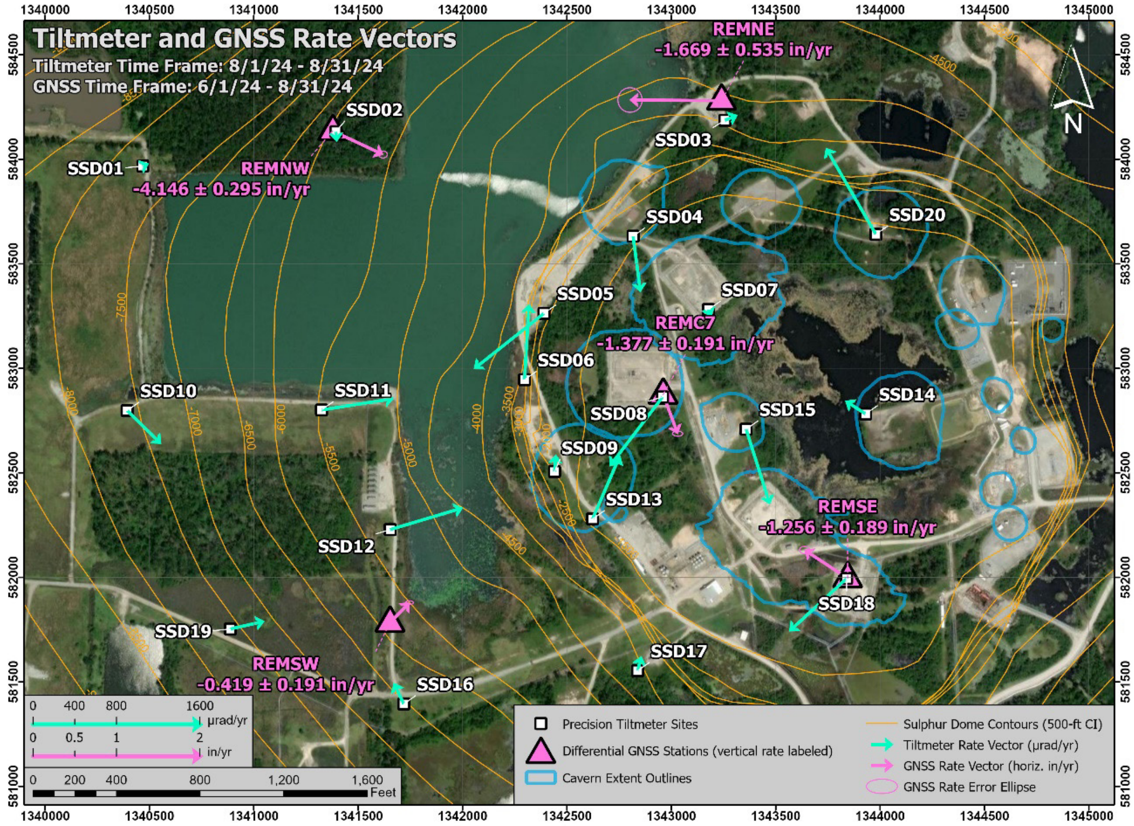


Figure 2. Map of deformation rate vectors for the tiltmeters and GNSS stations over their respective evaluated time frames. The tiltmeter vectors are shown in cyan and scaled by their respective values in units of microradians per year. The GNSS vectors and their corresponding error ellipses (derived 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.

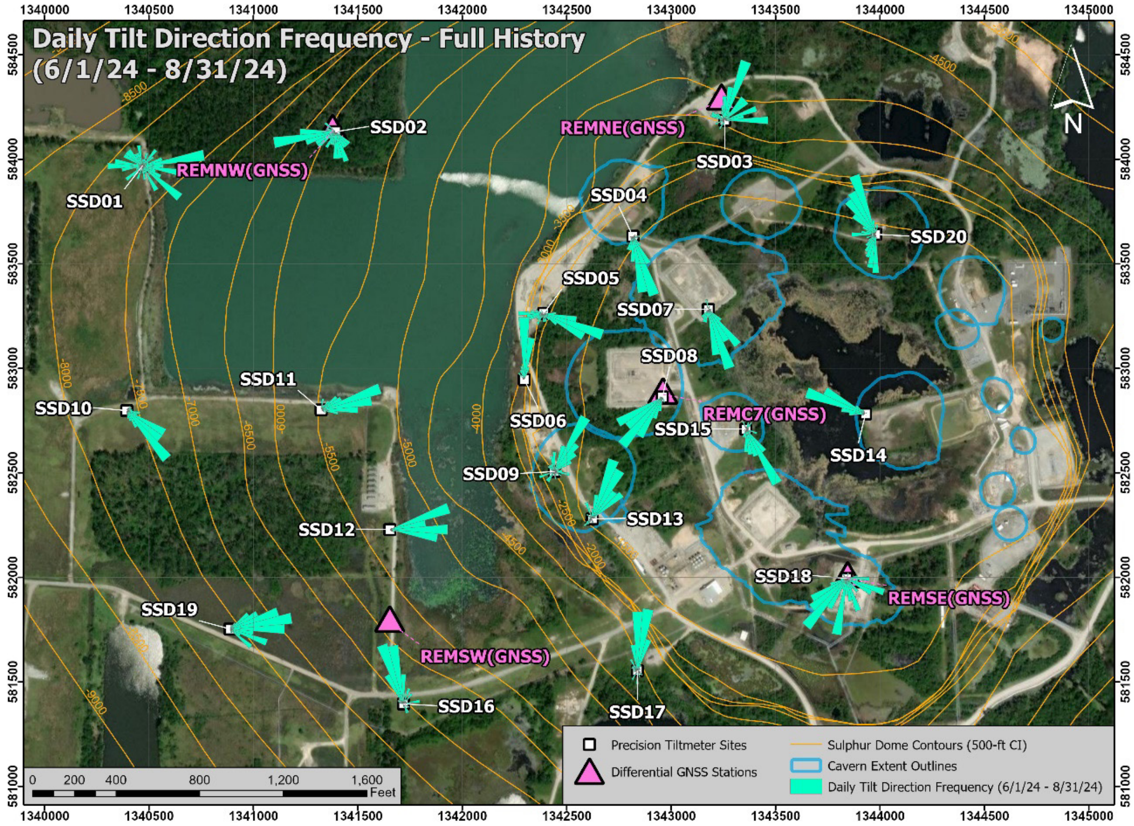


Figure 3. Map of daily tilt direction distribution for each tiltmeter for the full data history beginning in June 2024. Rose diagrams indicate the number of days that tilt was oriented along specific azimuths (bin size is 10°).

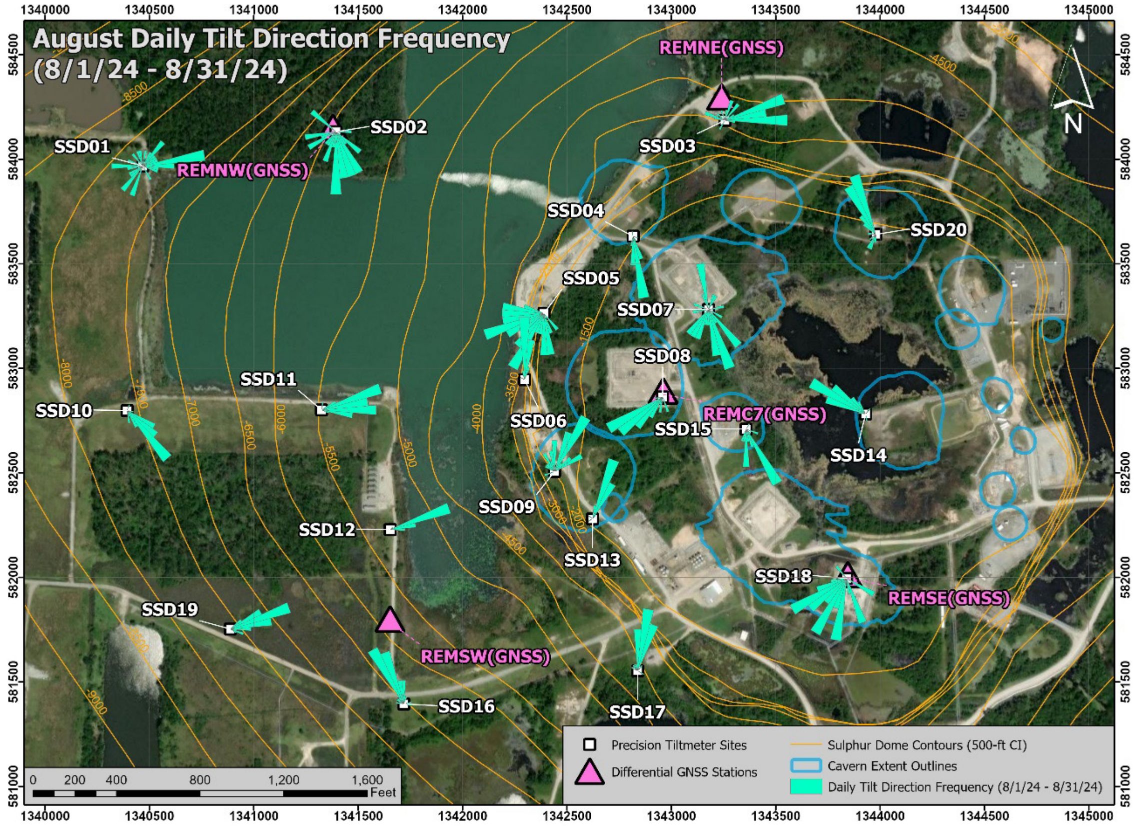


Figure 4. Map of daily tilt direction distribution for each tiltmeter for the current monthly reporting period. Rose diagrams indicate the number of days that tilt was oriented along specific azimuths (bin size is 10°).

Deformation Alert System

We are working on developing a draft alert system that incorporates elements of both tiltmeter direction and magnitude. Over the past three 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.

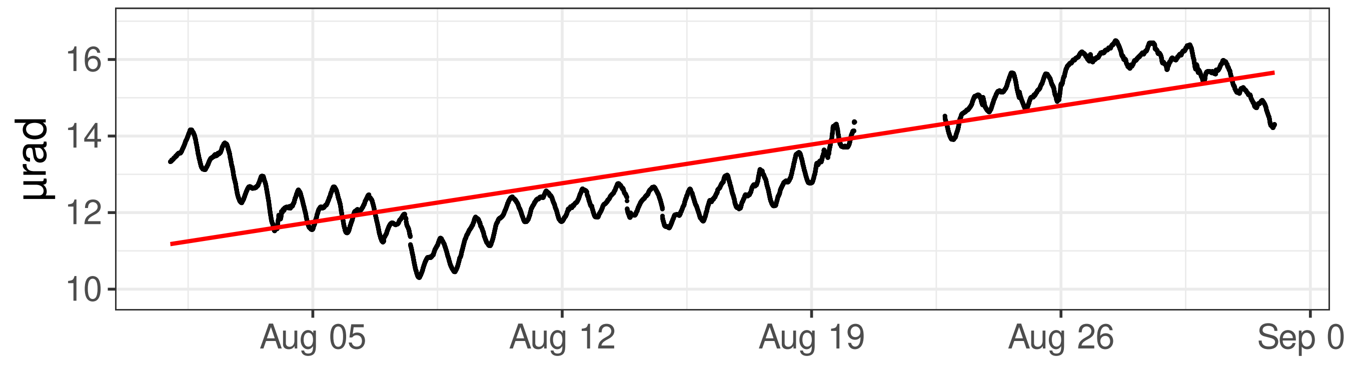
In contrast, shallow deformation, such as movement in the cap rock, is likely to affect nearby tiltmeter sites only. It is unlikely that a short-term (hour-by-hour) alert system is feasible for tiltmeter data. Our current plan is to establish a deformation alert that will trigger if a consistent pattern of tilt changes 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

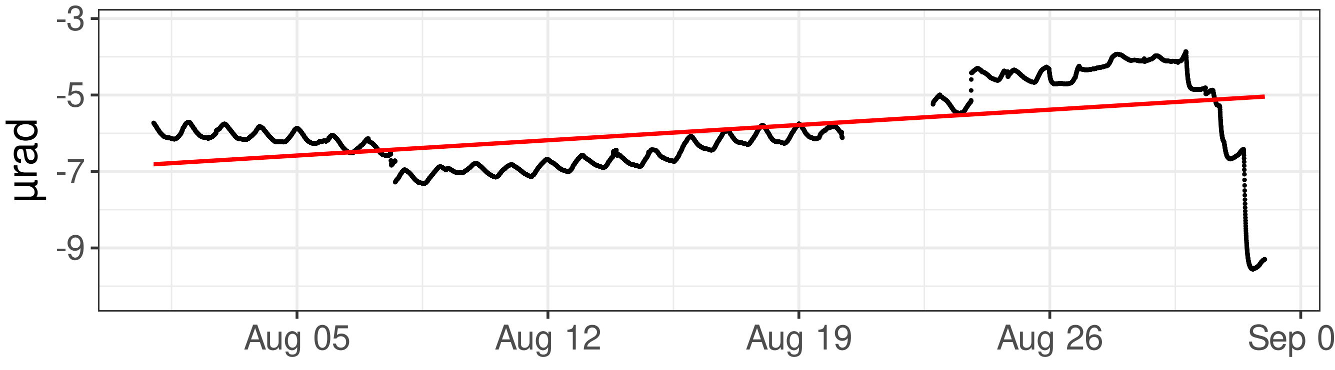
Tiltmeter Data Plots

SSD01, 08/01/2024 - 08/31/2024

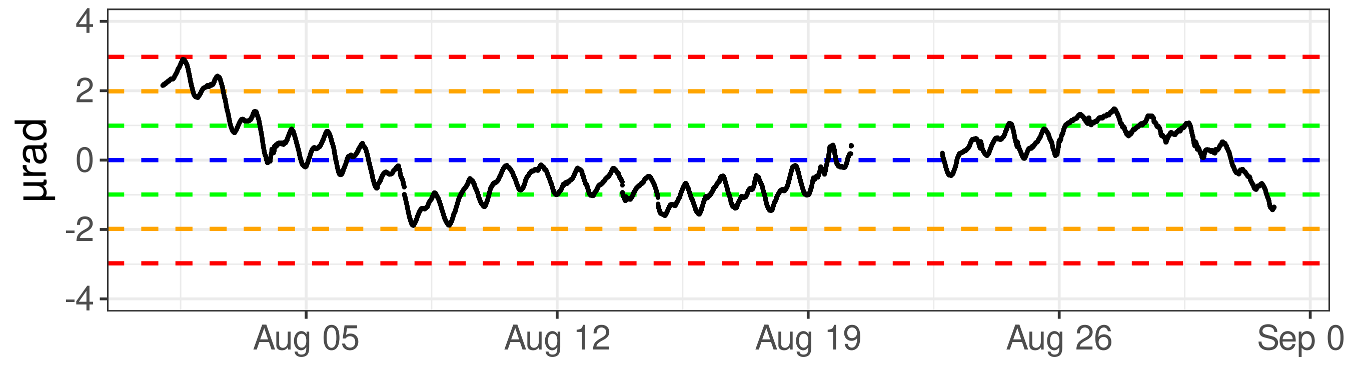
East tilt - raw values, Linear model R2 0.64



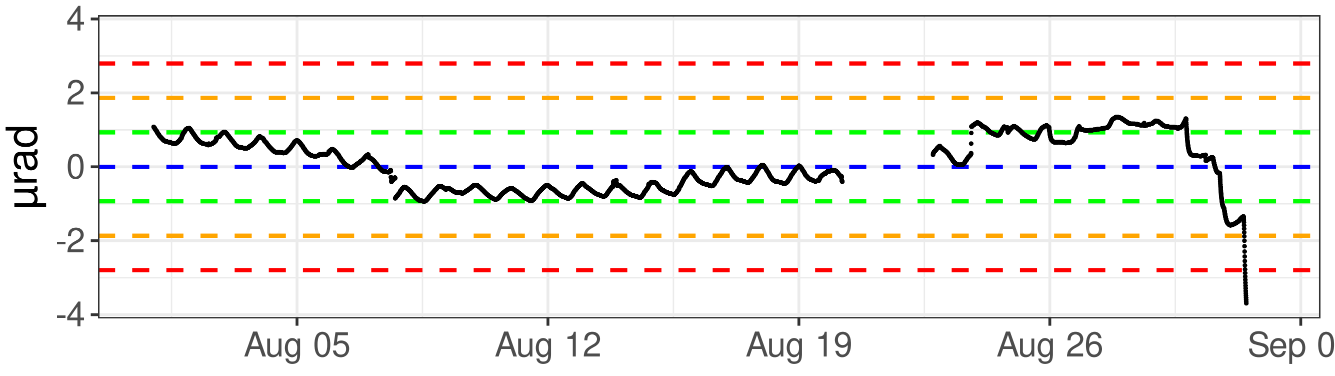
North tilt - raw values, Linear model R2 0.24



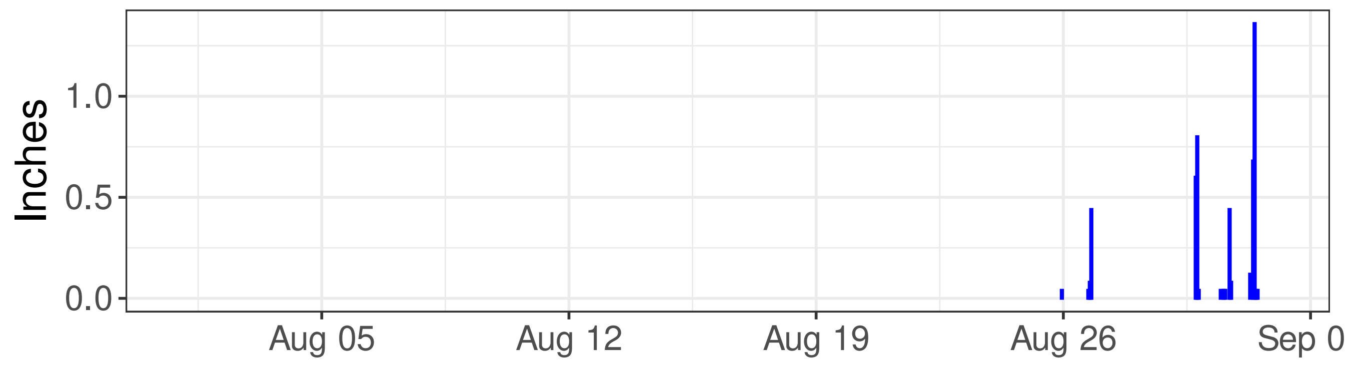
East tilt - detrended values



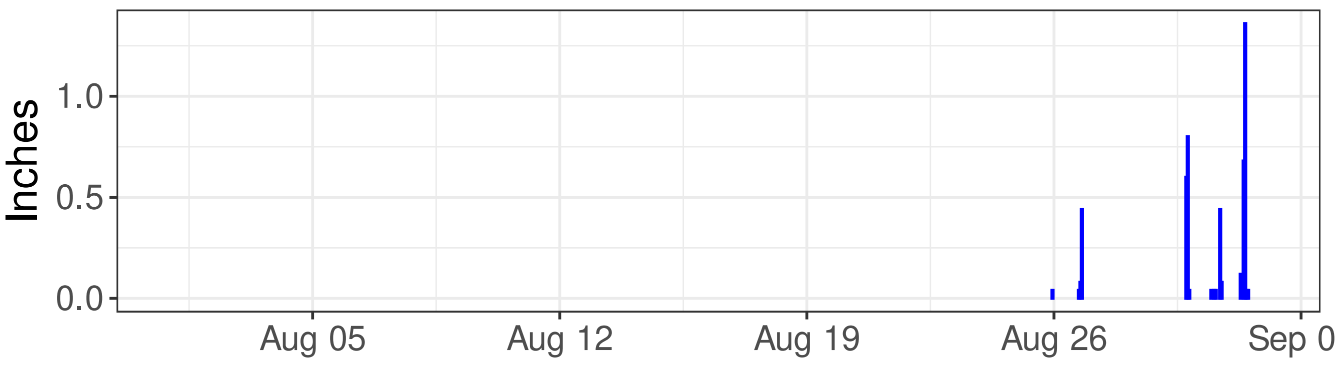
North tilt - detrended values



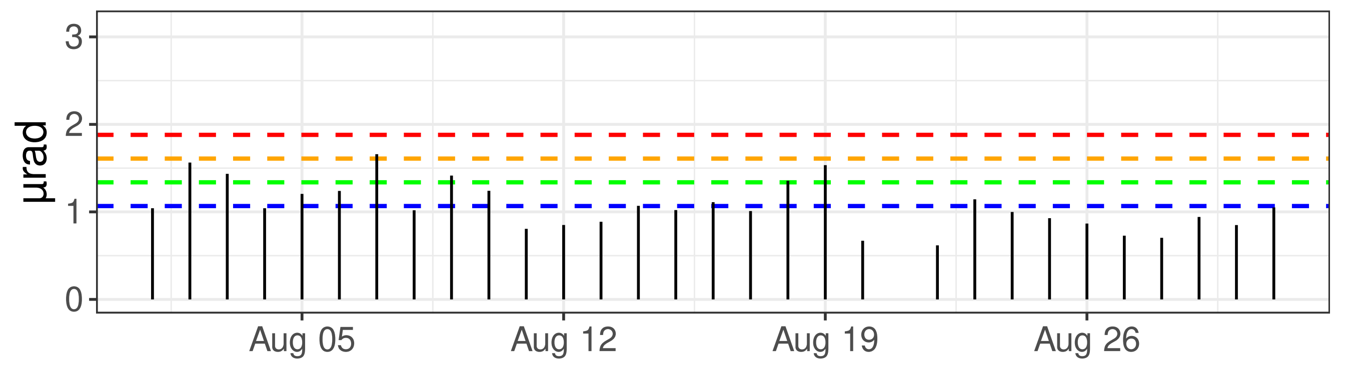
Hourly precipitation



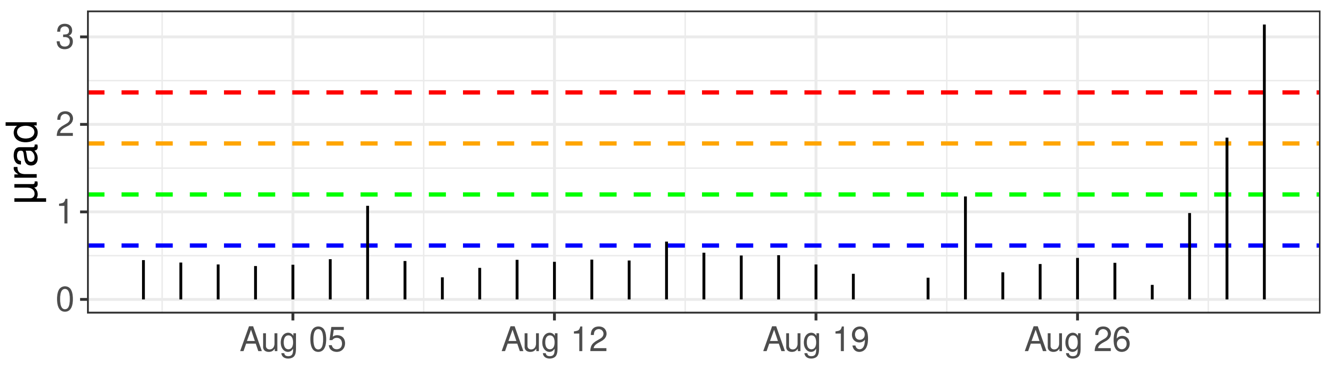
Hourly precipitation



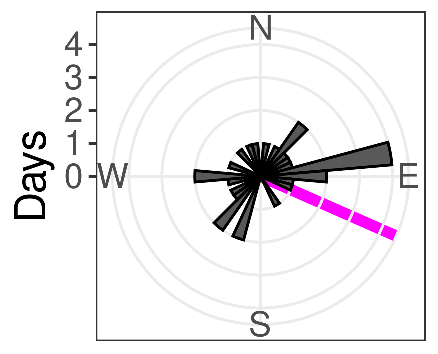
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: 52.91 ± 0.39 µrad/year

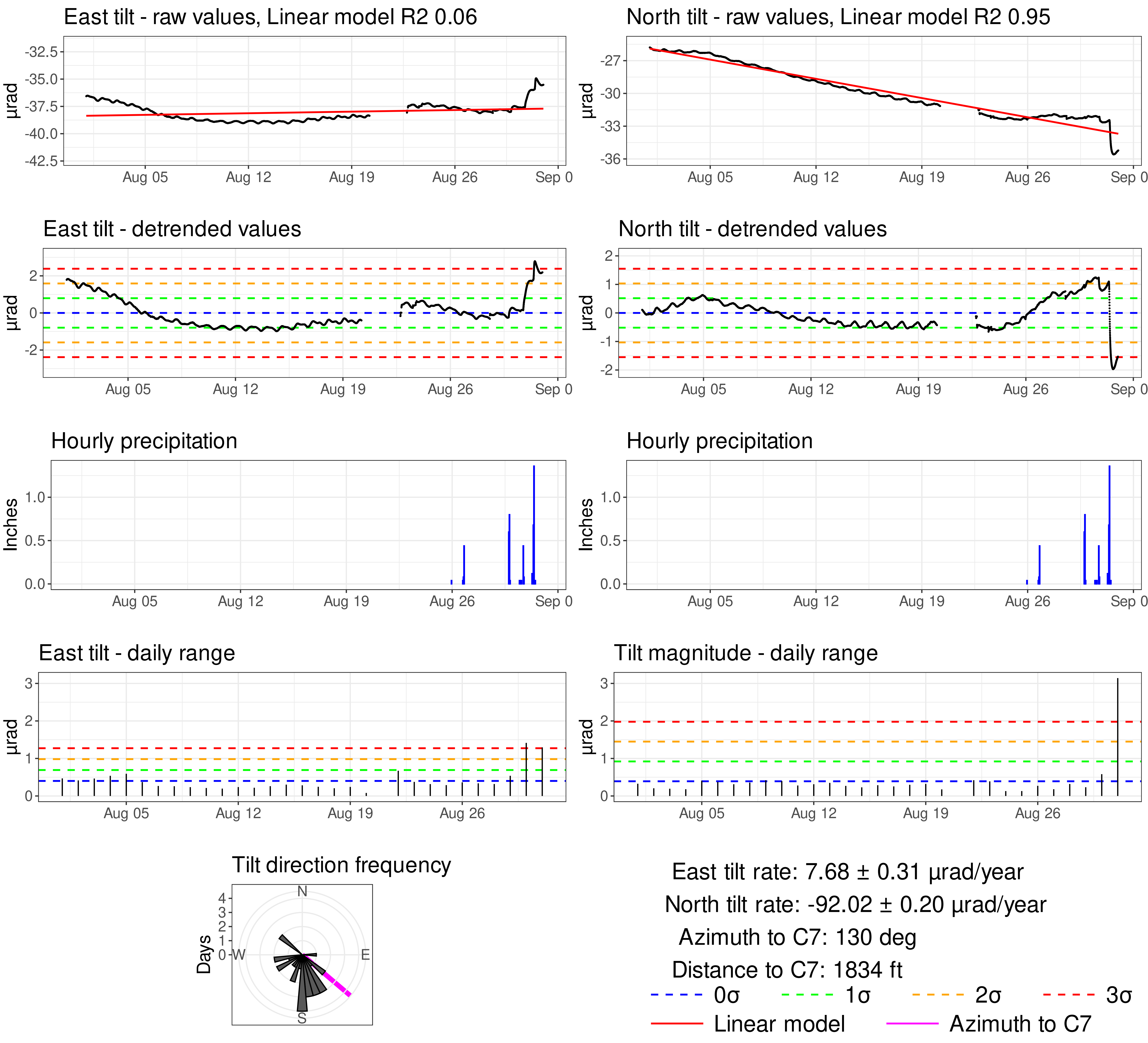
North tilt rate: 20.90 ± 0.37 µrad/year

Azimuth to C7: 114 deg

Distance to C7: 2538 ft

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

SSD02, 08/01/2024 - 08/31/2024



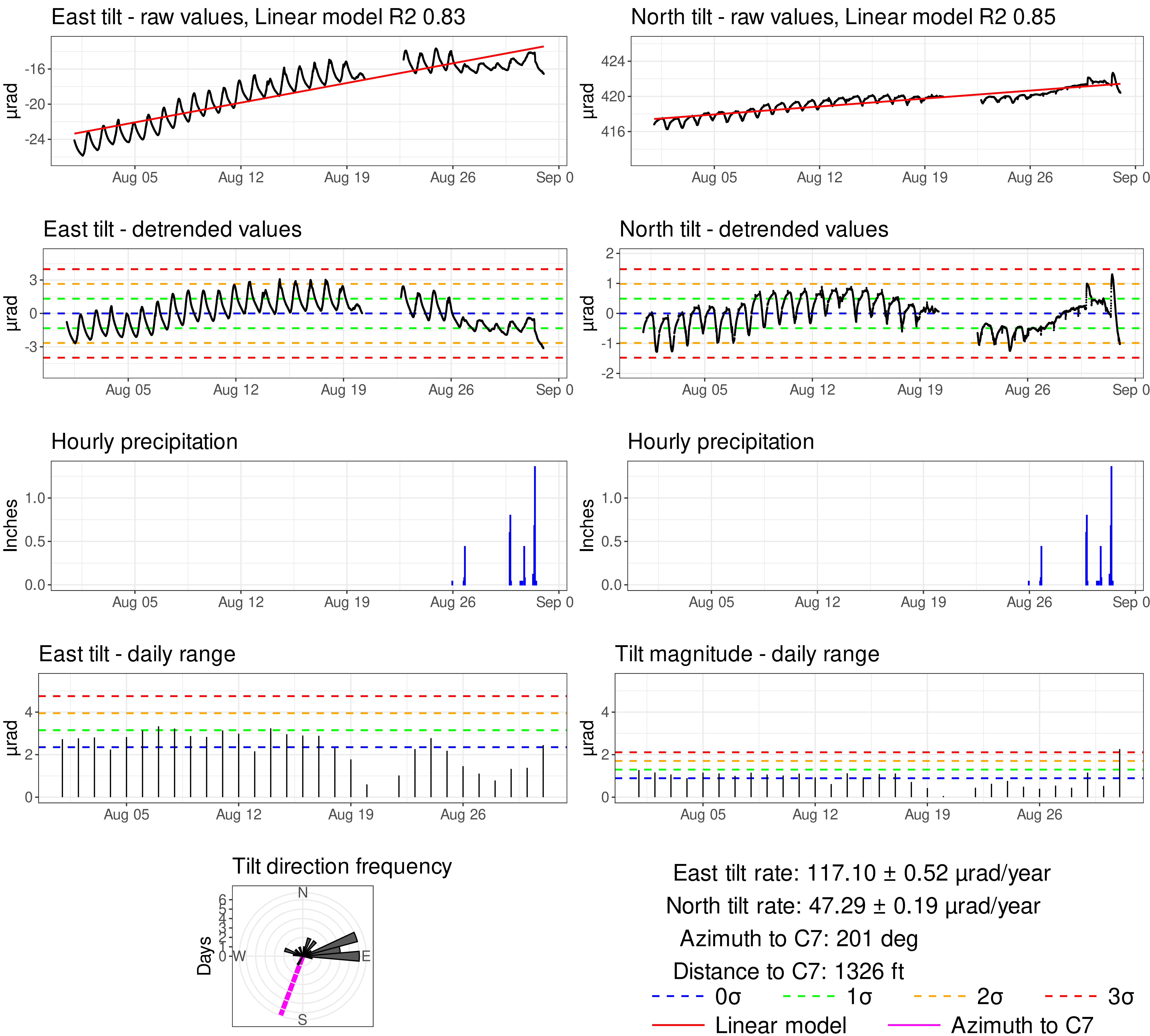
East tilt rate: 7.68 ± 0.31 µrad/year

North tilt rate: -92.02 ± 0.20 µrad/year

Azimuth to C7: 130 deg

Distance to C7: 1834 ft

SSD03, 08/01/2024 - 08/31/2024



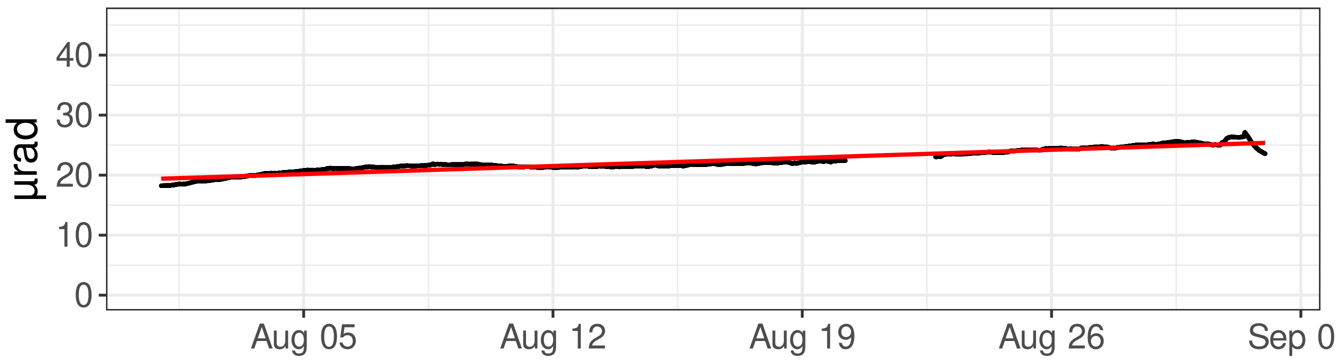
East tilt rate: 117.10 ± 0.52 µrad/year

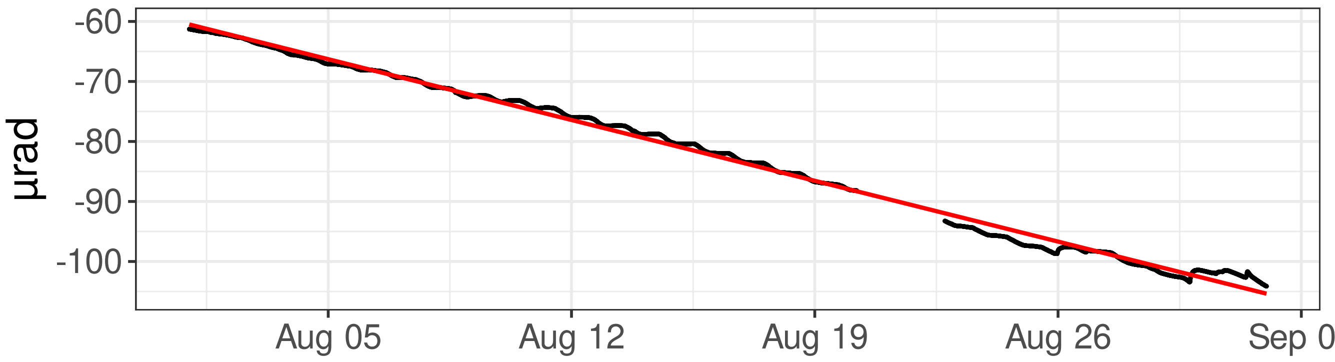
North tilt rate: 47.29 ± 0.19 µrad/year

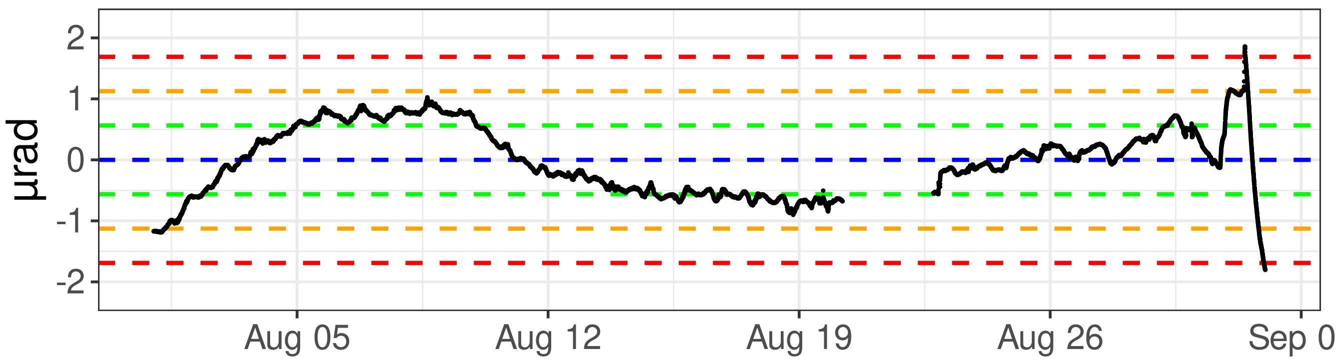
Azimuth to C7: 201 deg

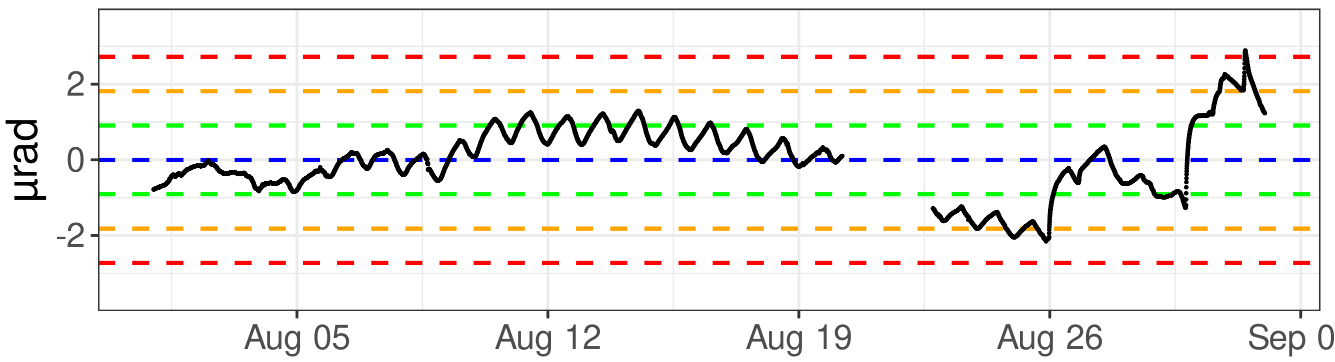
Distance to C7: 1326 ft

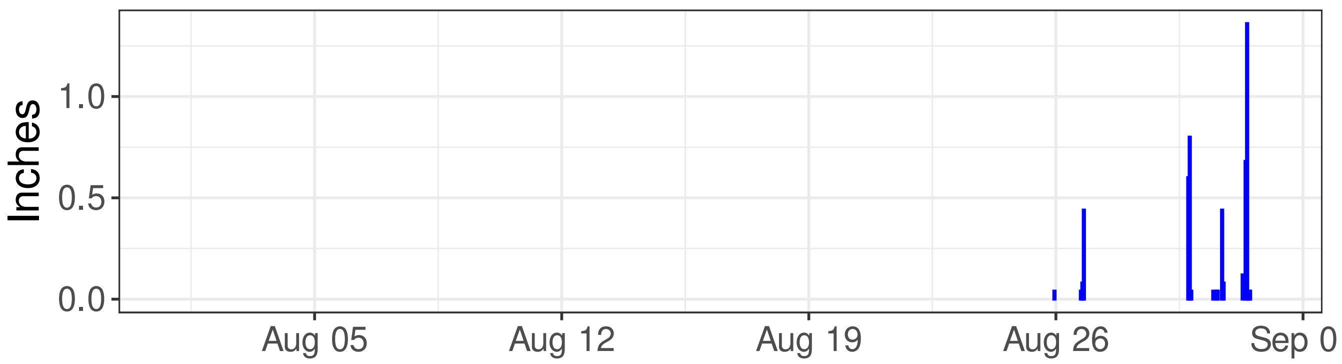
SSD04, 08/01/2024 - 08/31/2024

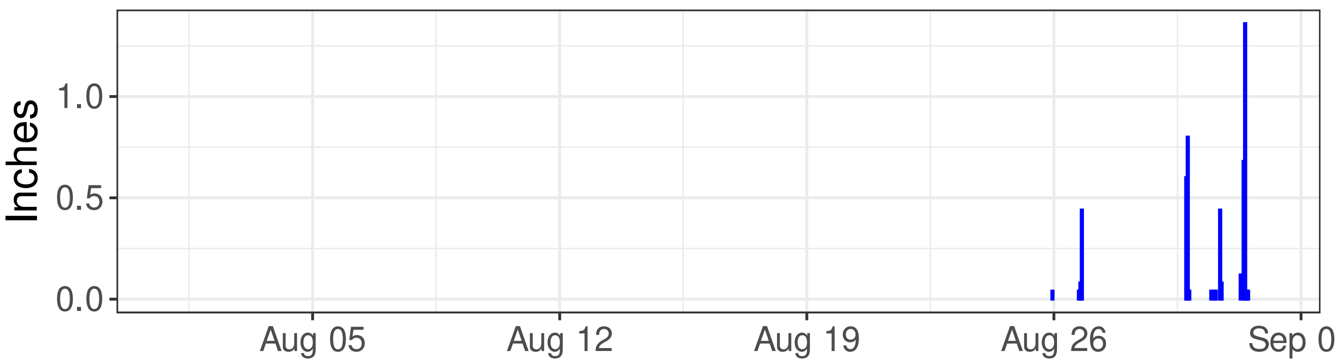

East tilt - raw values, Linear model R2 0.91

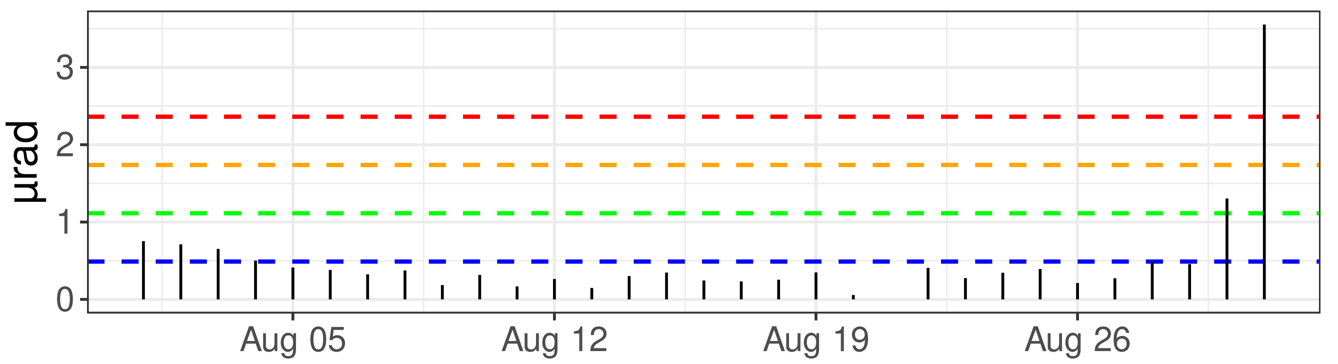

North tilt - raw values, Linear model R2 1.00

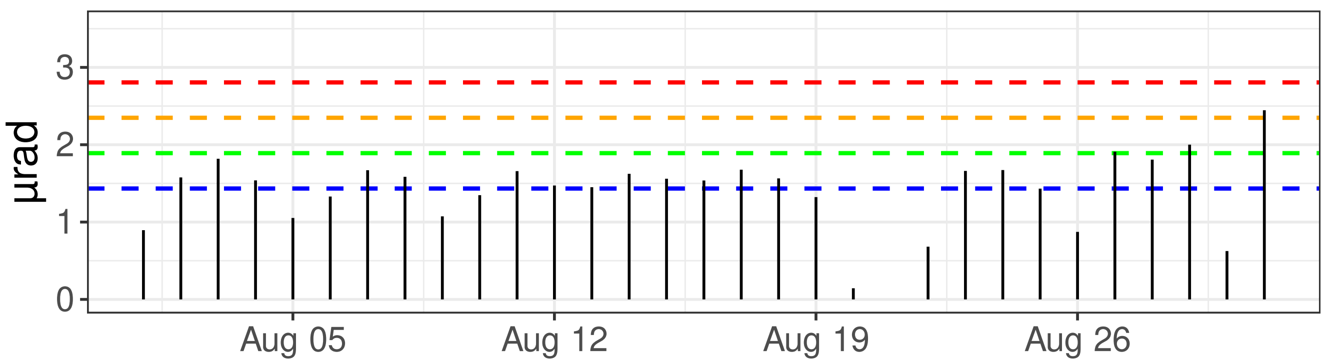

East tilt - detrended values

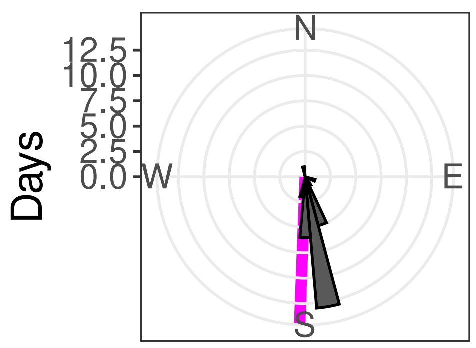

North tilt - detrended values


Hourly precipitation


Hourly precipitation


East tilt - daily range


Tilt magnitude - daily range


Tilt direction frequency

East tilt rate: 70.52 ± 0.22 µrad/year

North tilt rate: -529.71 ± 0.36 µrad/year

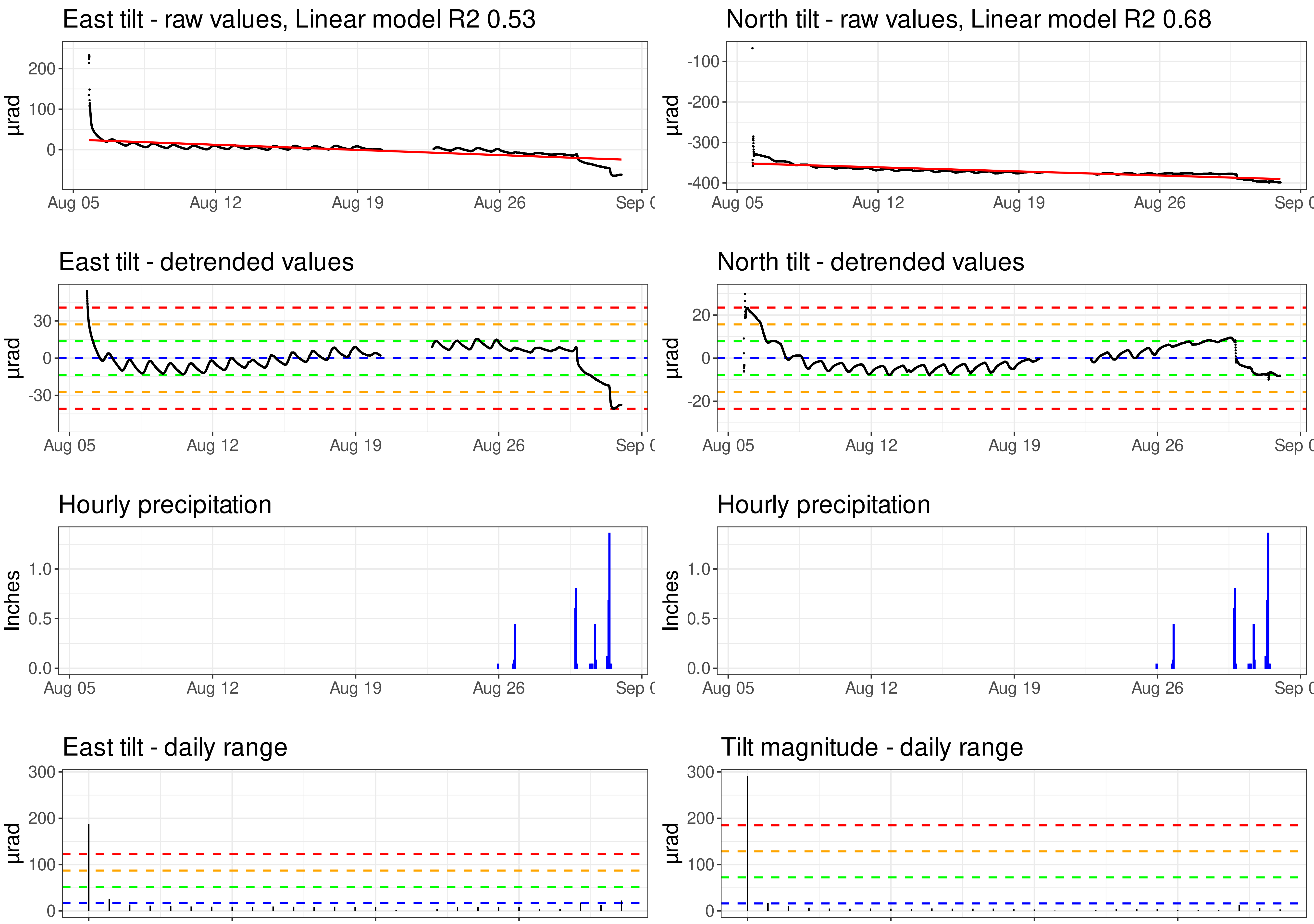
Azimuth to C7: 182 deg

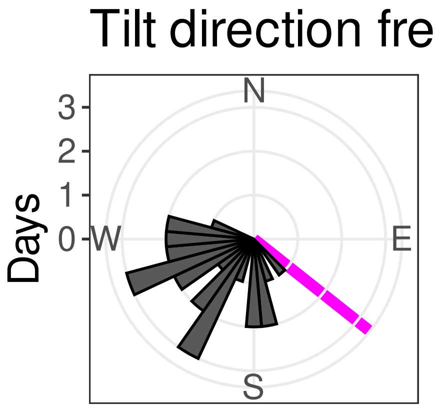
Distance to C7: 688 ft

- - - 0σ - - - 1σ - - - 2σ - - - 3σ

— Linear model — Azimuth to C7

SSD05, 08/05/2024 - 08/31/2024





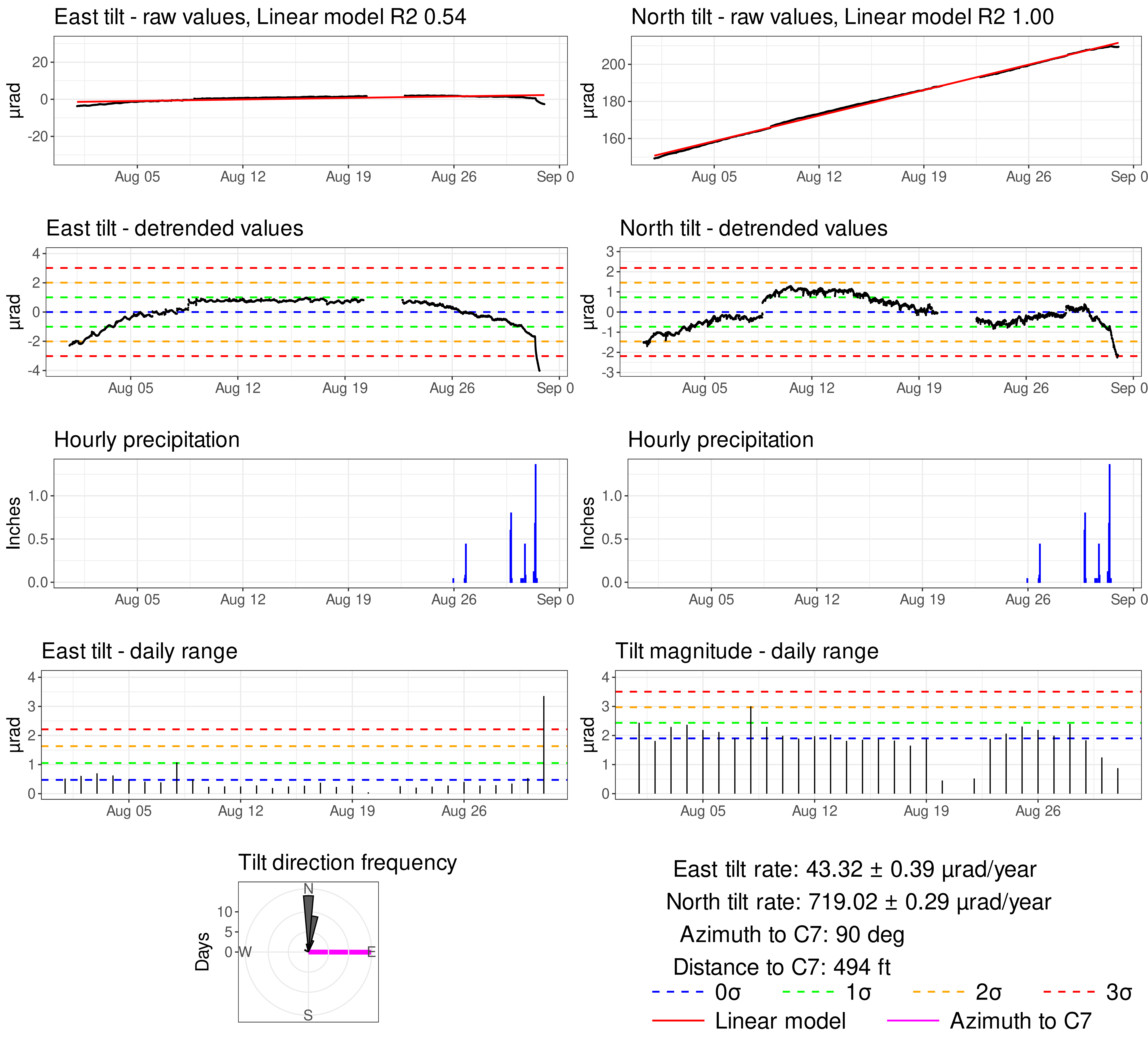
East tilt rate: -667.31 ± 6.81 µrad/year

North tilt rate: -529.47 ± 3.92 µrad/year

Azimuth to C7: 128 deg

Distance to C7: 512 ft

SSD06, 08/01/2024 - 08/31/2024



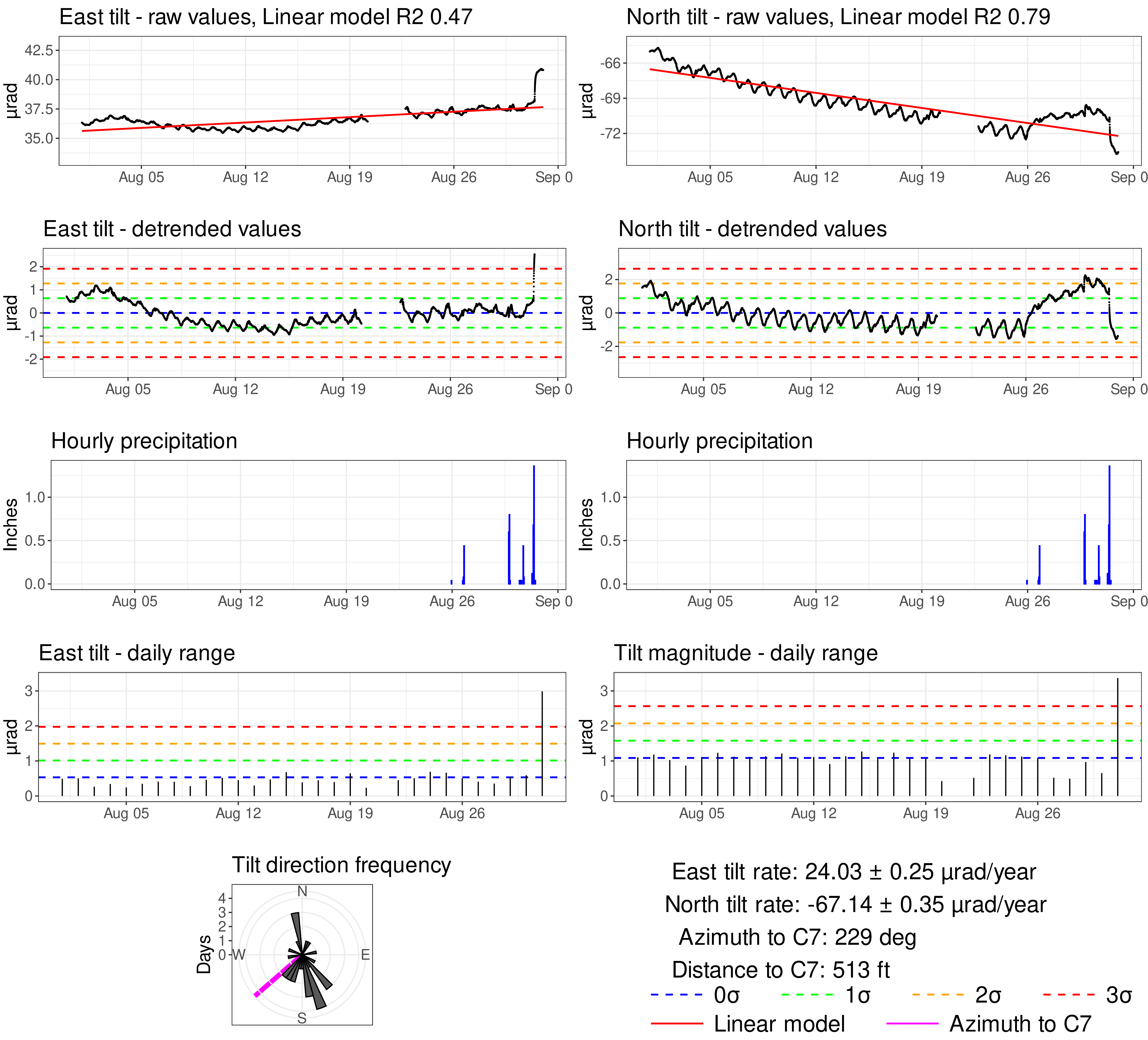
East tilt rate: 43.32 ± 0.39 µrad/year

North tilt rate: 719.02 ± 0.29 µrad/year

Azimuth to C7: 90 deg

Distance to C7: 494 ft

SSD07, 08/01/2024 - 08/31/2024



East tilt rate: 24.03 ± 0.25 µrad/year

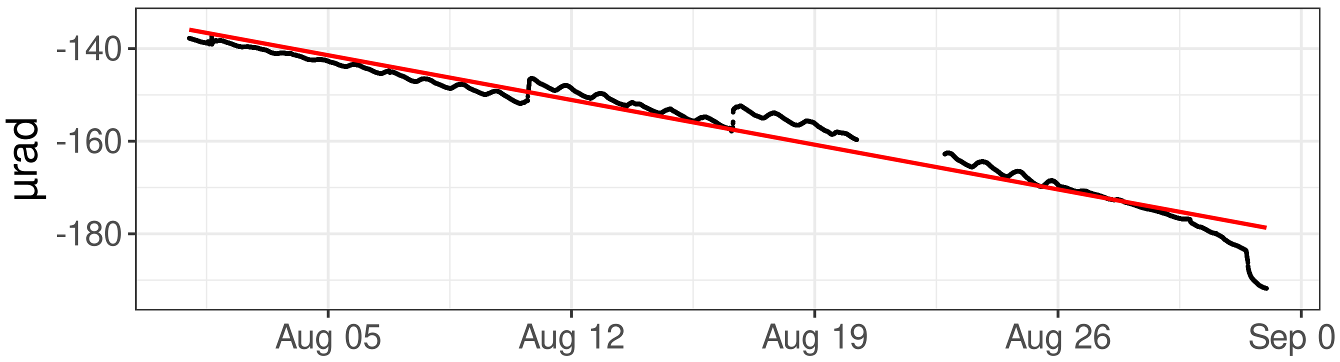
North tilt rate: -67.14 ± 0.35 µrad/year

Azimuth to C7: 229 deg

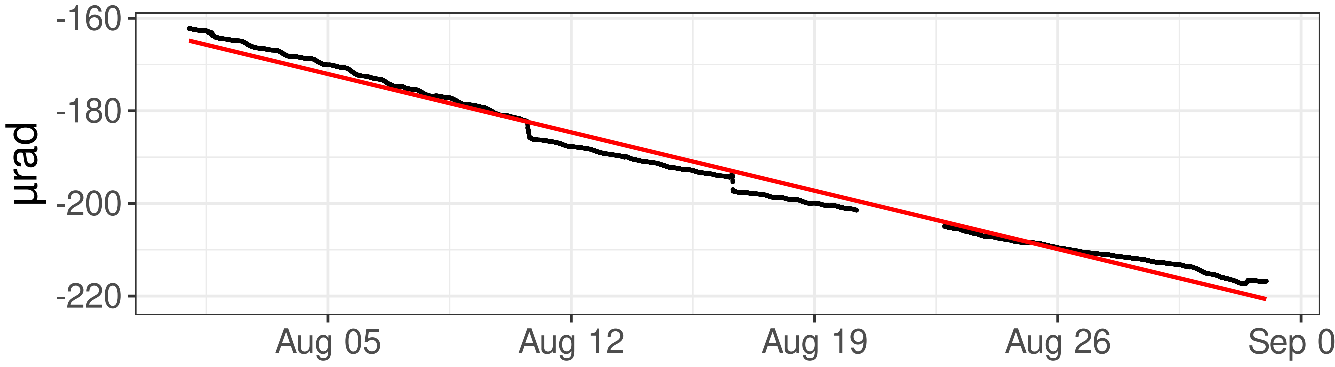
Distance to C7: 513 ft

SSD08, 08/01/2024 - 08/31/2024

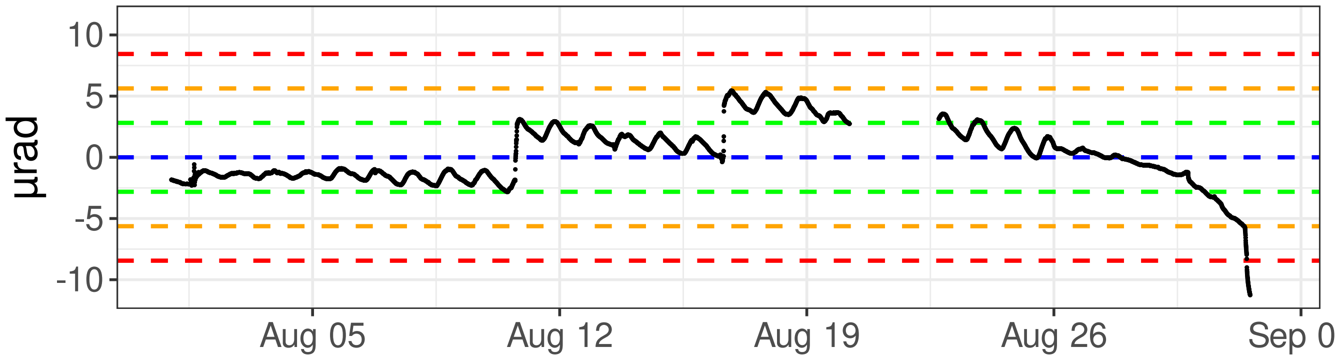
East tilt - raw values, Linear model R2 0.95



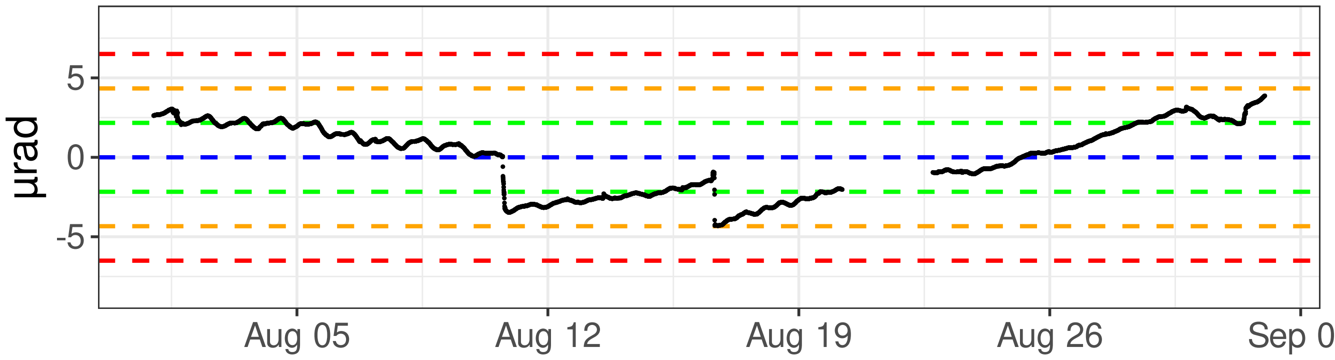
North tilt - raw values, Linear model R2 0.98



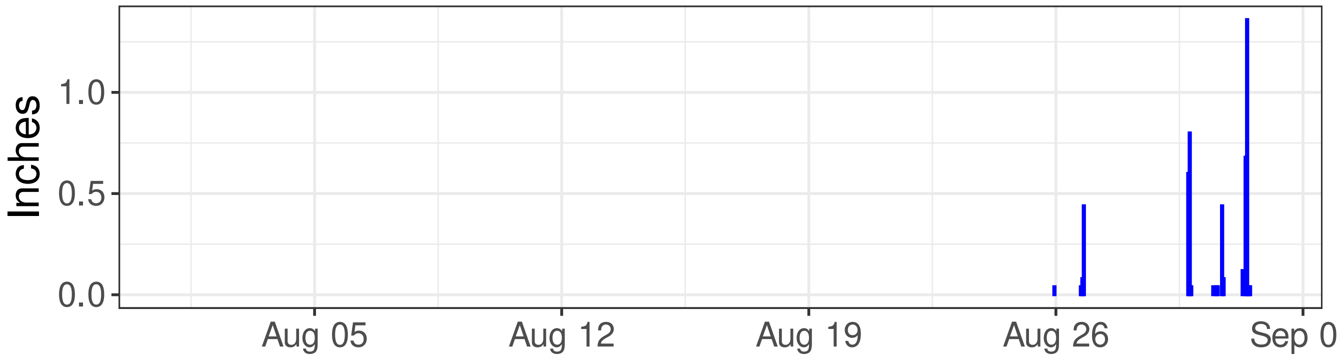
East tilt - detrended values



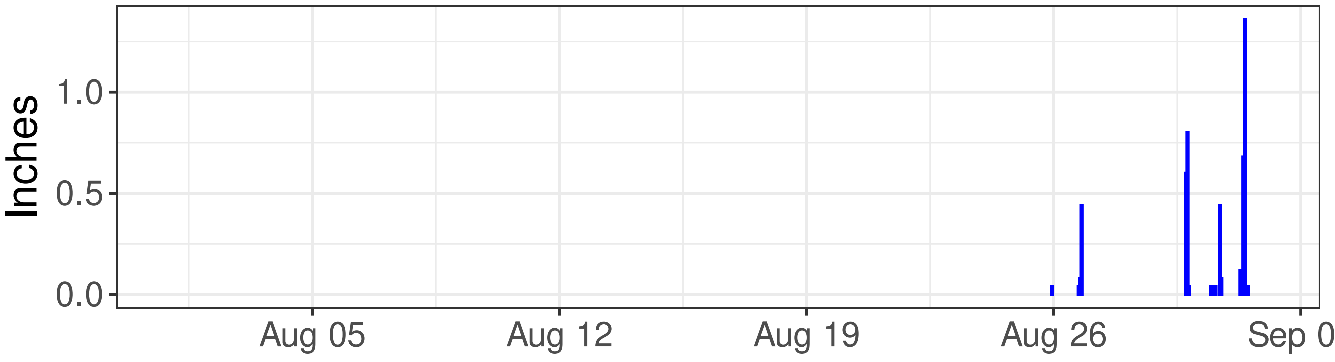
North tilt - detrended values



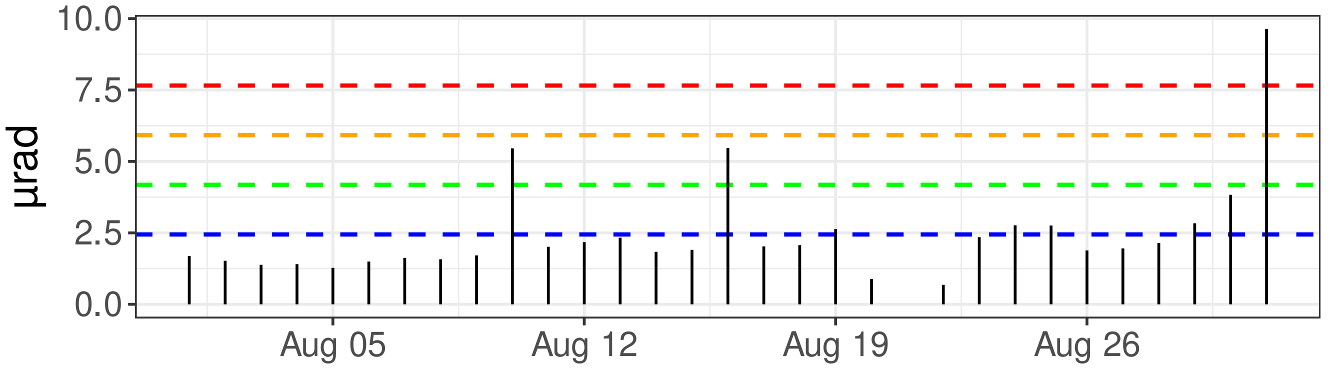
Hourly precipitation



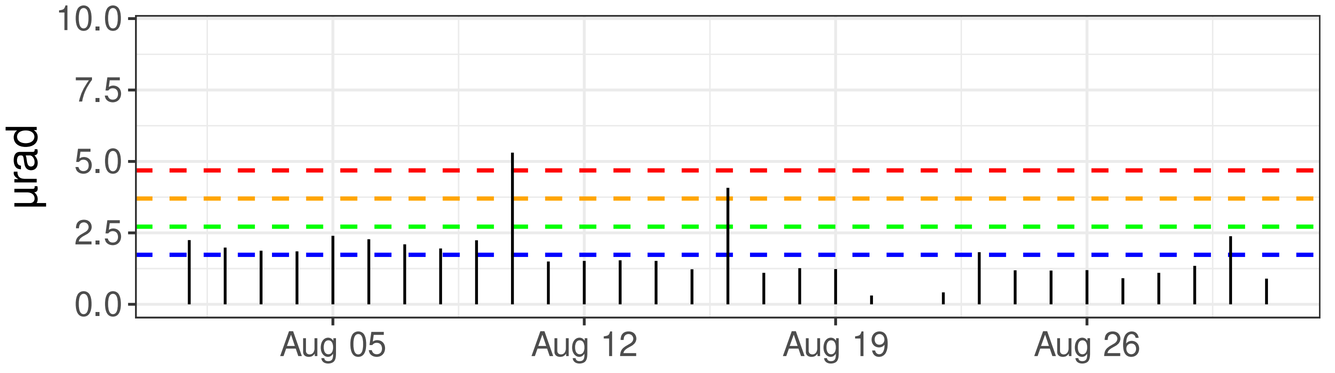
Hourly precipitation



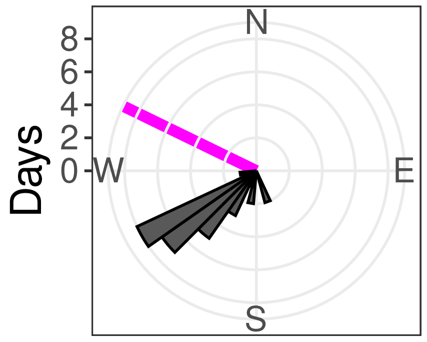
East tilt - daily range



Tilt magnitude - daily range



Tilt direction frequency



East tilt rate: -505.09 ± 1.11 µrad/year

North tilt rate: -659.00 ± 0.85 µrad/year

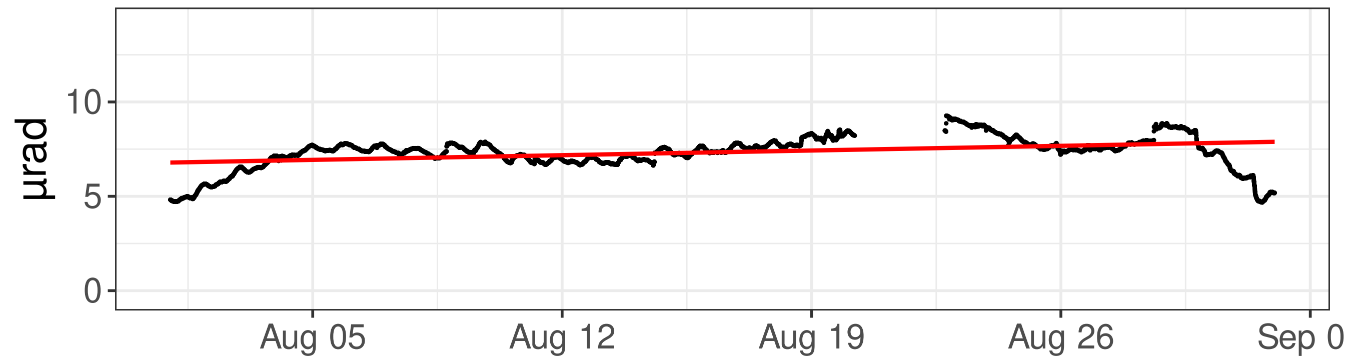
Azimuth to C7: 296 deg

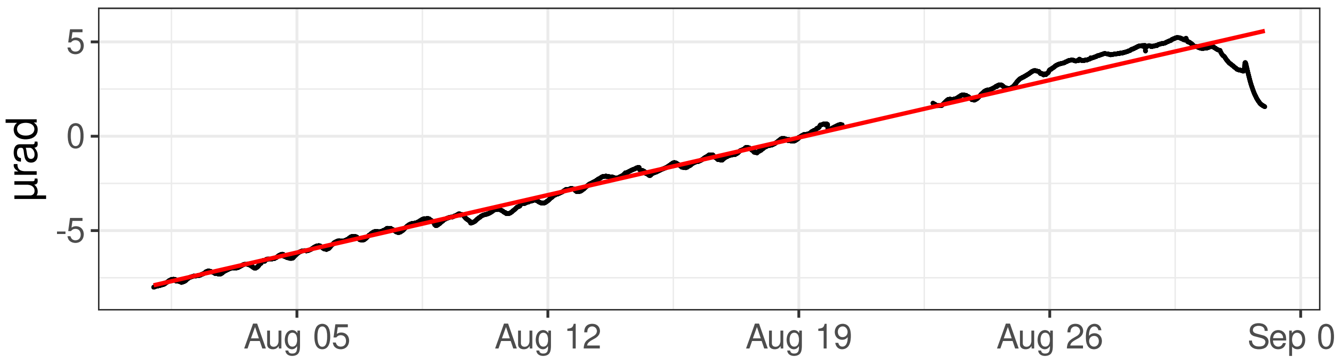
Distance to C7: 186 ft

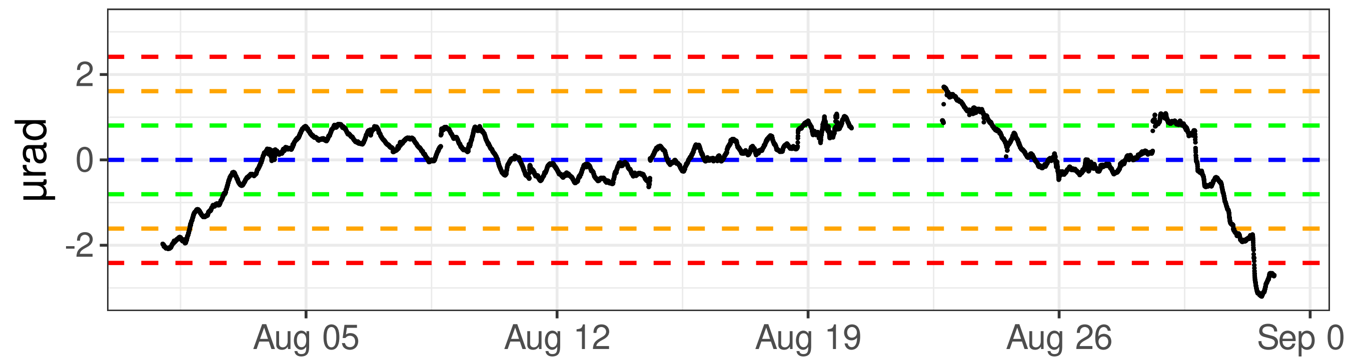
- - - 0σ - - - 1σ - - - 2σ - - - 3σ

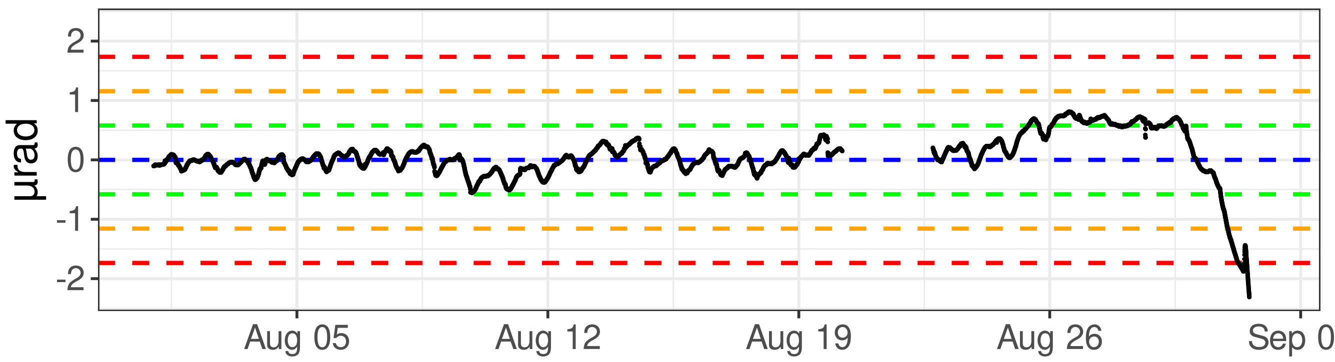
— Linear model — Azimuth to C7

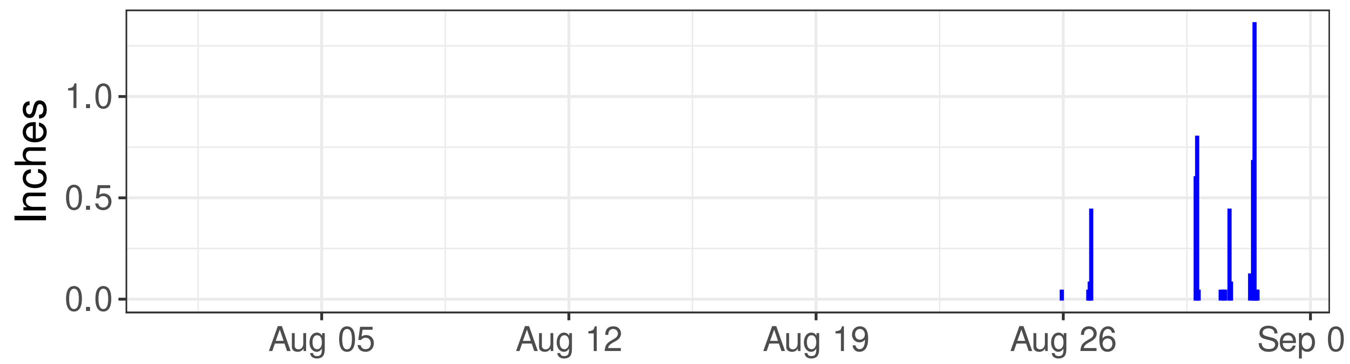
SSD09, 08/01/2024 - 08/31/2024

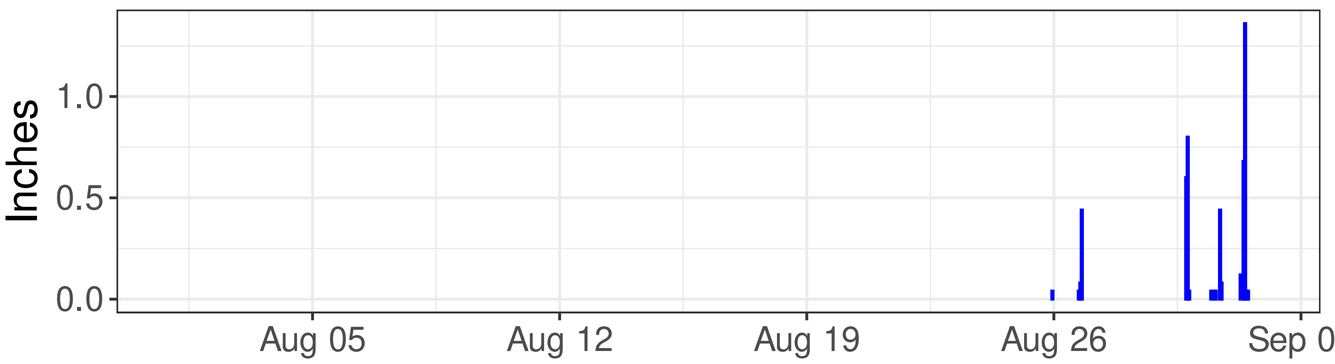

East tilt - raw values, Linear model R2 0.14

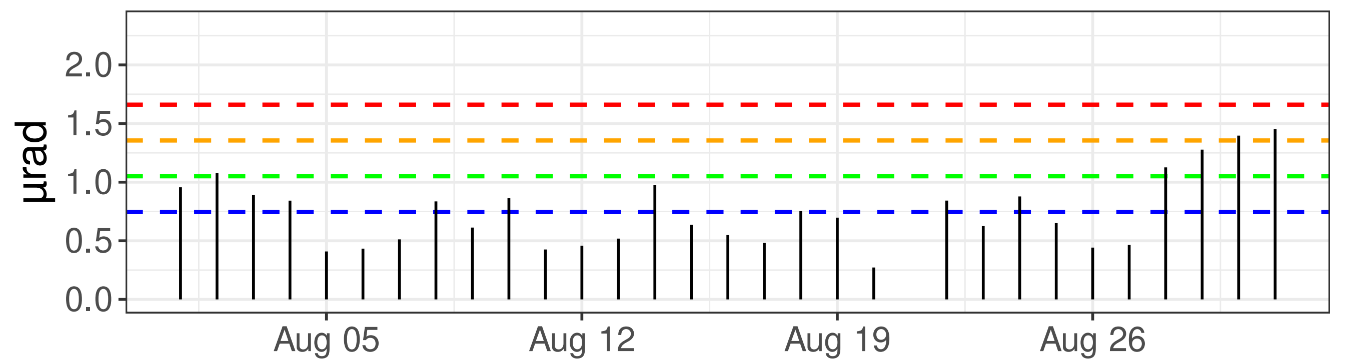

North tilt - raw values, Linear model R2 0.98

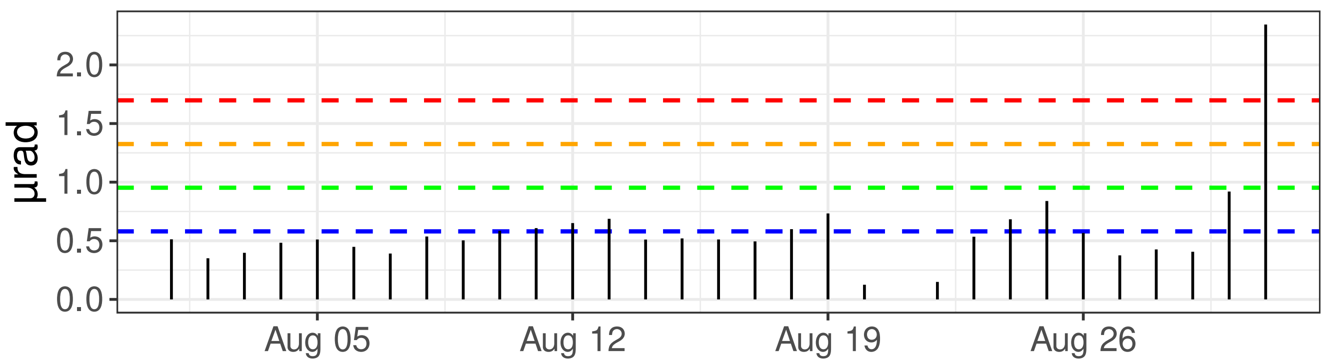

East tilt - detrended values

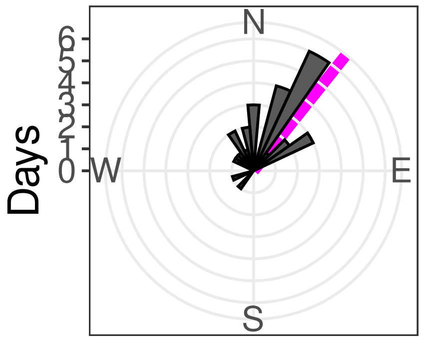

North tilt - detrended values


Hourly precipitation


Hourly precipitation


East tilt - daily range


Tilt magnitude - daily range


Tilt direction frequency

East tilt rate: 12.97 ± 0.32 µrad/year

North tilt rate: 159.17 ± 0.23 µrad/year

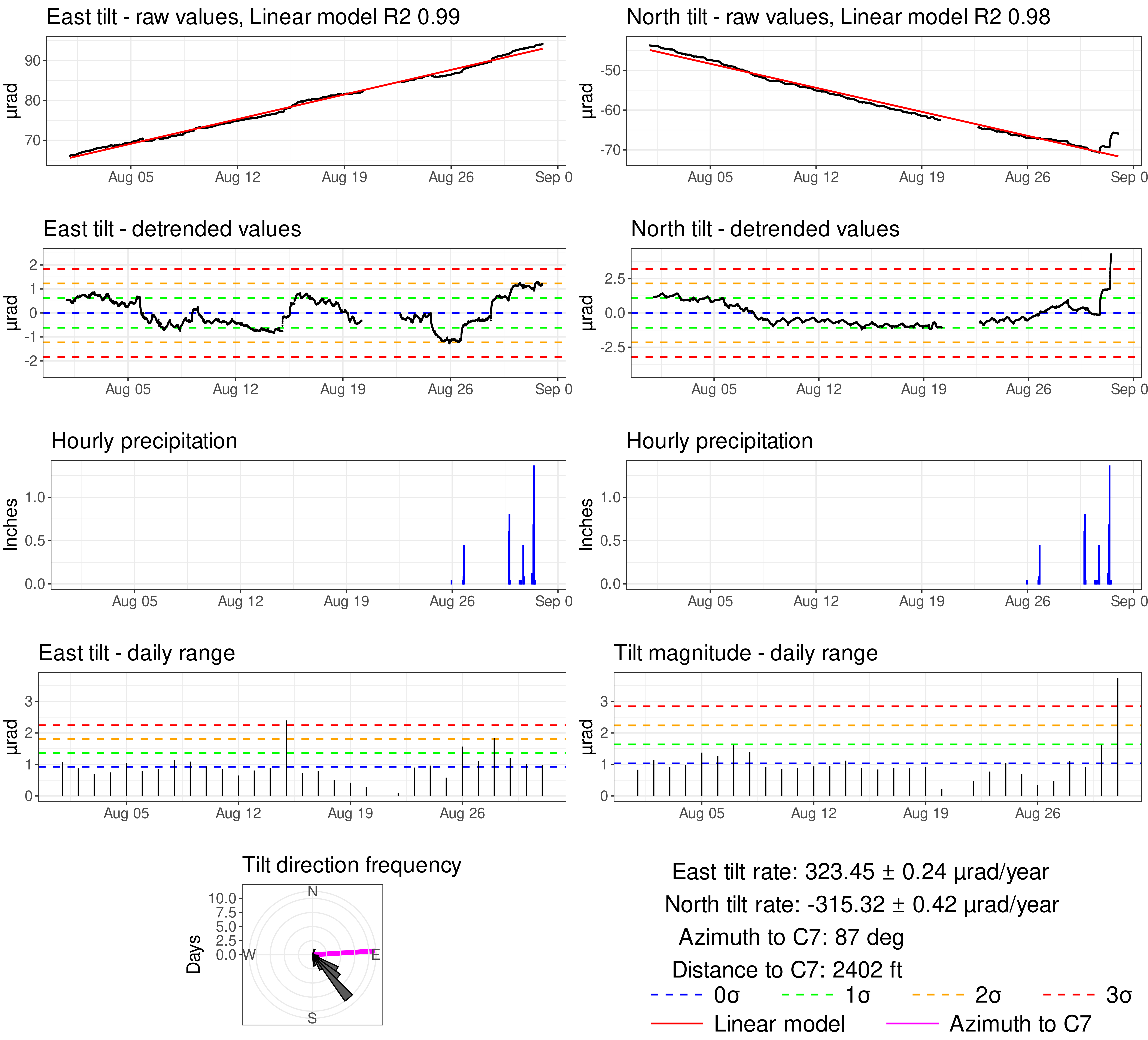
Azimuth to C7: 39 deg

Distance to C7: 561 ft

- - - 0σ - - - 1σ - - - 2σ - - - 3σ

— Linear model — Azimuth to C7

SSD10, 08/01/2024 - 08/31/2024



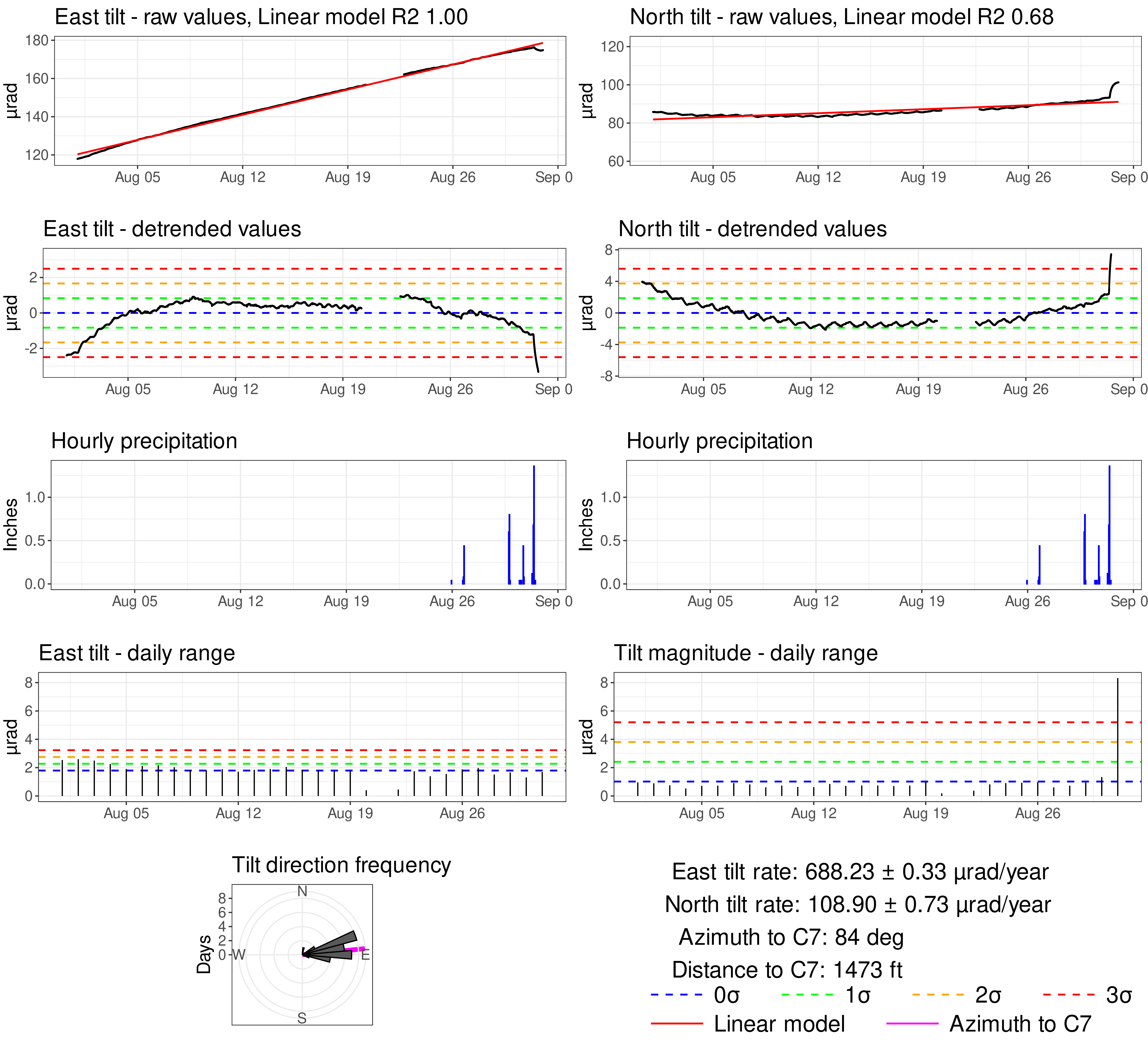
East tilt rate: 323.45 ± 0.24 µrad/year

North tilt rate: -315.32 ± 0.42 µrad/year

Azimuth to C7: 87 deg

Distance to C7: 2402 ft

SSD11, 08/01/2024 - 08/31/2024



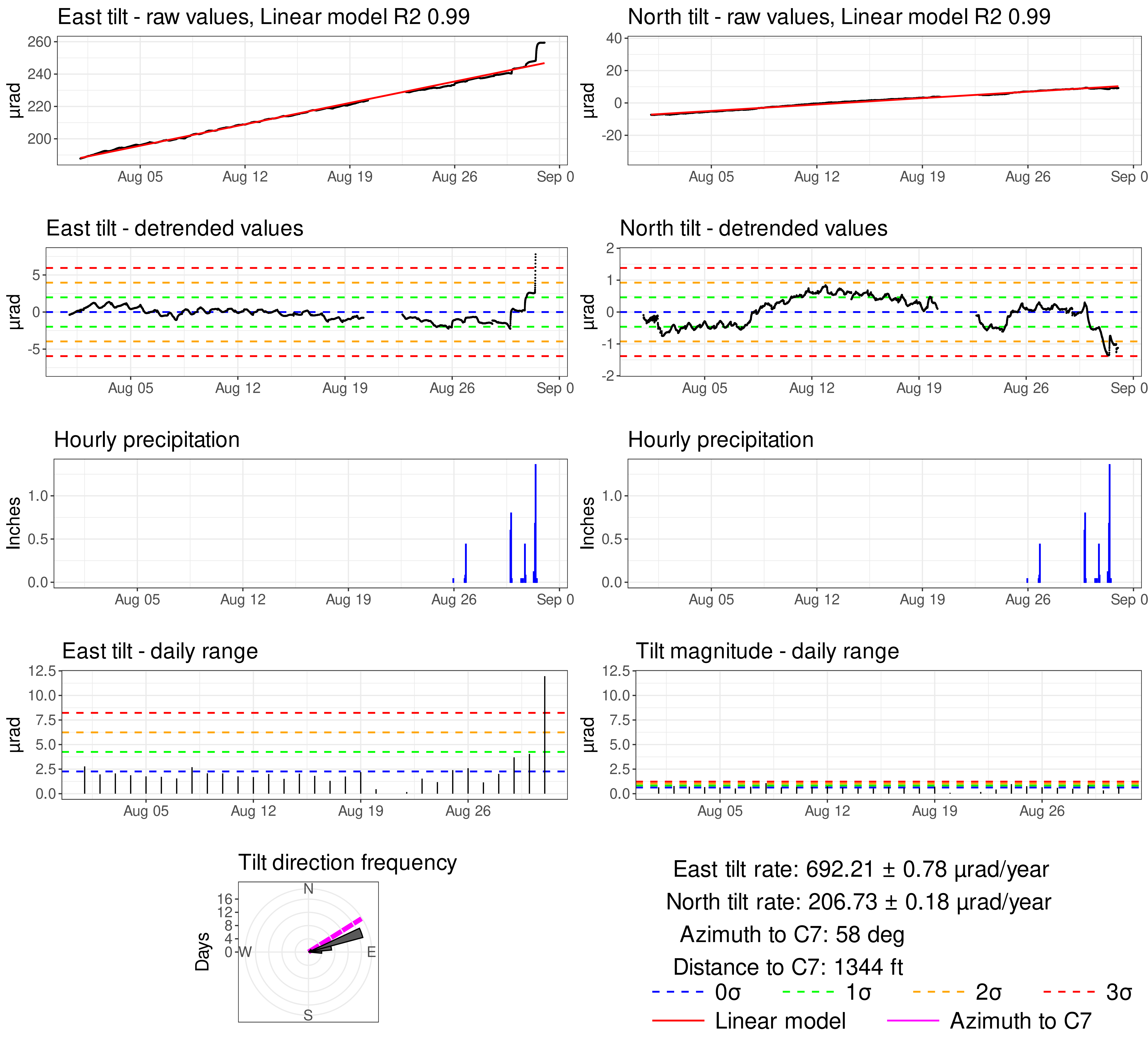
East tilt rate: 688.23 ± 0.33 µrad/year

North tilt rate: 108.90 ± 0.73 µrad/year

Azimuth to C7: 84 deg

Distance to C7: 1473 ft

SSD12, 08/01/2024 - 08/31/2024



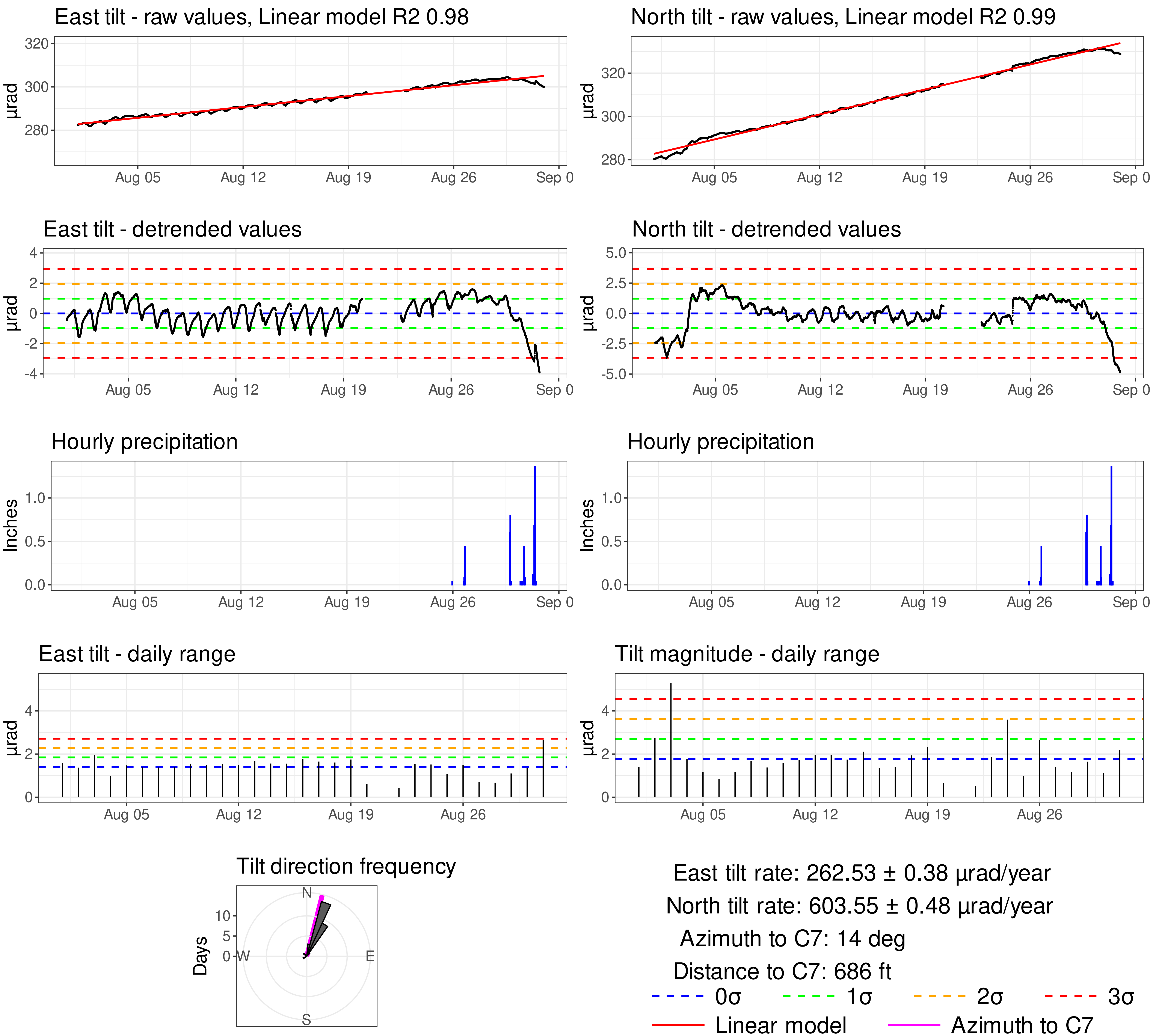
East tilt rate: 692.21 ± 0.78 µrad/year

North tilt rate: 206.73 ± 0.18 µrad/year

Azimuth to C7: 58 deg

Distance to C7: 1344 ft

SSD13, 08/01/2024 - 08/31/2024



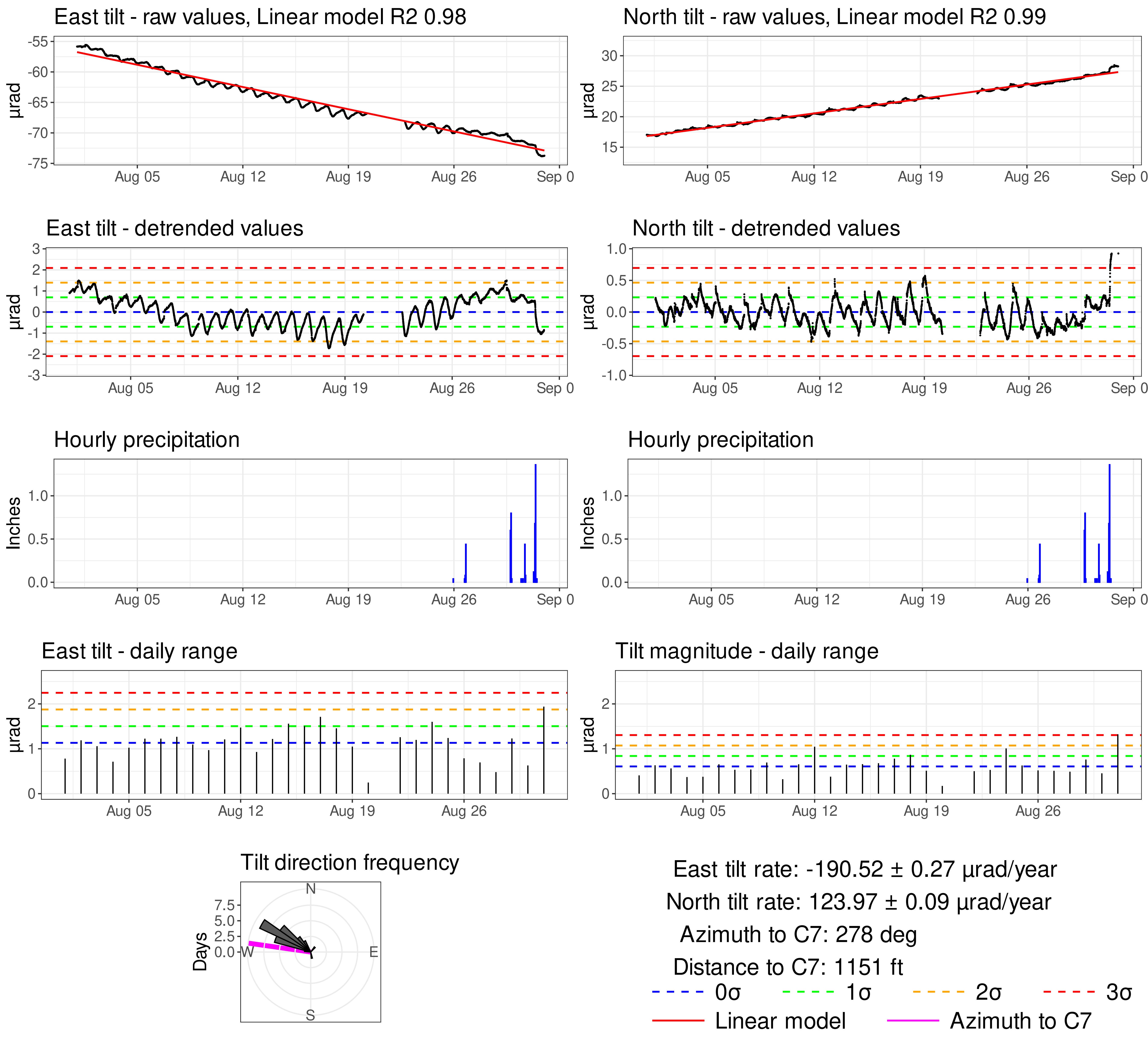
East tilt rate: 262.53 ± 0.38 µrad/year

North tilt rate: 603.55 ± 0.48 µrad/year

Azimuth to C7: 14 deg

Distance to C7: 686 ft

SSD14, 08/01/2024 - 08/31/2024



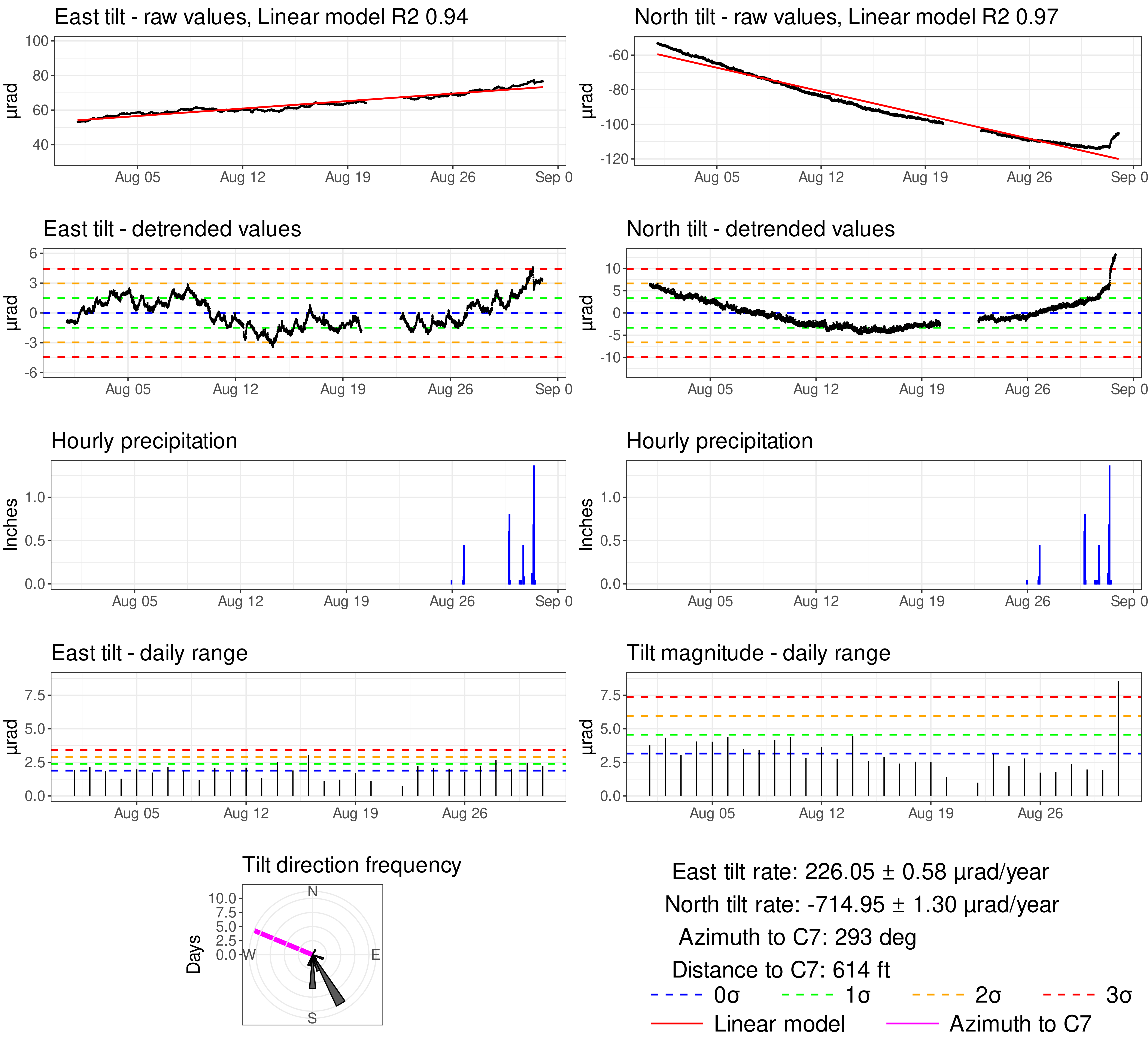
East tilt rate: -190.52 ± 0.27 µrad/year

North tilt rate: 123.97 ± 0.09 µrad/year

Azimuth to C7: 278 deg

Distance to C7: 1151 ft

SSD15, 08/01/2024 - 08/31/2024



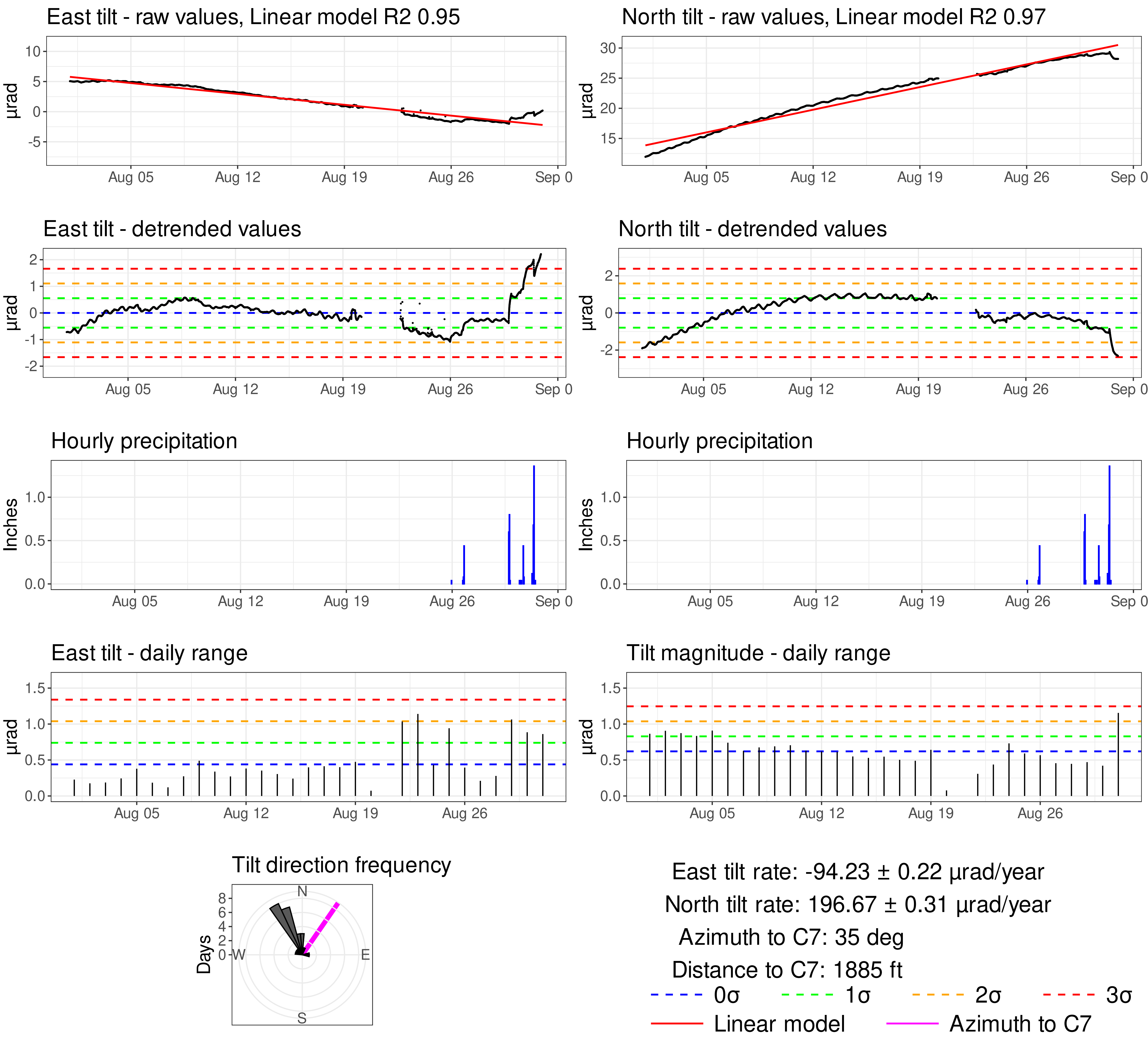
East tilt rate: 226.05 ± 0.58 µrad/year

North tilt rate: -714.95 ± 1.30 µrad/year

Azimuth to C7: 293 deg

Distance to C7: 614 ft

SSD16, 08/01/2024 - 08/31/2024



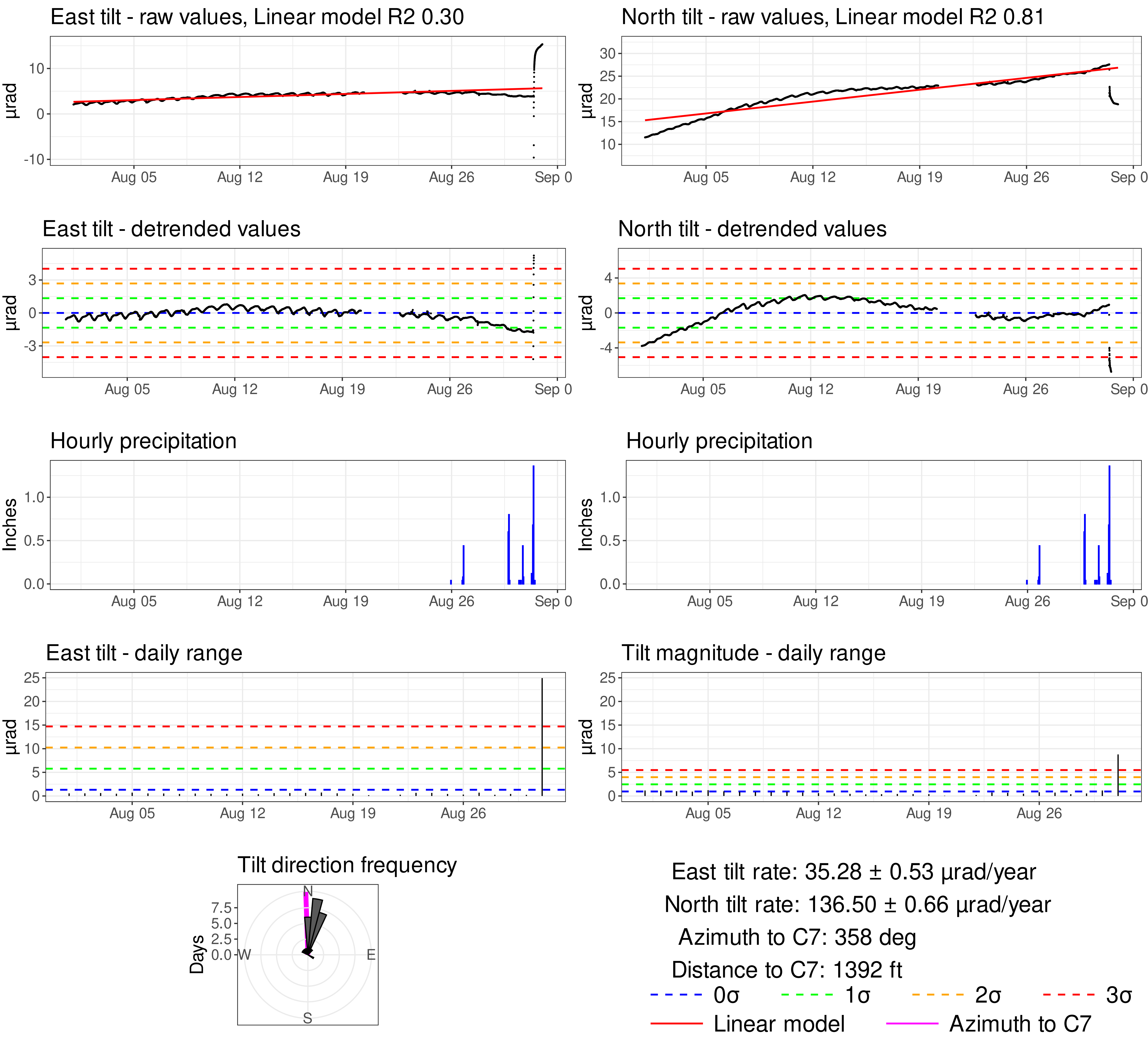
East tilt rate: -94.23 ± 0.22 µrad/year

North tilt rate: 196.67 ± 0.31 µrad/year

Azimuth to C7: 35 deg

Distance to C7: 1885 ft

SSD17, 08/01/2024 - 08/31/2024



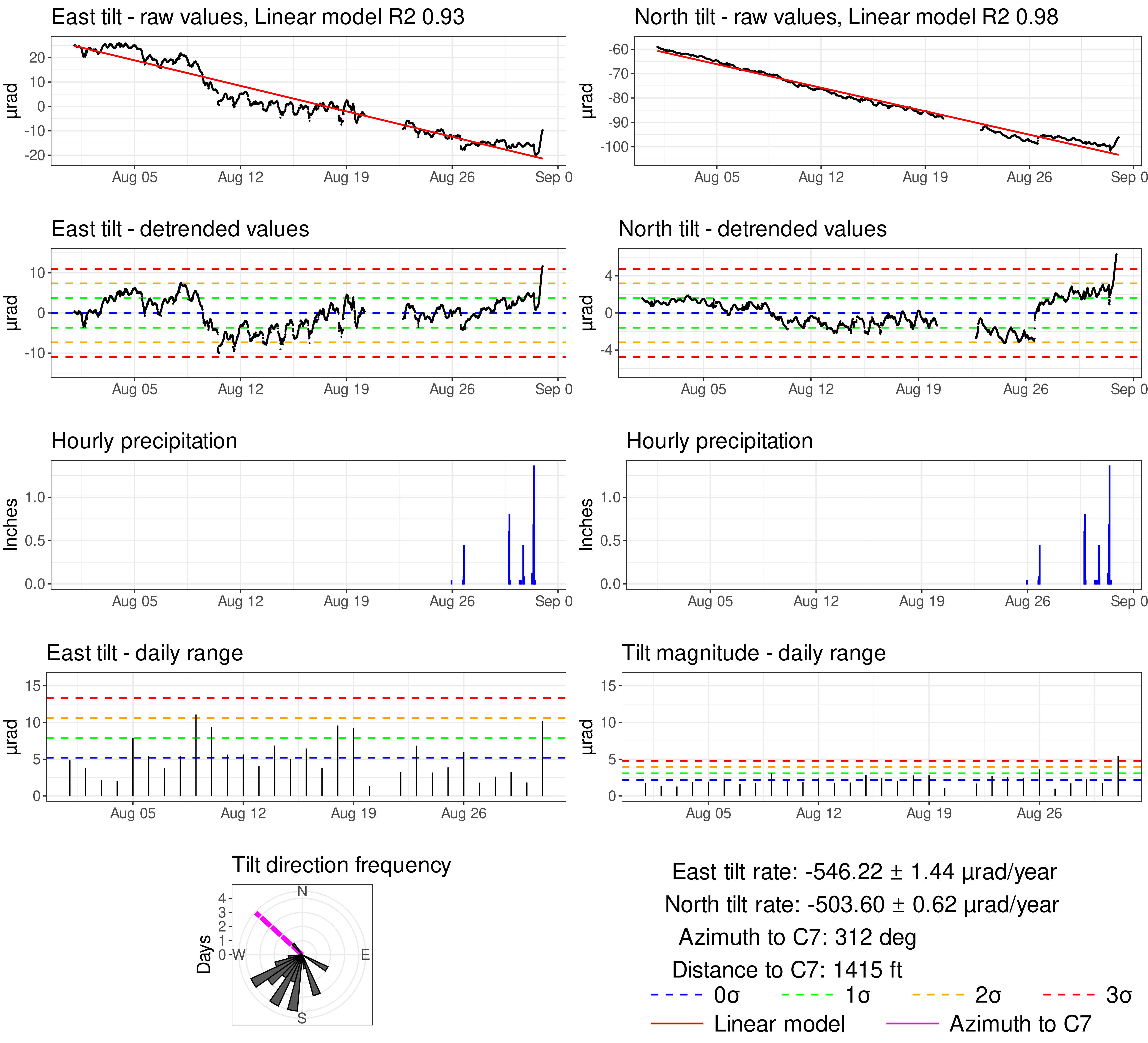
East tilt rate: 35.28 ± 0.53 µrad/year

North tilt rate: 136.50 ± 0.66 µrad/year

Azimuth to C7: 358 deg

Distance to C7: 1392 ft

SSD18, 08/01/2024 - 08/31/2024



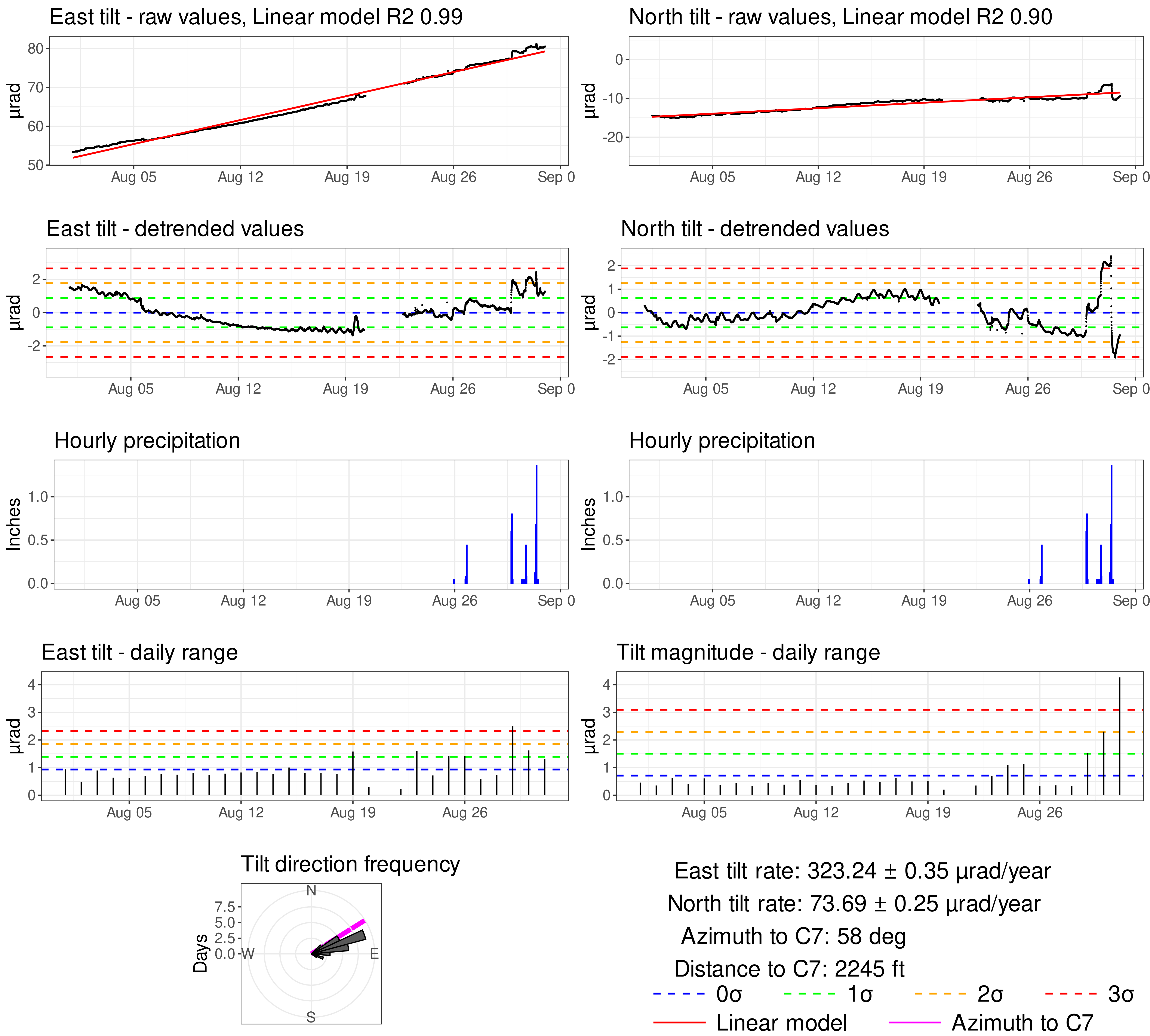
East tilt rate: -546.22 ± 1.44 µrad/year

North tilt rate: -503.60 ± 0.62 µrad/year

Azimuth to C7: 312 deg

Distance to C7: 1415 ft

SSD19, 08/01/2024 - 08/31/2024



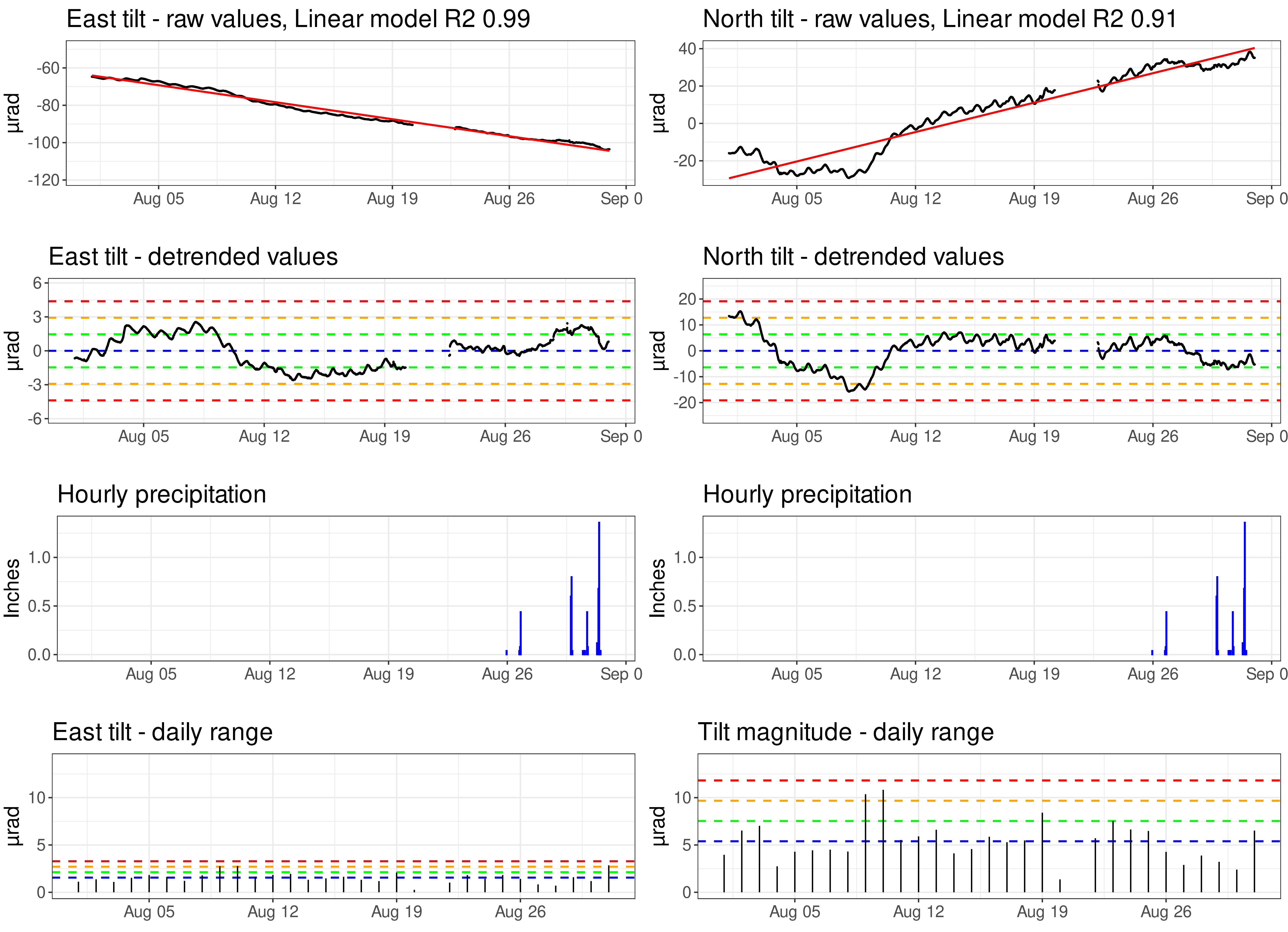
East tilt rate: 323.24 ± 0.35 µrad/year

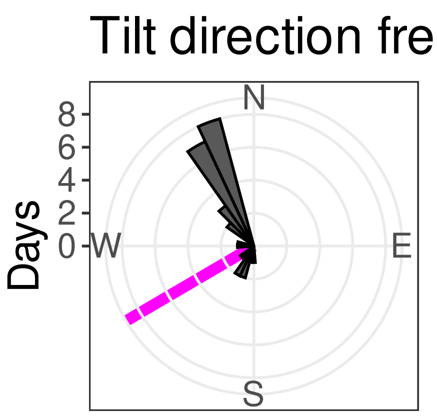
North tilt rate: 73.69 ± 0.25 µrad/year

Azimuth to C7: 58 deg

Distance to C7: 2245 ft

SSD20, 08/01/2024 - 08/31/2024



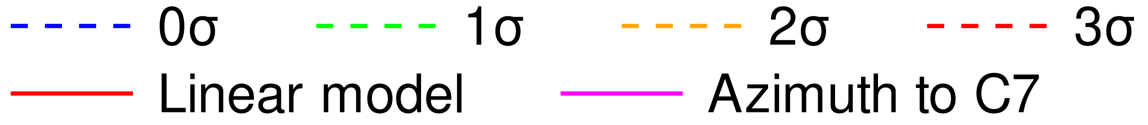


East tilt rate: -475.86 ± 0.57 µrad/year

North tilt rate: 823.40 ± 2.50 µrad/year

Azimuth to C7: 240 deg

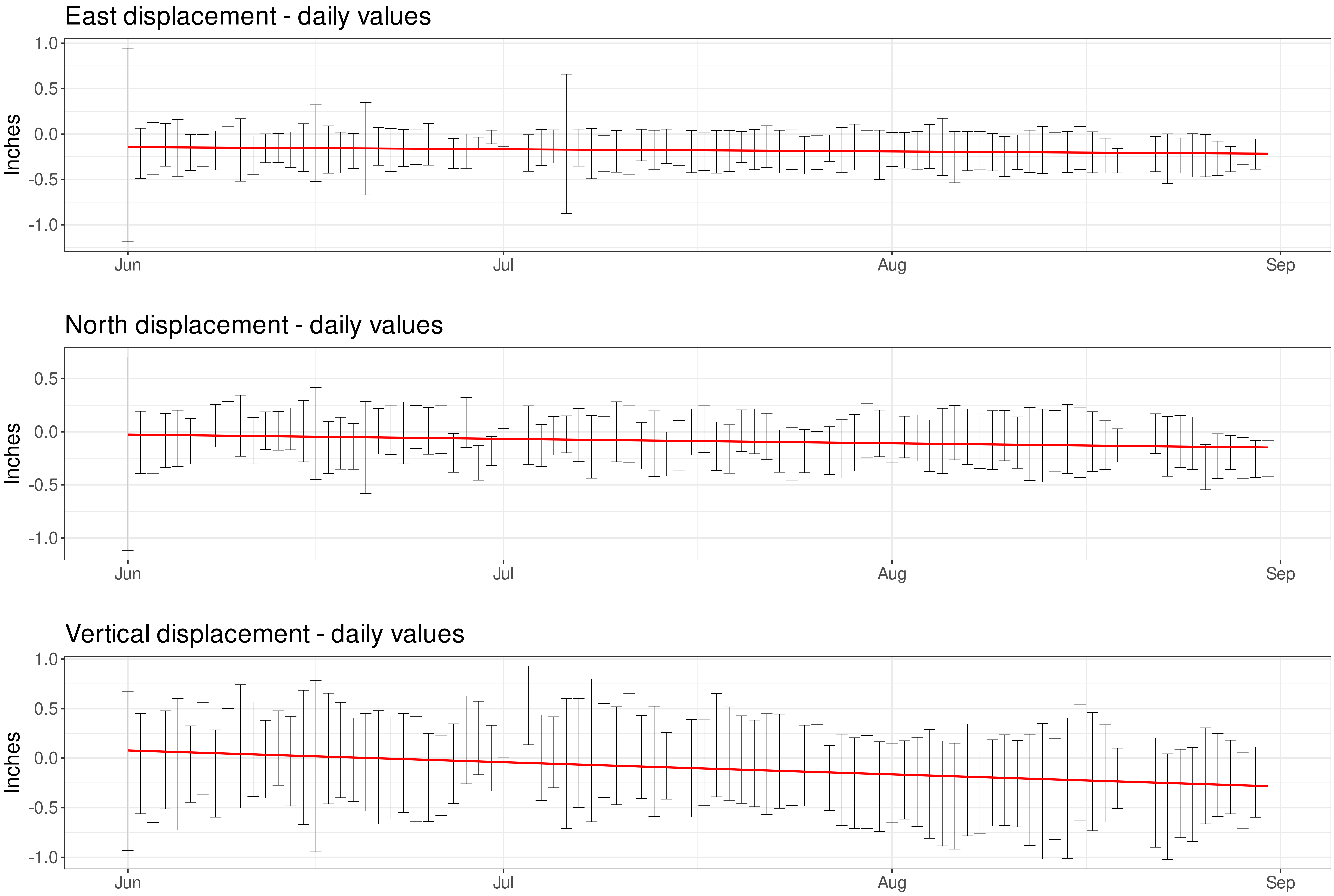
Distance to C7: 1378 ft



APPENDIX 2

GNSS Data Plots

REMC7, 06/01/2024 - 08/31/2024

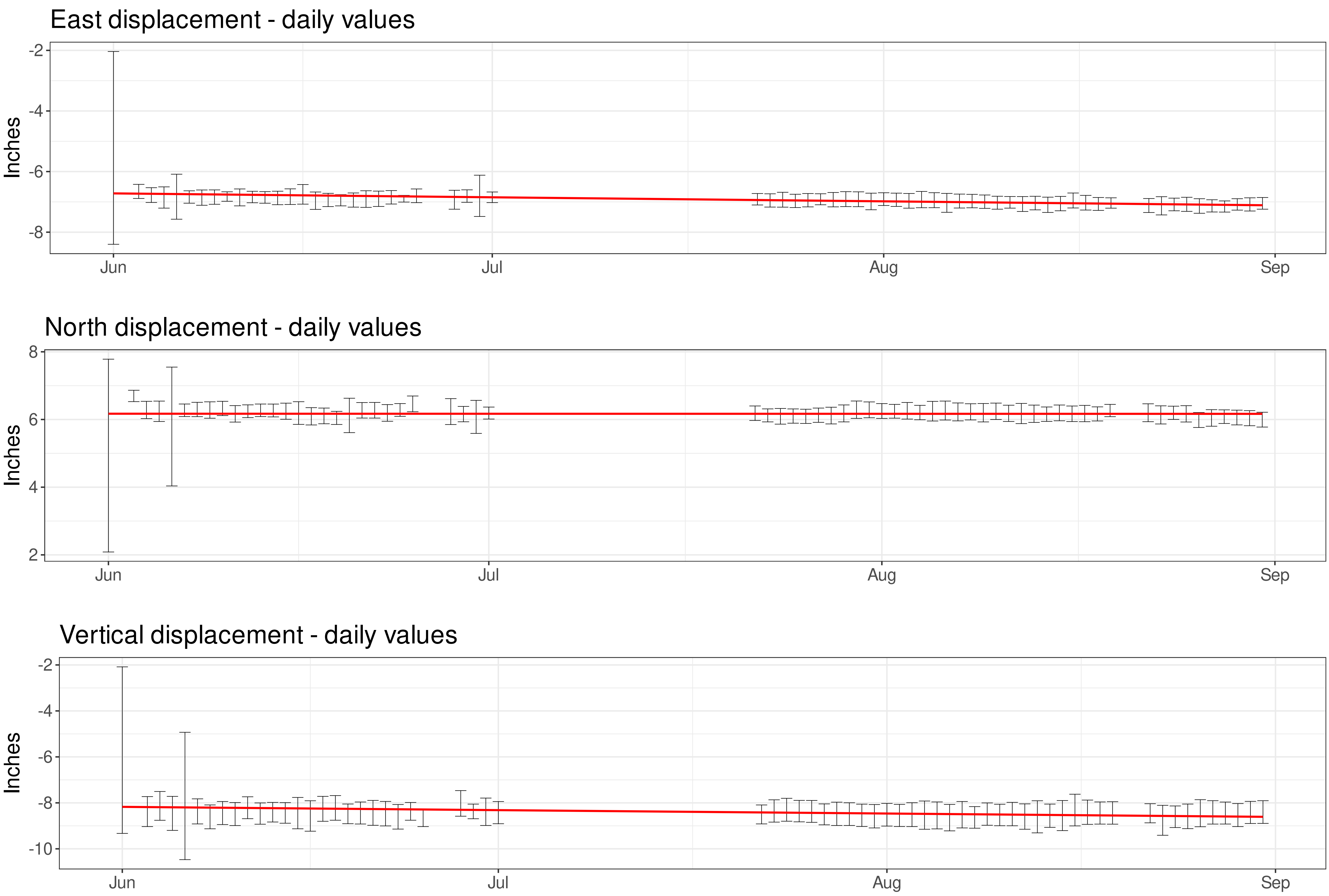


Local east rate: 0.174 ± 0.060 in/year, R2: 0.24
Local north rate: -0.468 ± 0.123 in/year, R2: 0.16
Local vertical rate: -1.377 ± 0.192 in/year, R2: 0.42

— 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 - 08/31/2024

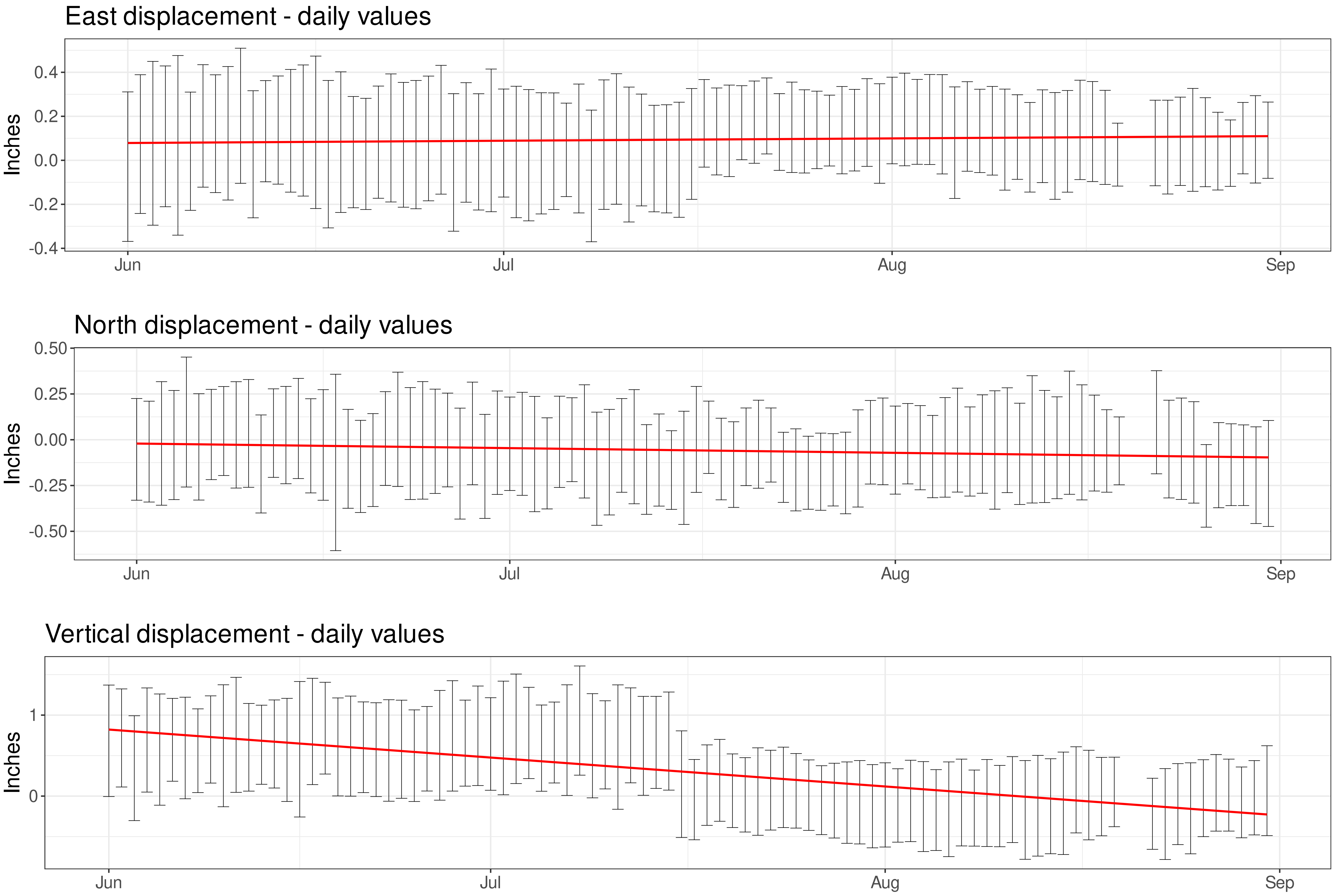


Local east rate: -1.095 ± 0.294 in/year, R2: 0.30
Local north rate: 0.007 ± 0.290 in/year, R2: 0.00
Local vertical rate: -1.670 ± 0.535 in/year, R2: 0.14

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 - 08/31/2024



Local east rate: 0.601 ± 0.082 in/year, R2: 0.03

Local north rate: -0.281 ± 0.105 in/year, R2: 0.09

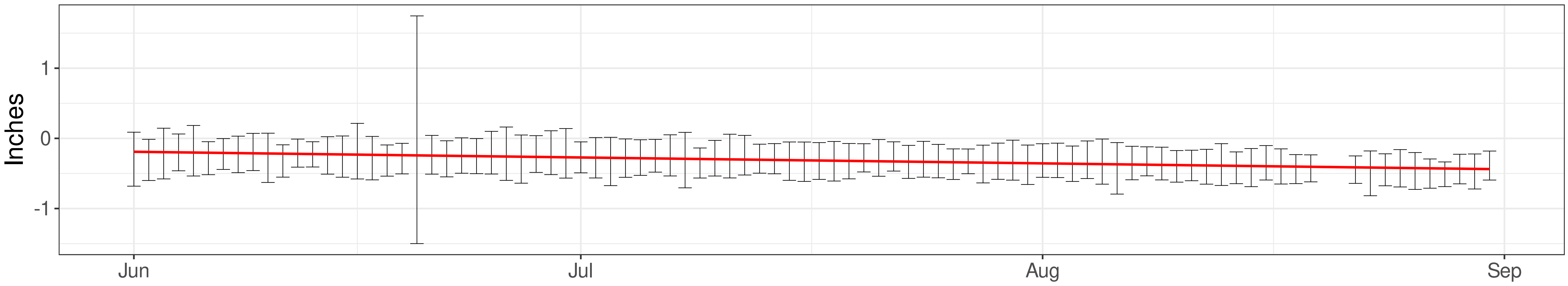
Local vertical rate: -4.147 ± 0.295 in/year, R2: 0.71

— Linear model

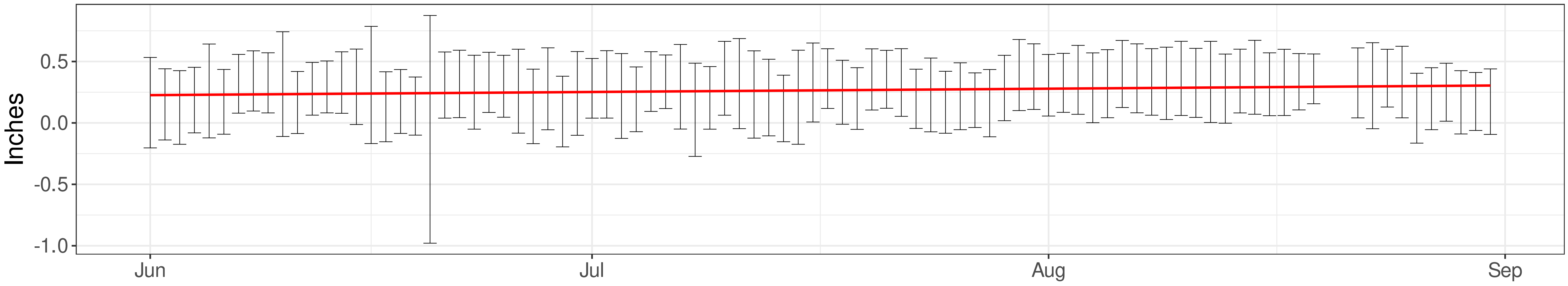
Local rate values have been calculated by removing the regional tectonic plate rates, estimated at site SAS4, from the raw data displayed in the charts.

REMSE, 06/01/2024 - 08/31/2024

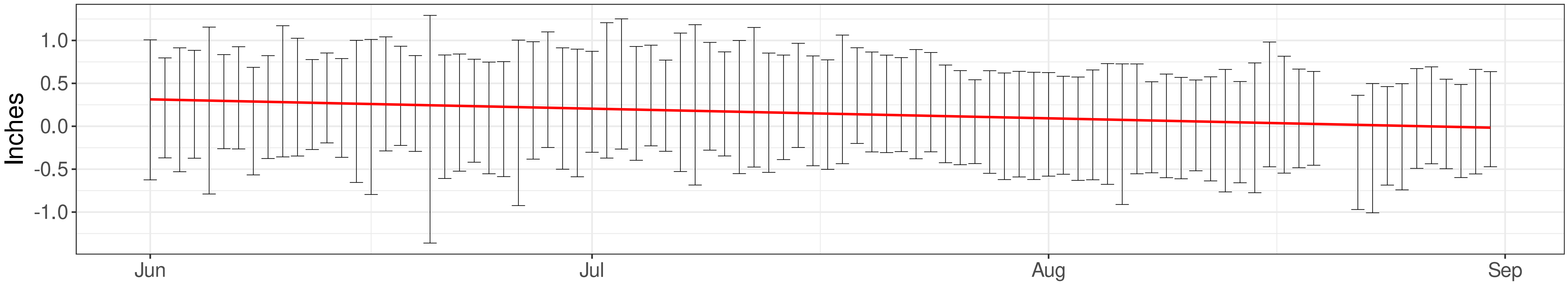
East displacement - daily values



North displacement - daily values



Vertical displacement - daily values

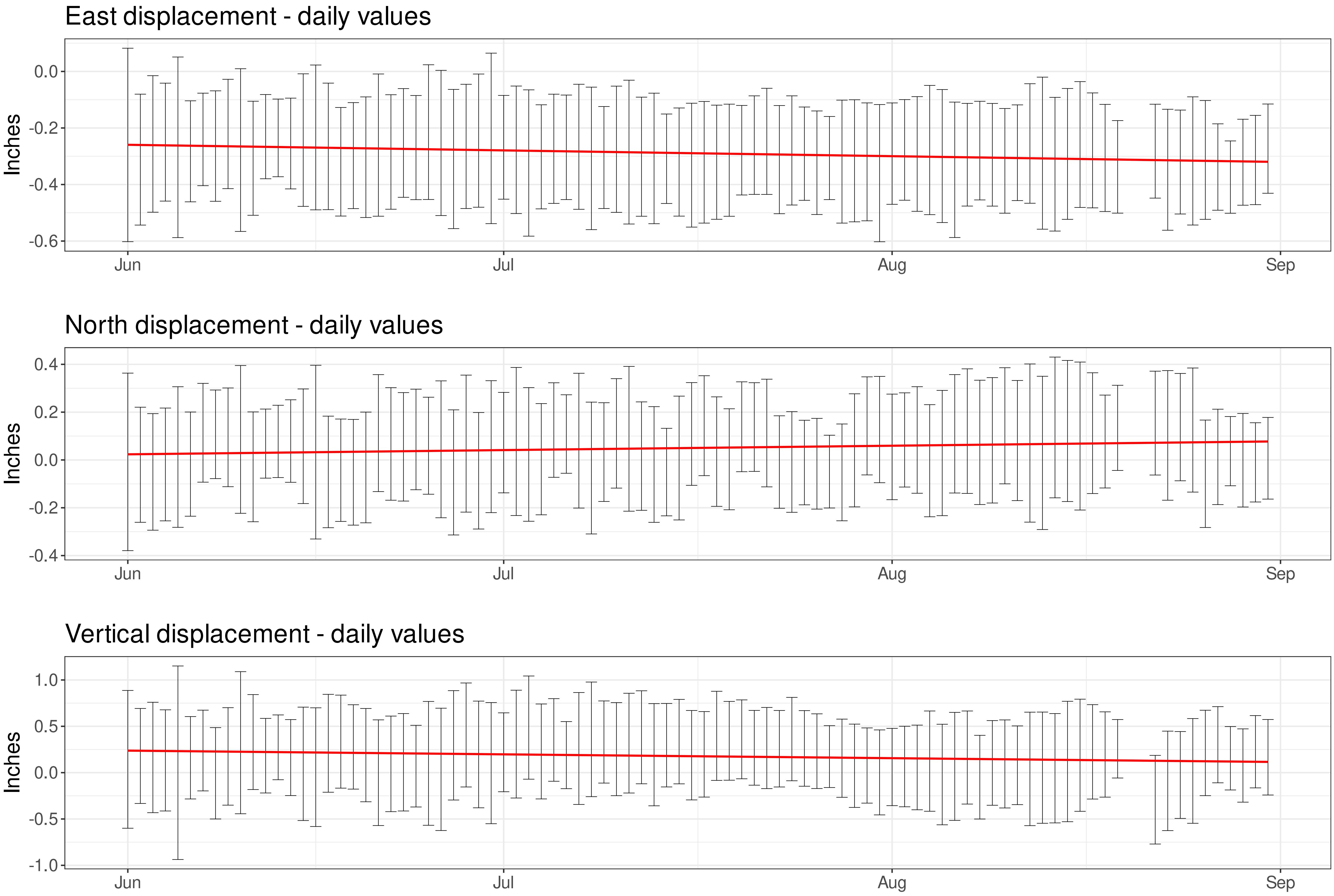


Local east rate:	-0.515 ± 0.086 in/year, R2: 0.61
Local north rate:	0.337 ± 0.124 in/year, R2: 0.07
Local vertical rate:	-1.257 ± 0.190 in/year, R2: 0.38

— 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 - 08/31/2024



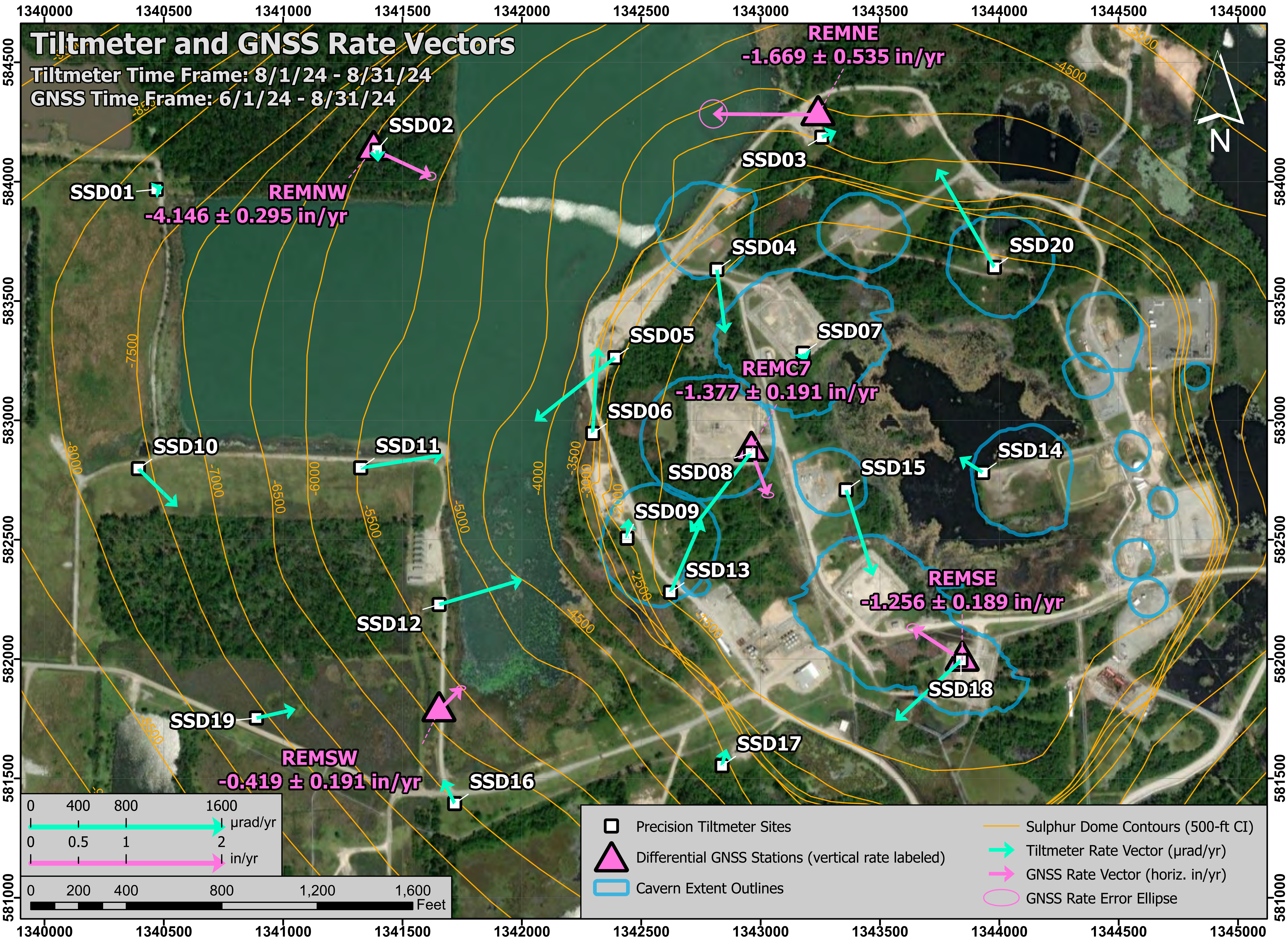
Local east rate:	0.234 ± 0.044 in/year, R2: 0.29
Local north rate:	0.239 ± 0.090 in/year, R2: 0.06
Local vertical rate:	-0.419 ± 0.191 in/year, R2: 0.07

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

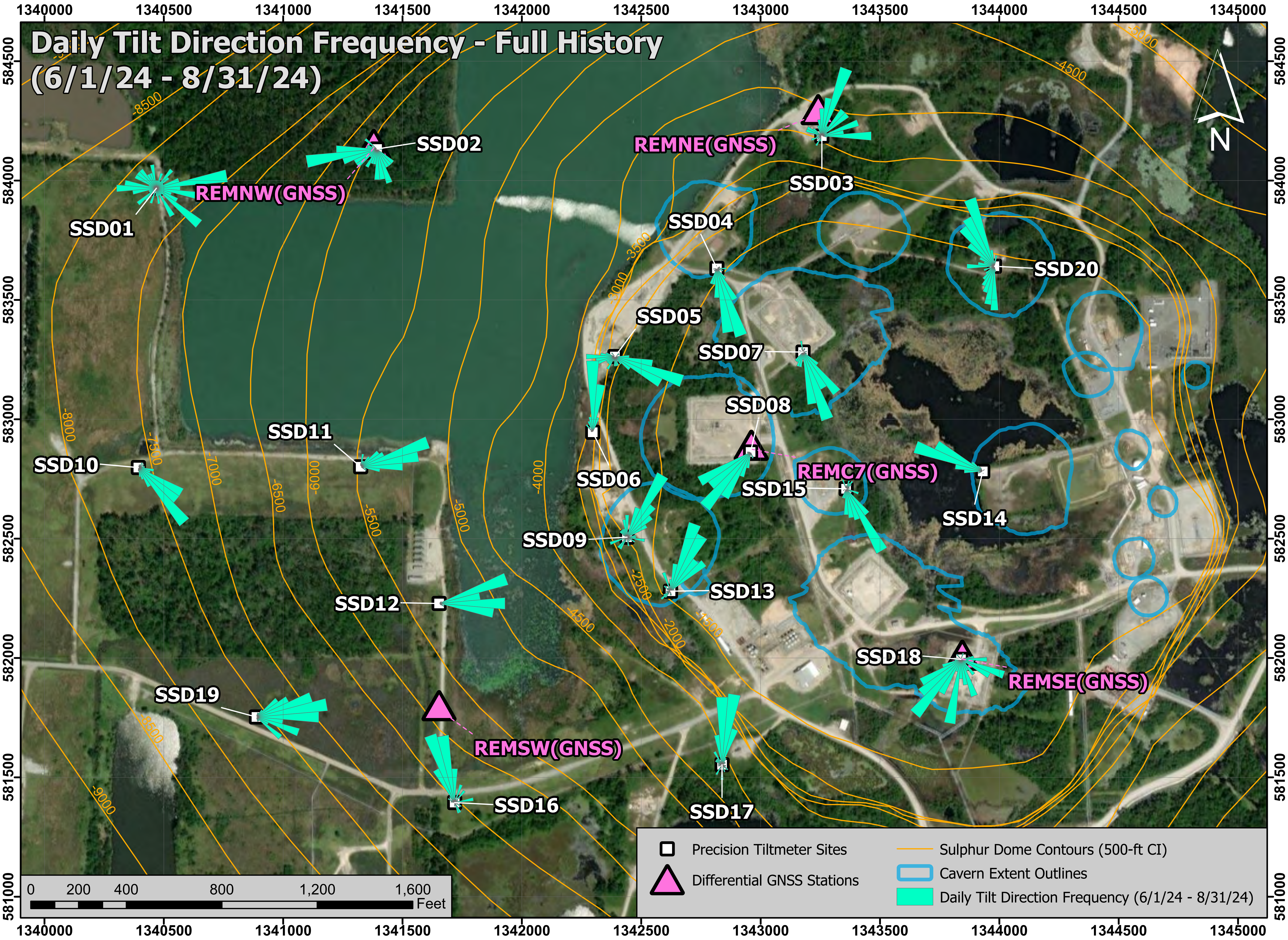


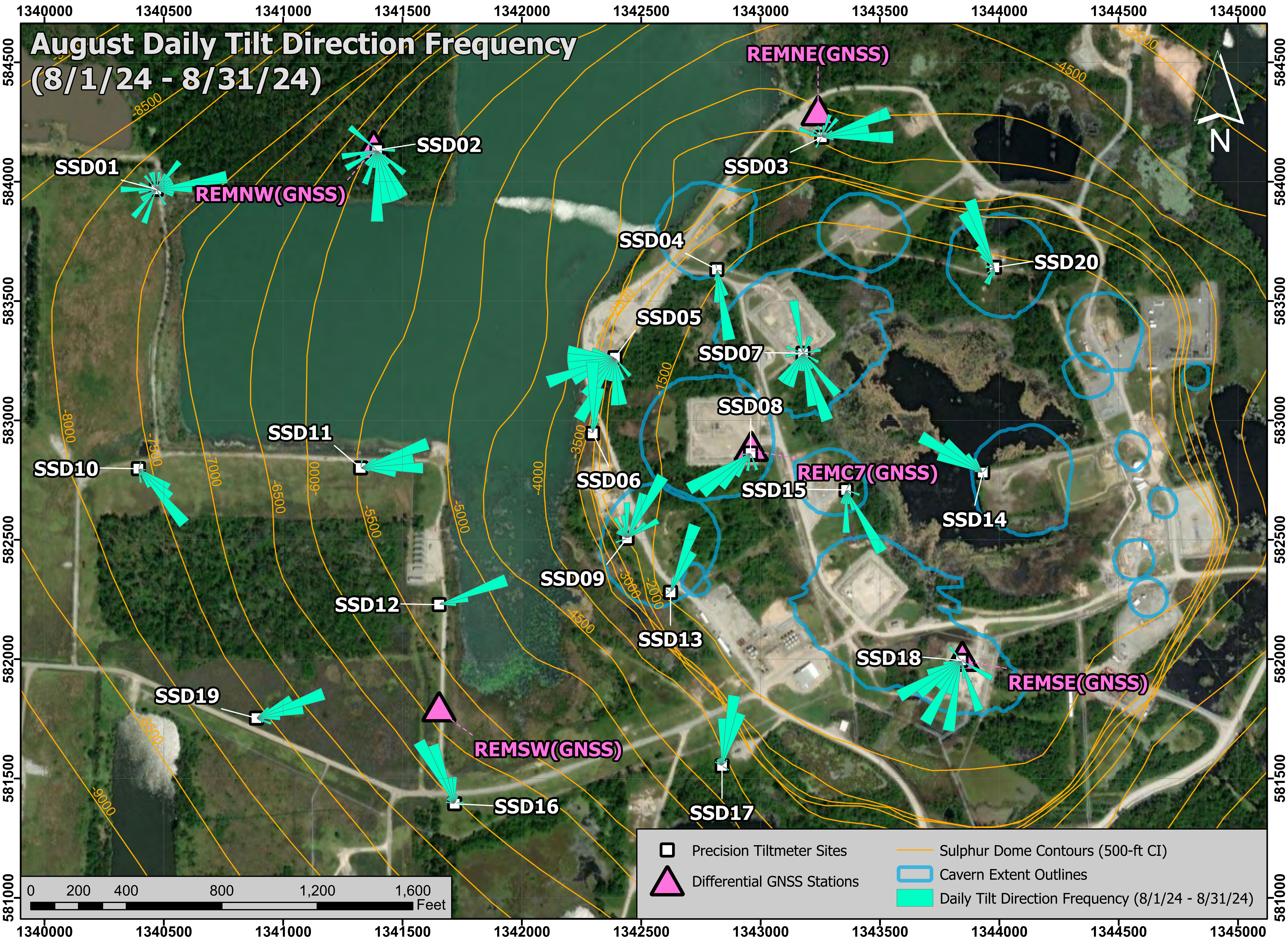
Tiltmeter and GNSS Rate Vectors

Tiltmeter Time Frame: 8/1/24 - 8/31/24
GNSS Time Frame: 6/1/24 - 8/31/24

☐	Precision Tiltmeter Sites
▲	Differential GNSS Stations (vertical rate labeled)
▭	Cavern Extent Outlines
—	Sulphur Dome Contours (500-ft CI)
→	Tiltmeter Rate Vector (µrad/yr)
→	GNSS Rate Vector (horiz. in/yr)
○	GNSS Rate Error Ellipse

Daily Tilt Direction Frequency - Full History (6/1/24 - 8/31/24)





August Daily Tilt Direction Frequency (8/1/24 - 8/31/24)

ATTACHMENT B

SNT InSAR report - August 11, 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
Sunday, August 11, 2024

Analysis Report Date:

August 16, 2024

Dataset Information

Satellite Source	Sentinel-1 (SNT)
Revisit Frequency	12 days
Most Recent Image Date	Sunday, August 11, 2024
Dataset Image Count	207
Dataset Time Range	October 4, 2016 - August 11, 2024
Dataset Length	7.85 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 or eastward movement and positive acceleration values indicate slowing rates of subsidence or eastward movement.

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 not show any material increases (≥ -0.10) in the negative velocity and/or negative acceleration of LOS displacement in any of the 15 AOI point groups. This suggests that subsidence rates have not increased over the past two years relative to the historical data that has been collected since October 2016.

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. This observation suggests that statistically relevant areas of change are not currently evident within the rate change maps.

NATHANIEL L. BYARS
License No. 40697

Nathaniel Byars

Date Signed: August 16, 2024
Austin, Texas

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

InSAR Data Sources

InSAR Data

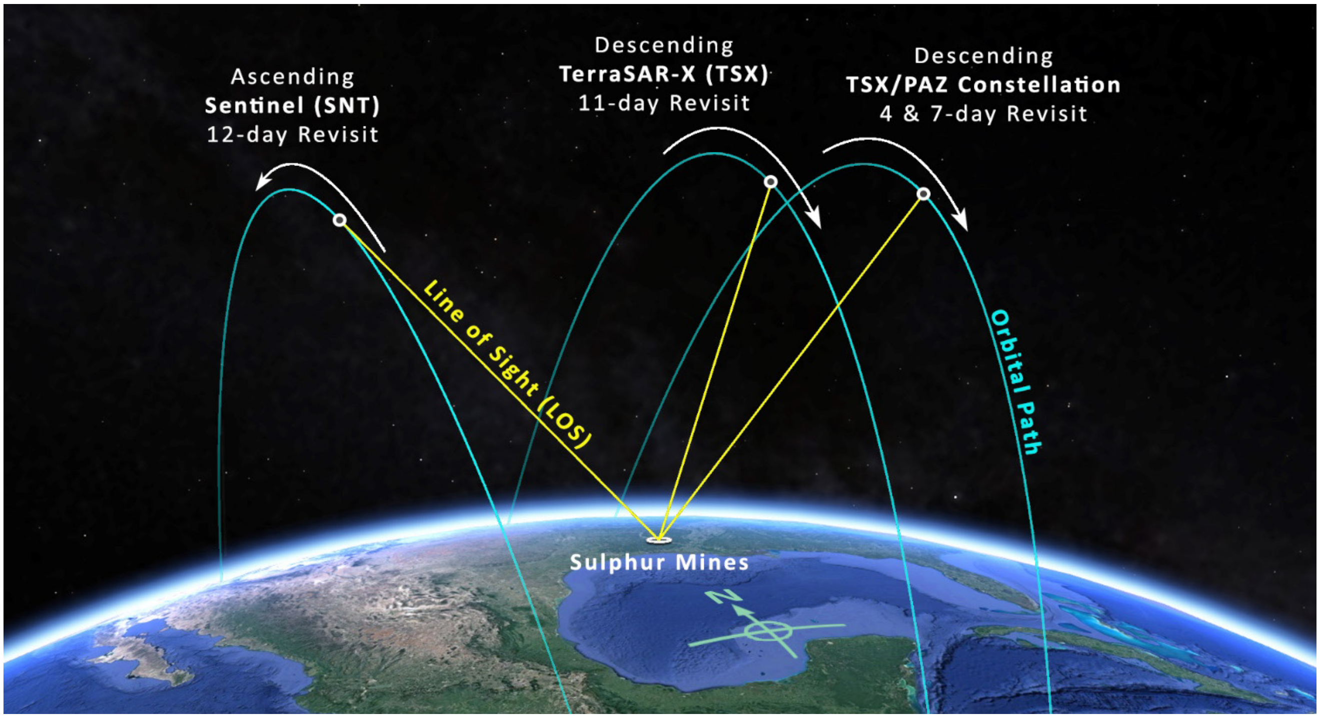
Interferometric Synthetic Aperture Radar (InSAR) is the most well established method to continually evaluate small, normally undetectable, ground movement over a large area. Radar imagery collected via satellites over successive orbital passes is used to identify and define measurement points on the 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) displacment 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 desceding orbit denotes the satellite is moving from north to south.

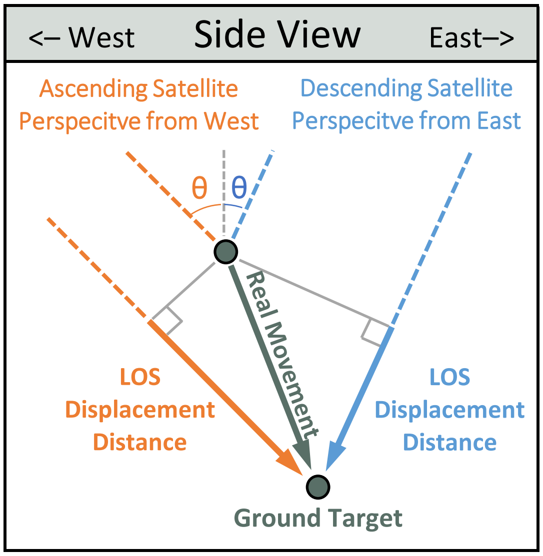
The first dataset comes from a low-resolution Sentinel-1 (SNT) satellite on an ascending orbit that captures data from the west of the site on a 12-day frequency. The second comes from a pair of high resolution satellites that share the same descending orbit and capture data from east of the site. These 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

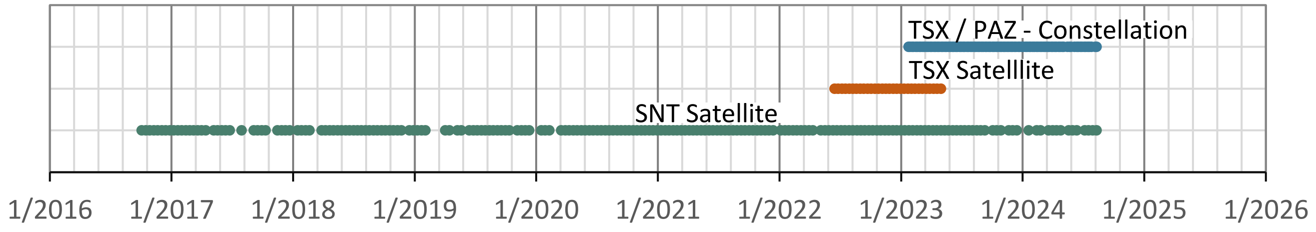
LOS displacement measurements refer to a change in distance between the satellite sensor and the ground target. Measurement positions on the west side of the Sulphur Dome are are known to be experiencing some eastward movement toward the dome center due to the geometry of the subsidence basin. The InSAR 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.



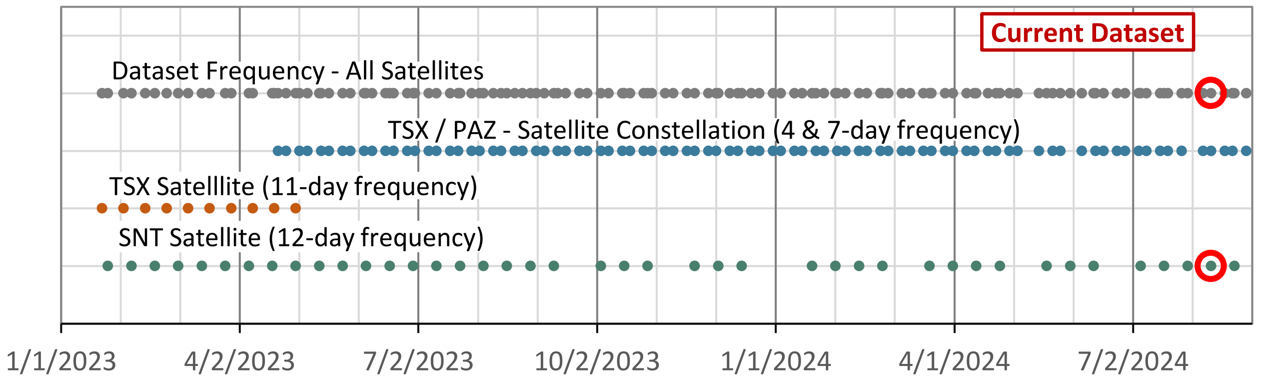
Satellite Properties & Image Frequency

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

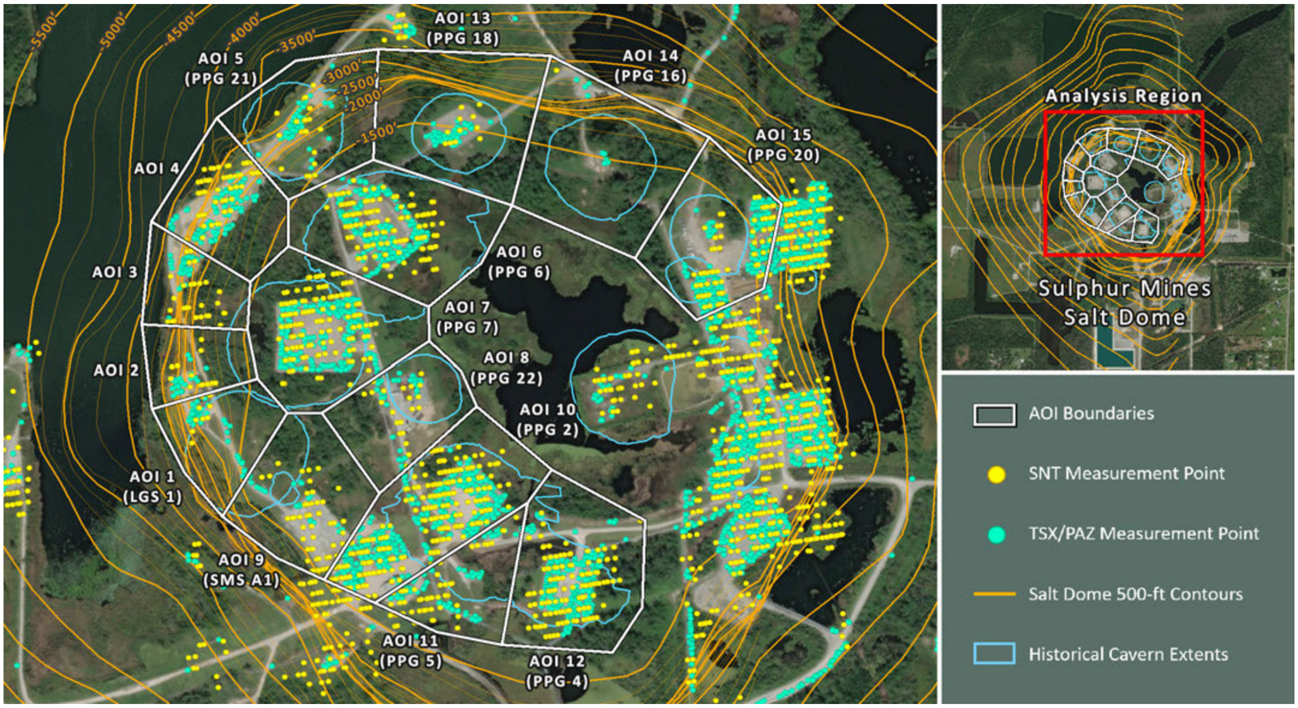
Dataset Measurement History



Dataset Update Frequency



AOI Boundaries & InSAR Measurement Points

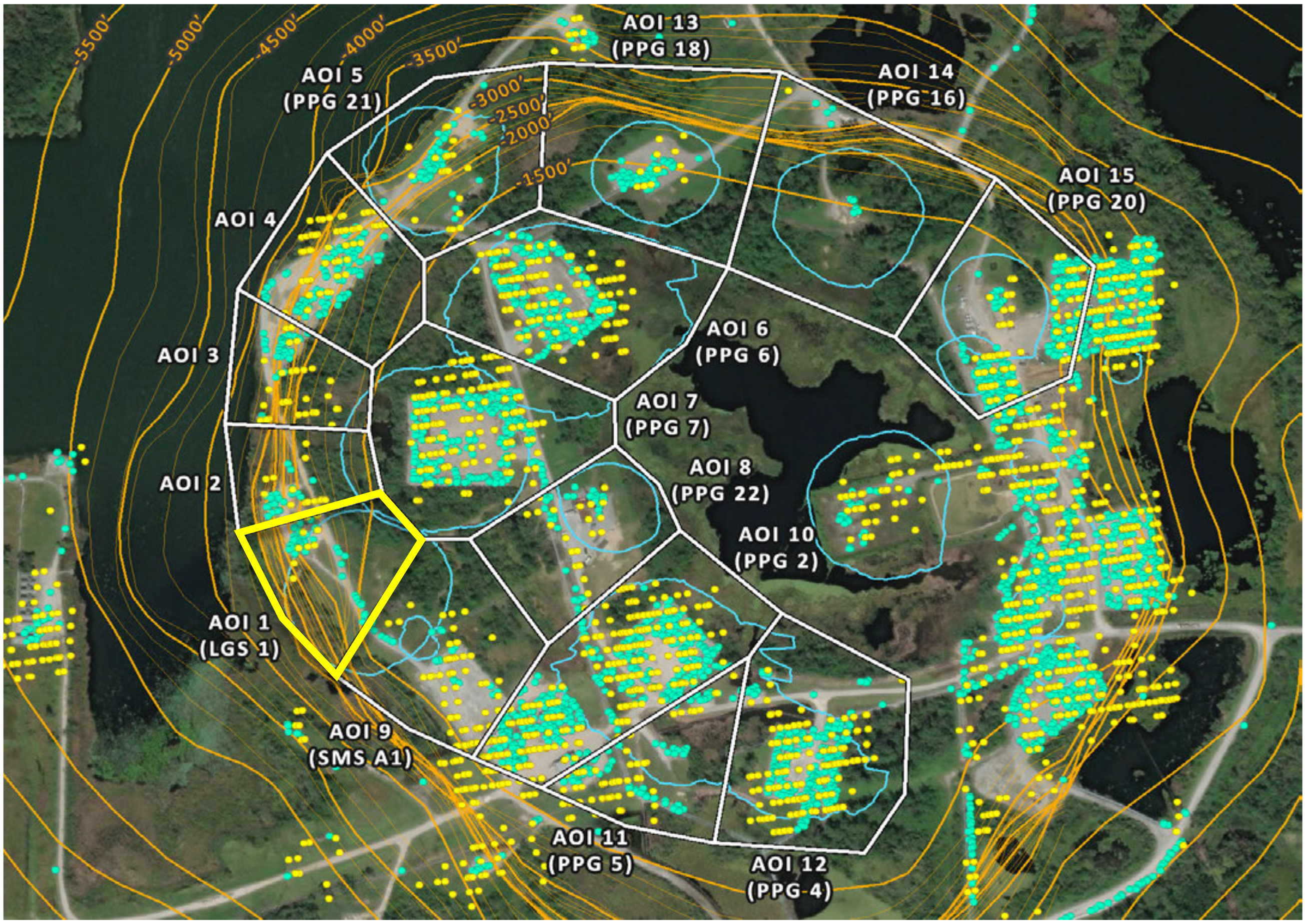


Subsidence Monitoring Areas of Interest (AOIs)

To visually convey and evaluate trend consistency for the displacement time series of each ground target, measurment 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.

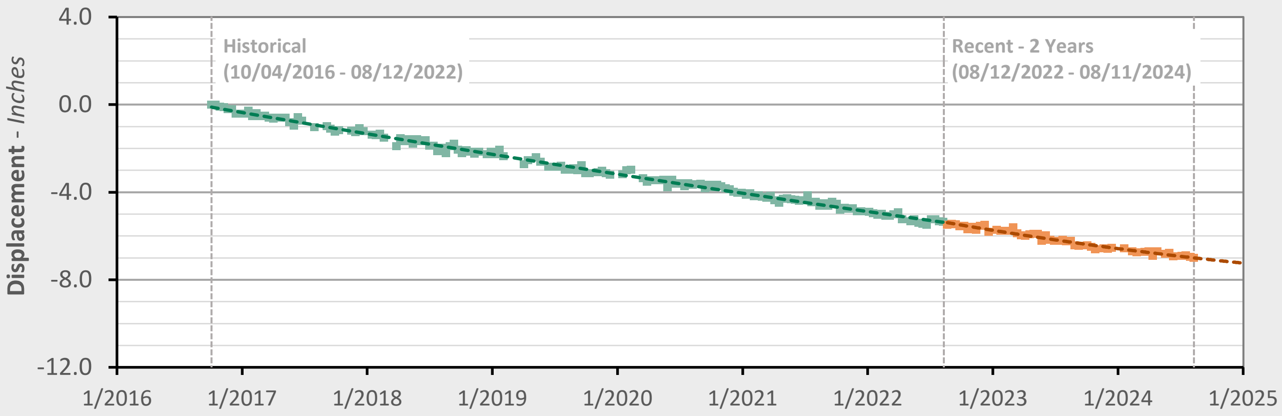
AOI Name	SNT (8/11/2024)	LOS Velocity *(in/yr)*			LOS Acceleration *(in/yr^2)*		
	Point Count	Historical	Recent	Change	Historical	Recent	Change
AOI 1 *(LGS 1)*	12	-0.80	-0.63	+0.17	+0.04	+0.20	+0.16
AOI 2	16	-0.78	-0.77	+0.01	+0.06	+0.11	+0.06
AOI 3	29	-0.66	-0.54	+0.12	+0.03	+0.14	+0.12
AOI 4	62	-0.77	-0.70	+0.07	+0.00	-0.01	-0.01
AOI 5 *(PPG 21)*	25	-0.66	-0.49	+0.17	+0.02	+0.05	+0.04
AOI 6 *(PPG 6)*	134	-0.87	-0.82	+0.05	+0.05	+0.05	-0.00
AOI 7 *(PPG 7)*	140	-1.00	-1.01	-0.01	+0.07	+0.08	+0.01
AOI 8 *(PPG 22)*	20	-1.06	-1.13	-0.08	+0.11	+0.10	-0.01
AOI 9 *(SMS A1)*	59	-0.86	-0.72	+0.14	+0.07	+0.16	+0.08
AOI 10 *(PPG 2)*	231	-0.90	-0.97	-0.06	+0.09	+0.03	-0.06
AOI 11 *(PPG 5)*	52	-0.90	-0.76	+0.14	+0.06	+0.14	+0.08
AOI 12 *(PPG 4)*	120	-0.73	-0.34	+0.40	+0.05	+0.36	+0.31
AOI 13 *(PPG 18)*	12	-0.61	-0.44	+0.17	+0.04	+0.16	+0.13
AOI 14 *(PPG 16)*	1	-0.21	+0.18	+0.39	+0.07	+0.69	+0.63
AOI 15 *(PPG 20)*	74	-0.28	-0.22	+0.06	+0.05	+0.05	+0.00

AOI 1 *(LGS 1)* - Location Map



AOI 1 *(LGS 1)* - Displacement Time Series

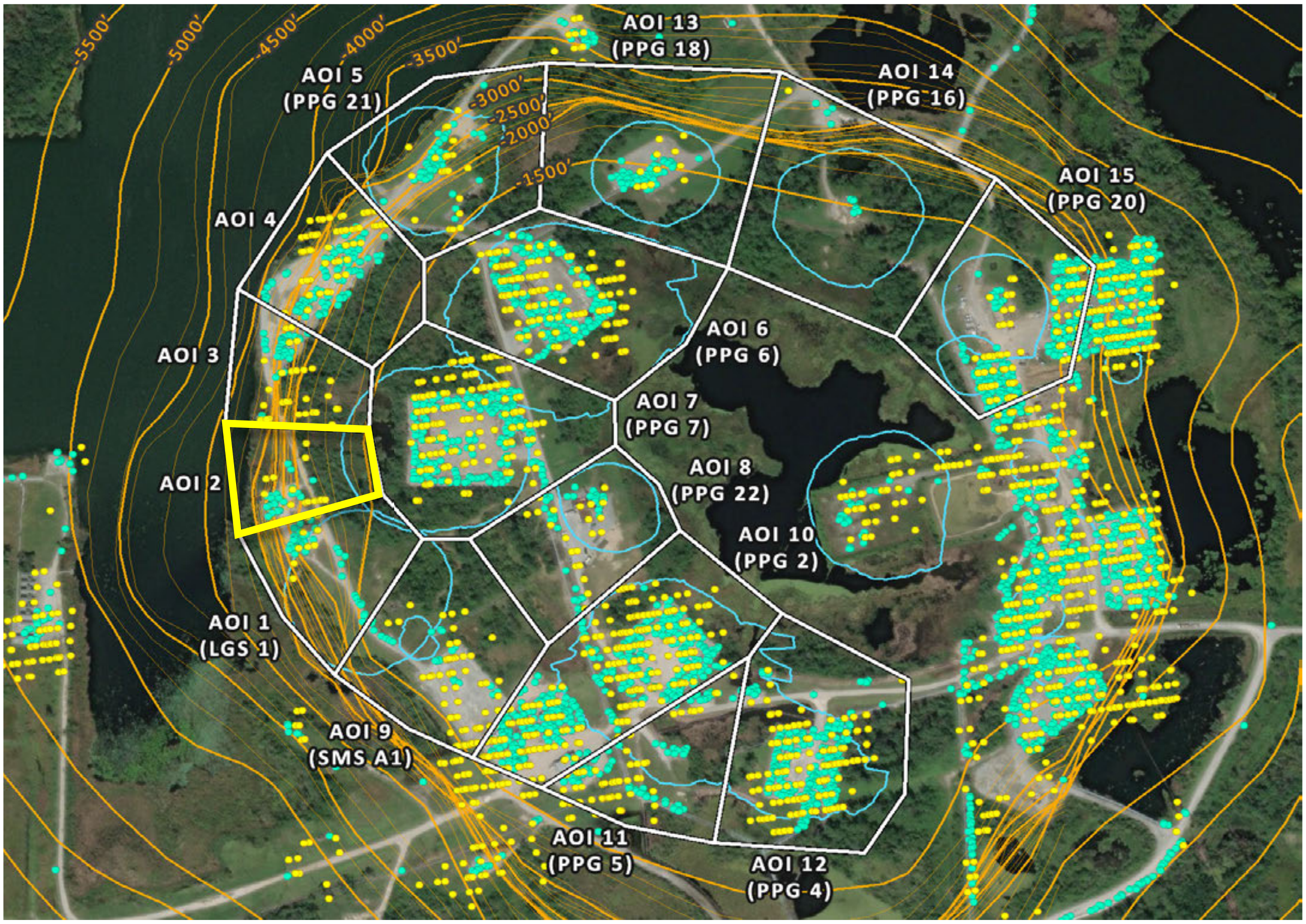
SNT (8/11/2024) Point Count: **12**



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.80 in/yr	-0.63 in/yr	+0.17 in/yr
Acceleration:	+0.04 in/yr^2	+0.20 in/yr^2	+0.16 in/yr^2

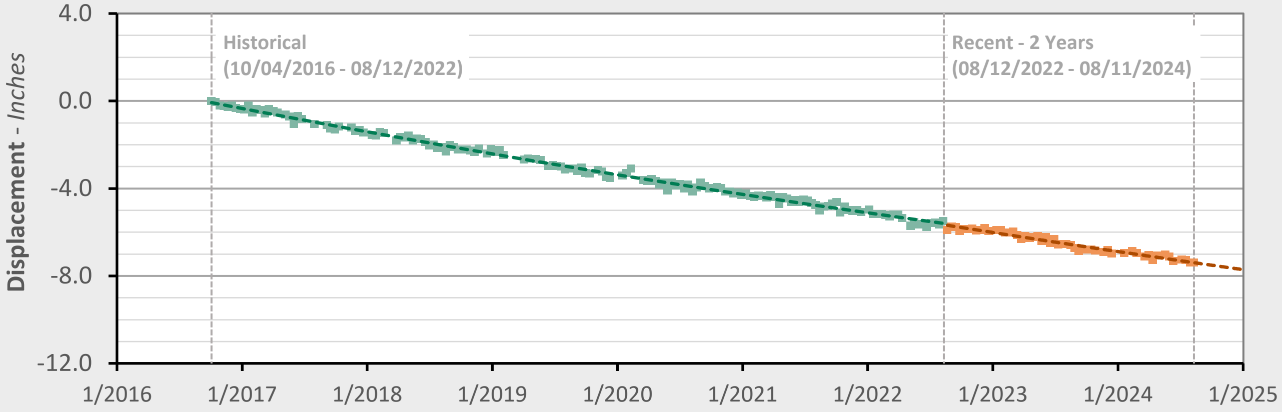
■ Historical LOS Displacement Measurement
---- Historical Trend Line (Quadratic Regression)
■ Recent LOS Displacement Measurement
---- Historical Trend Line (Quadratic Regression)

AOI 2 - Location Map



AOI 2 - Displacement Time Series

SNT (8/11/2024) Point Count: **16**



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.78 in/yr	-0.77 in/yr	+0.01 in/yr
Acceleration:	+0.06 in/yr^2	+0.11 in/yr^2	+0.06 in/yr^2

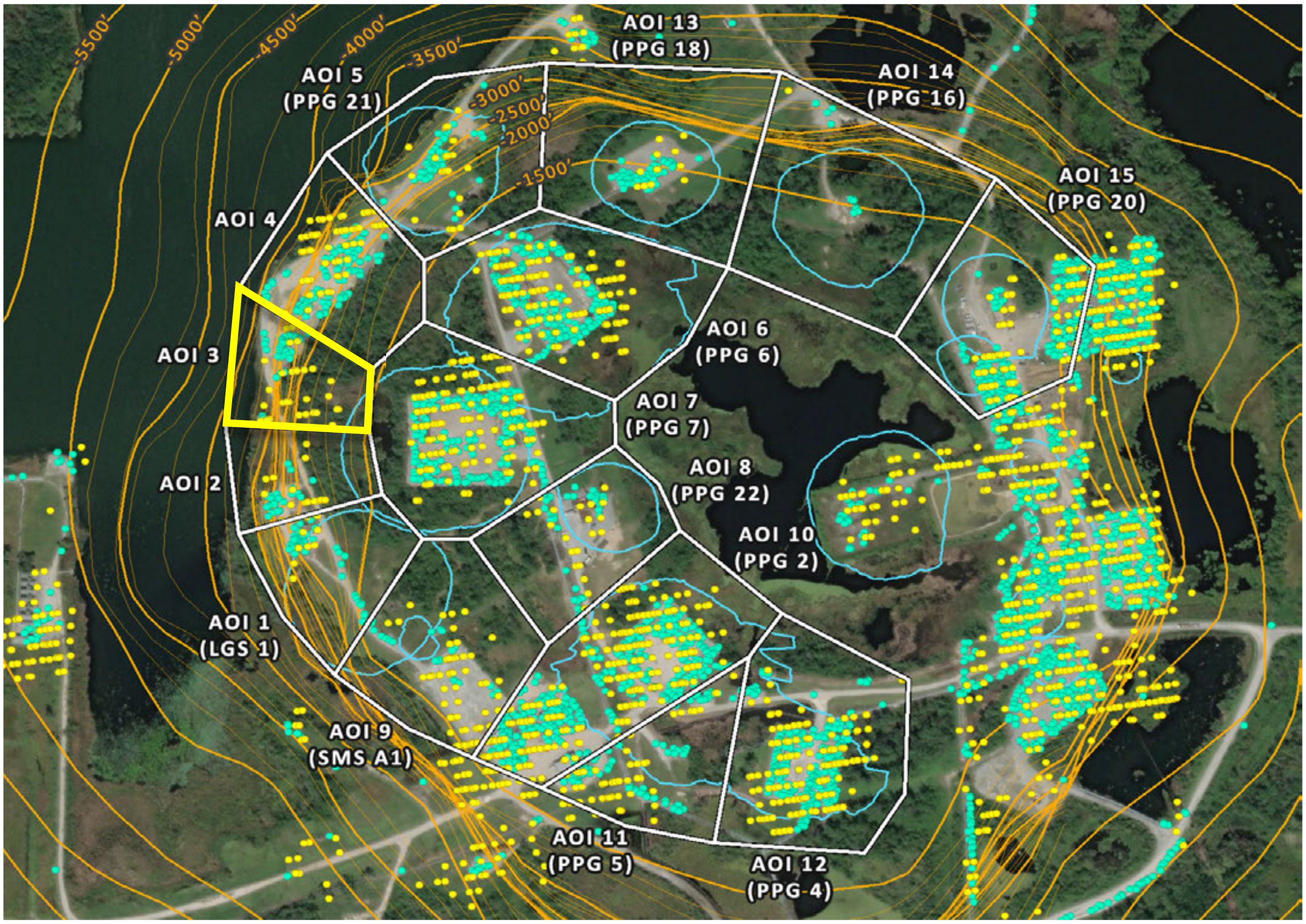
■ Historical LOS Displacement Measurement

---- Historical Trend Line (Quadratic Regression)

■ Recent LOS Displacement Measurement

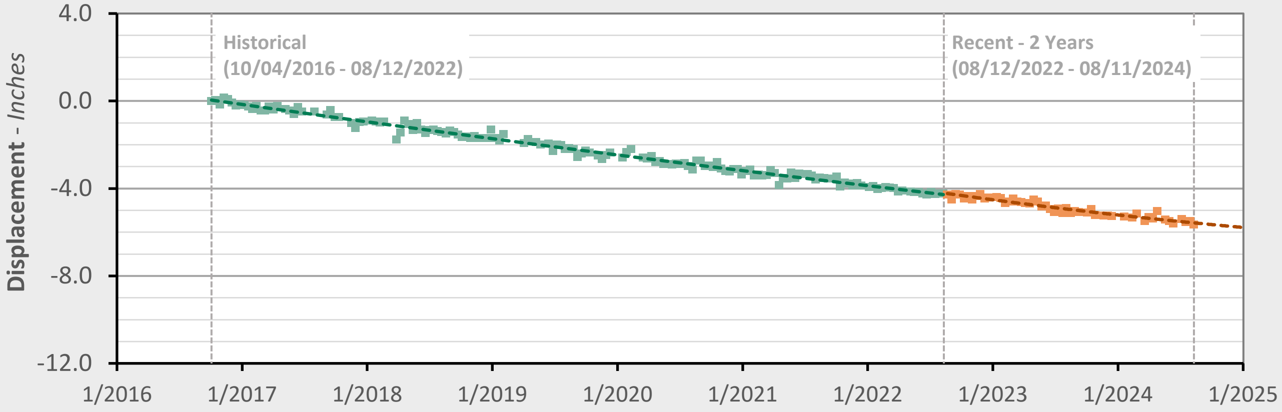
---- Historical Trend Line (Quadratic Regression)

AOI 3 - Location Map



AOI 3 - Displacement Time Series

SNT (8/11/2024) Point Count: **29**



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.66 in/yr	-0.54 in/yr	+0.12 in/yr
Acceleration:	+0.03 in/yr^2	+0.14 in/yr^2	+0.12 in/yr^2

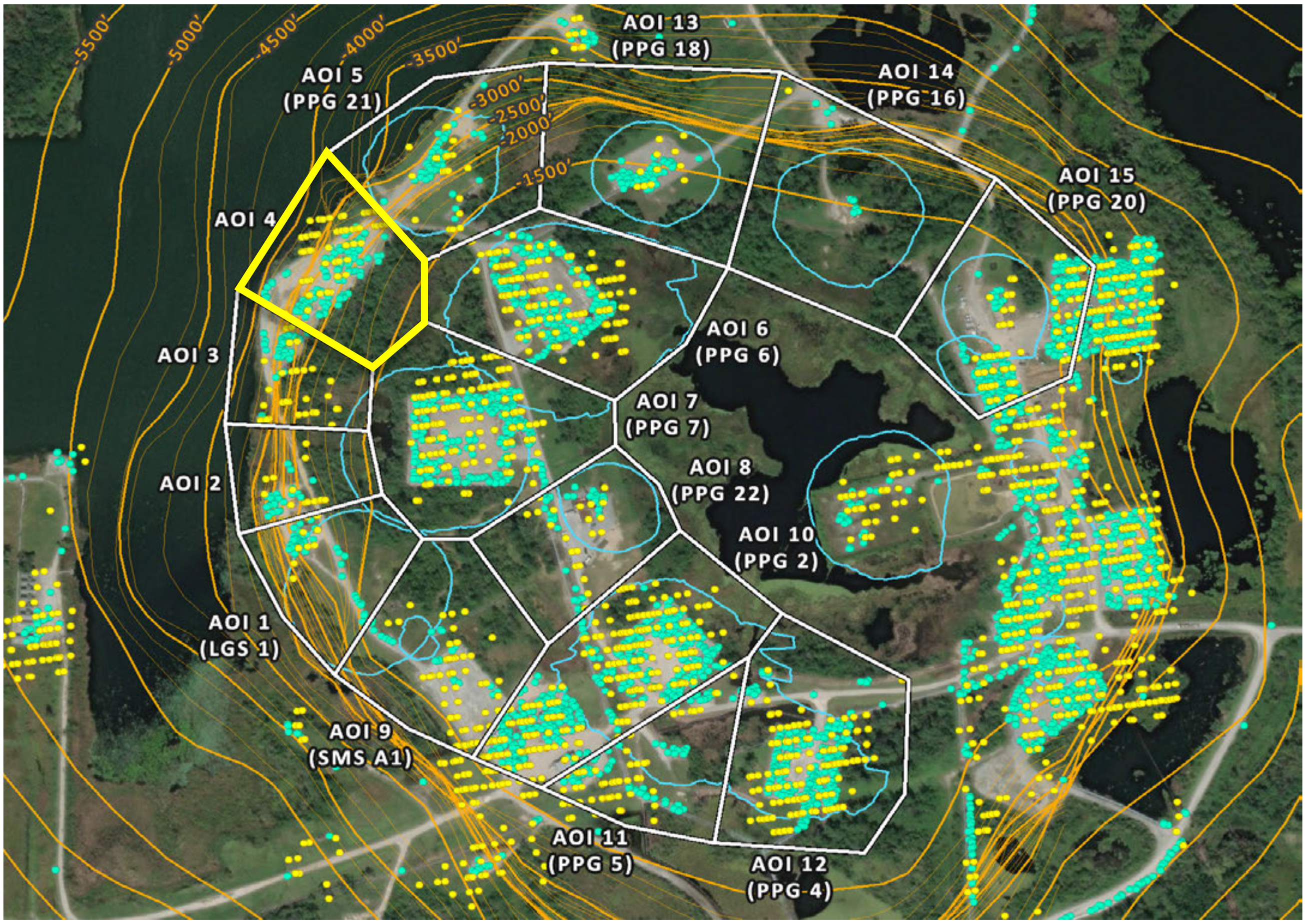
🟩 Historical LOS Displacement Measurement

---- Historical Trend Line (Quadratic Regression)

🟧 Recent LOS Displacement Measurement

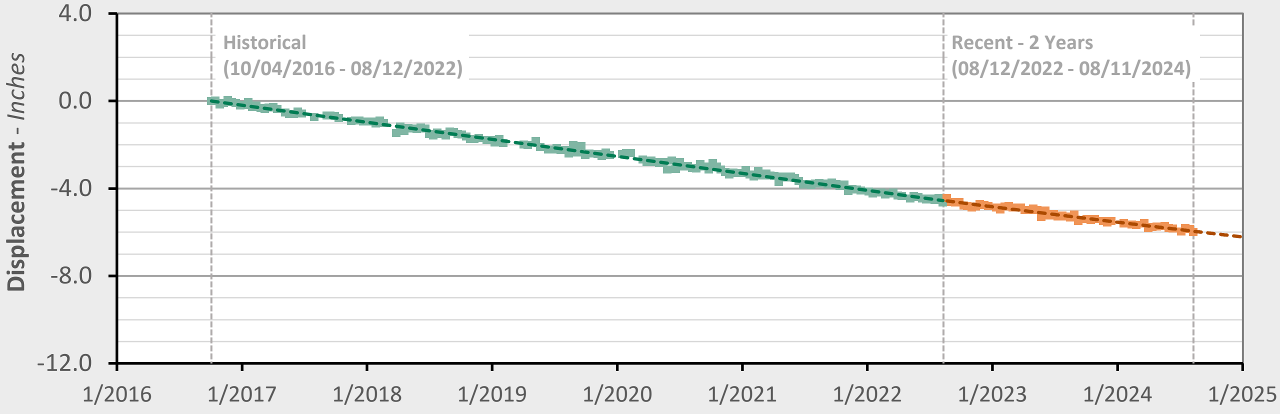
---- Historical Trend Line (Quadratic Regression)

AOI 4 - Location Map



AOI 4 - Displacement Time Series

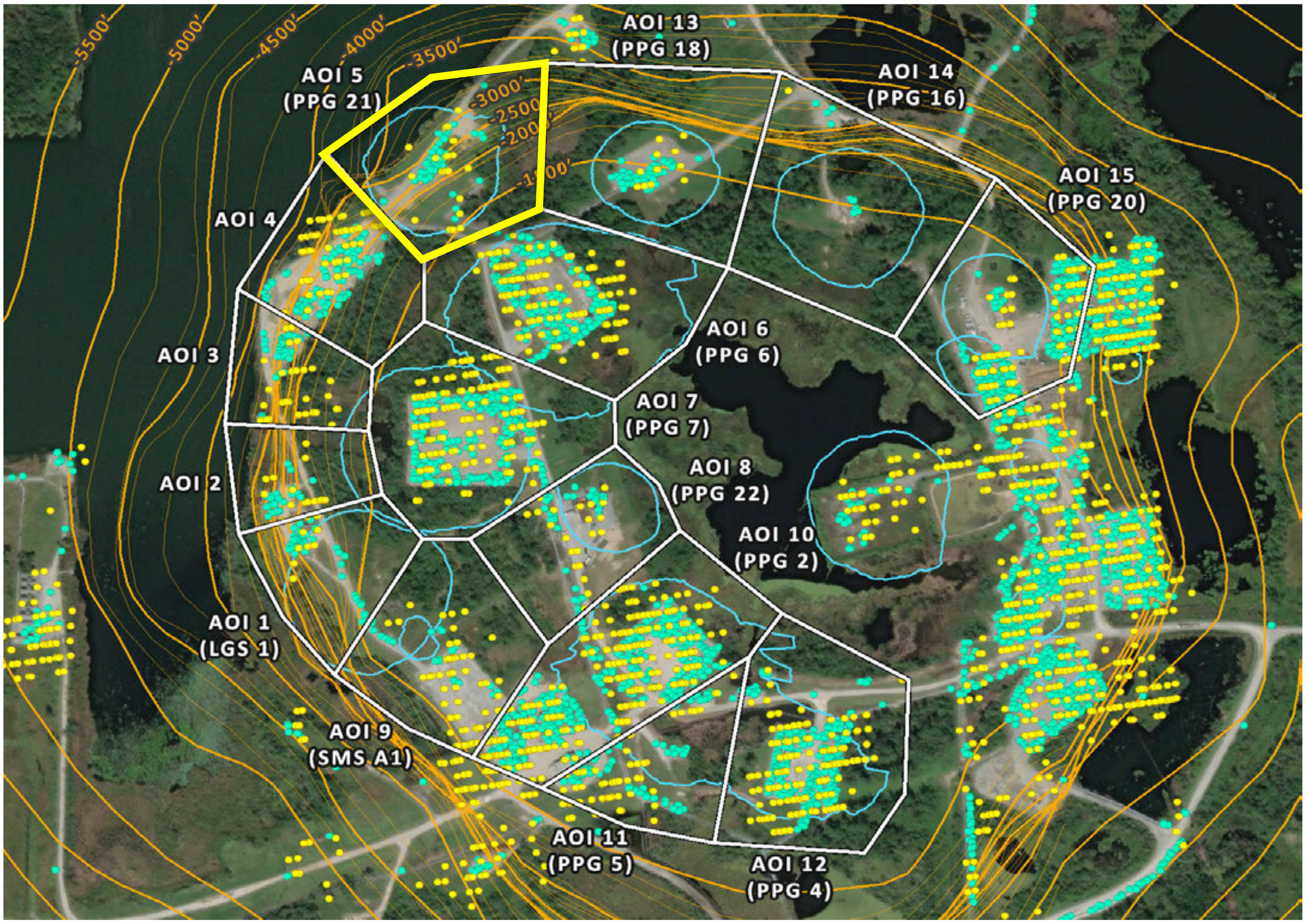
SNT (8/11/2024) Point Count: **62**



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.77 in/yr	-0.70 in/yr	+0.07 in/yr
Acceleration:	+0.00 in/yr^2	-0.01 in/yr^2	-0.01 in/yr^2

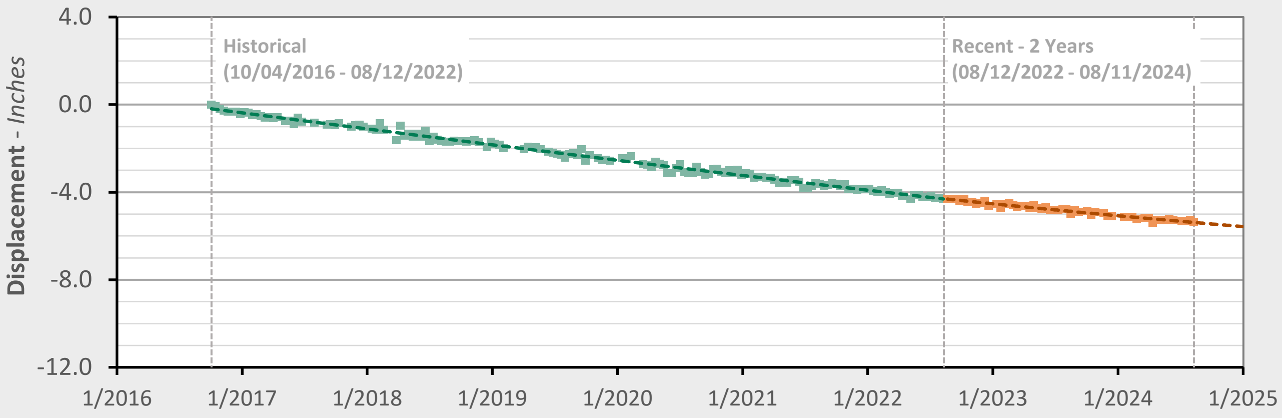
🟩 Historical LOS Displacement Measurement
---- Historical Trend Line (Quadratic Regression)
🟧 Recent LOS Displacement Measurement
---- Historical Trend Line (Quadratic Regression)

AOI 5 *(PPG 21)* - Location Map



AOI 5 *(PPG 21)* - Displacement Time Series

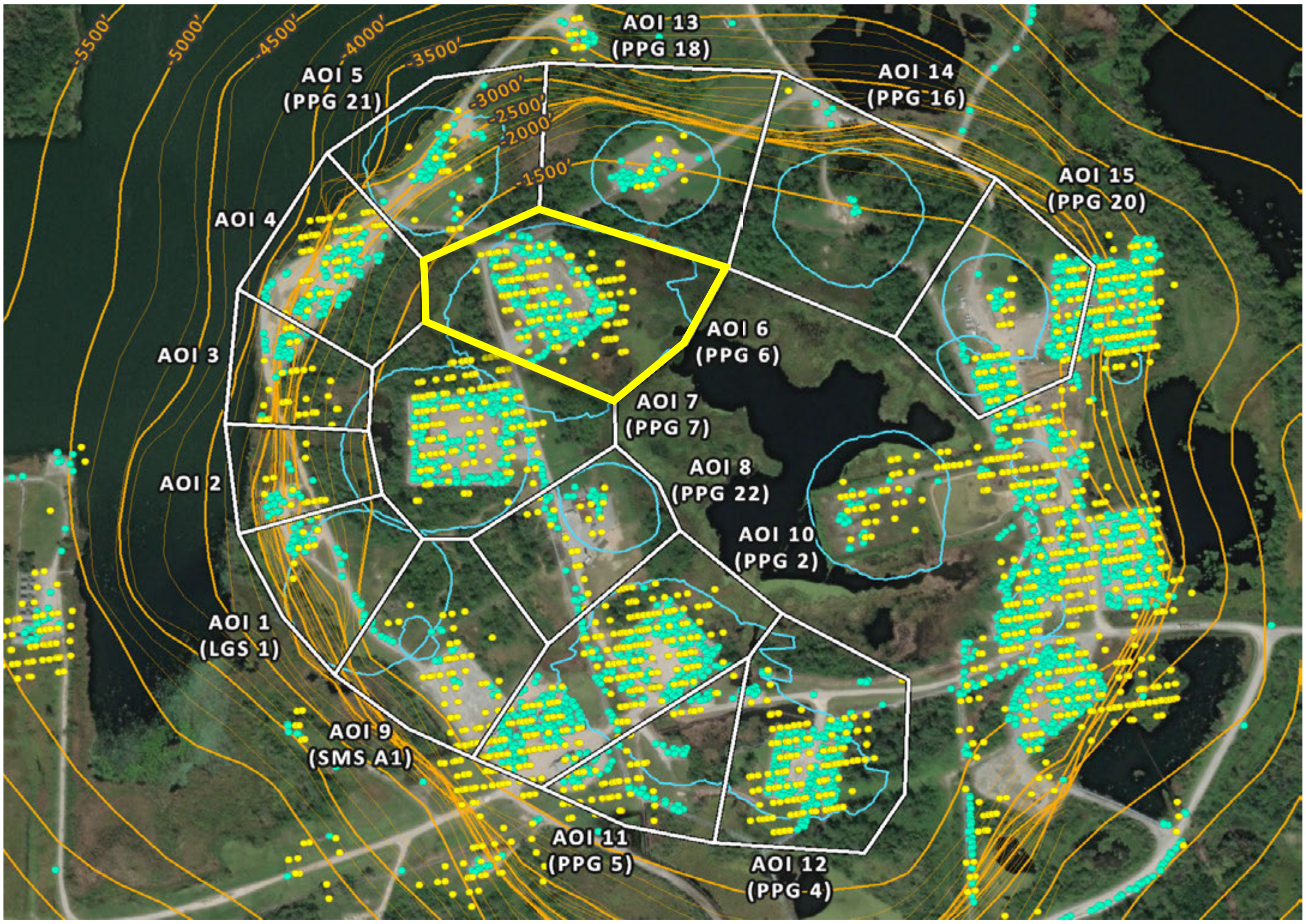
SNT (8/11/2024) Point Count: **25**



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.66 in/yr	-0.49 in/yr	+0.17 in/yr
Acceleration:	+0.02 in/yr^2	+0.05 in/yr^2	+0.04 in/yr^2

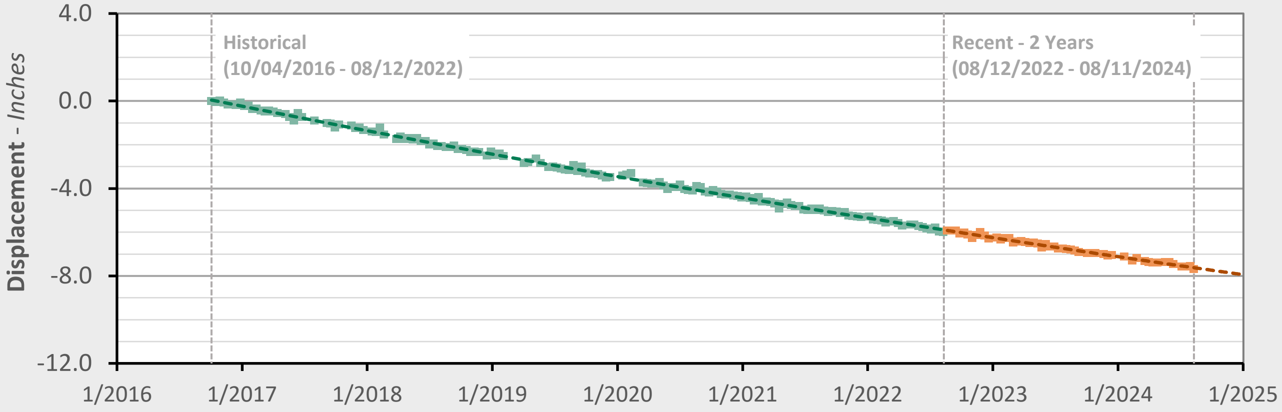
■ Historical LOS Displacement Measurement
---- Historical Trend Line (Quadratic Regression)
■ Recent LOS Displacement Measurement
---- Historical Trend Line (Quadratic Regression)

AOI 6 *(PPG 6)* - Location Map



AOI 6 *(PPG 6)* - Displacement Time Series

SNT (8/11/2024) Point Count: **134**



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.87 in/yr	-0.82 in/yr	+0.05 in/yr
Acceleration:	+0.05 in/yr^2	+0.05 in/yr^2	-0.00 in/yr^2

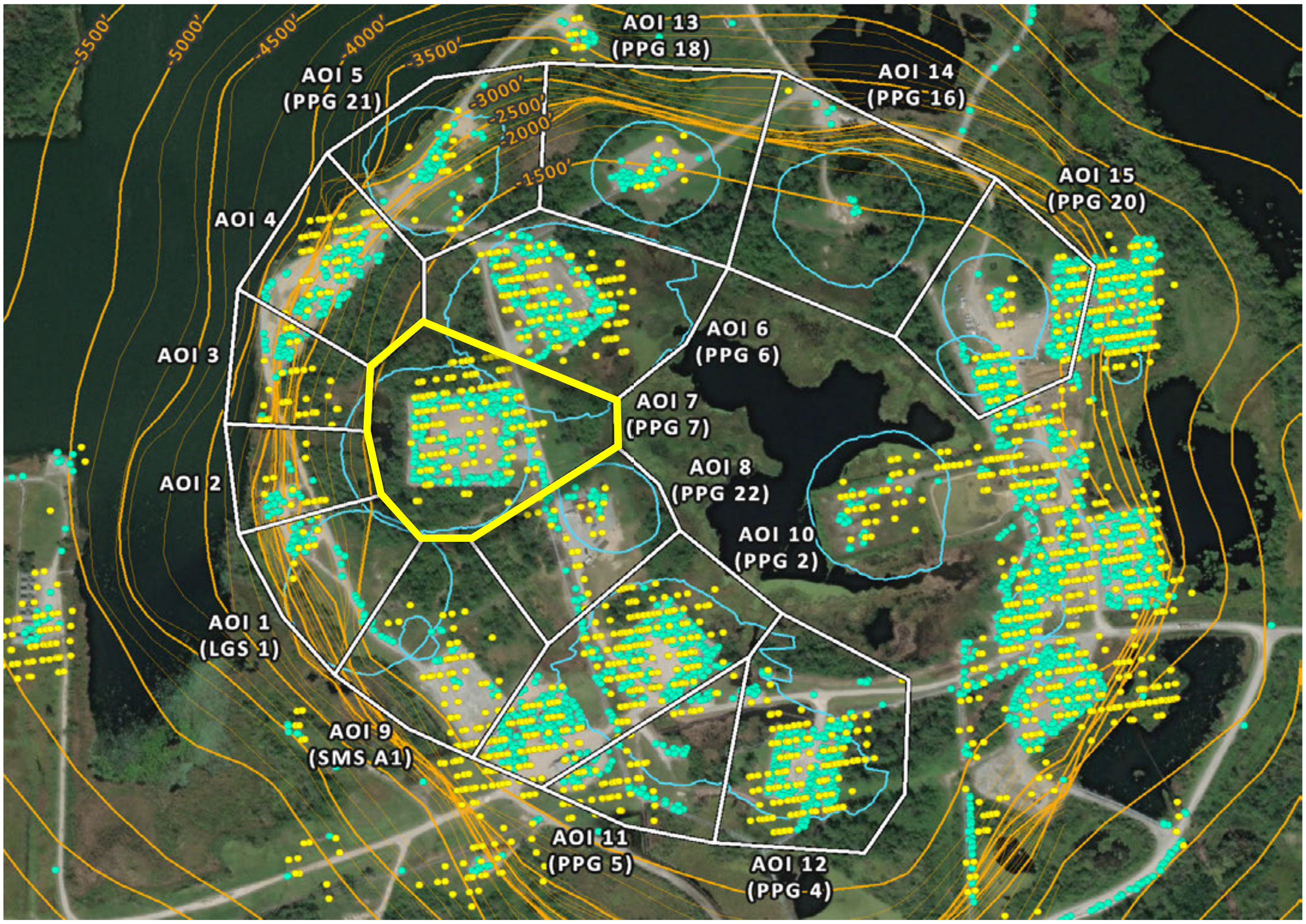
■ Historical LOS Displacement Measurement

---- Historical Trend Line (Quadratic Regression)

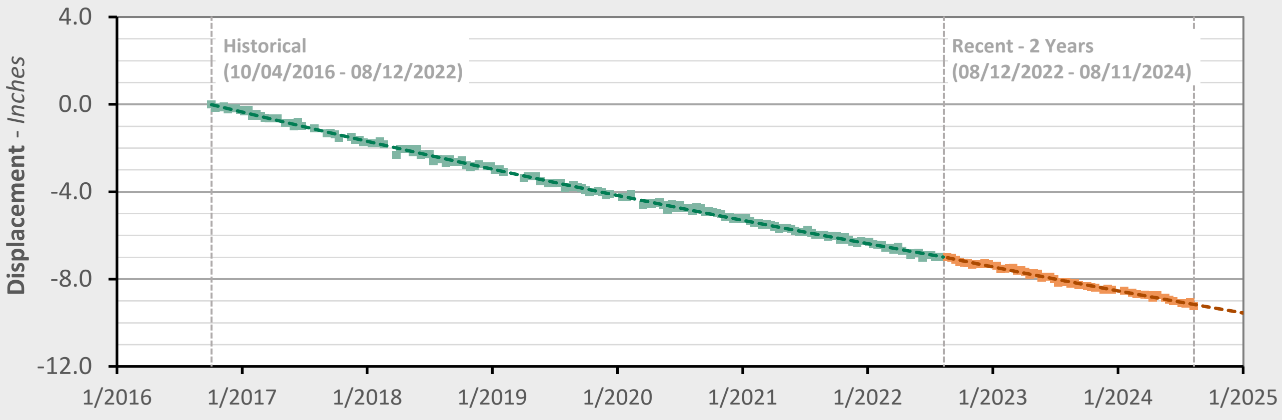
■ Recent LOS Displacement Measurement

---- Historical Trend Line (Quadratic Regression)

AOI 7 *(PPG 7)* - Location Map



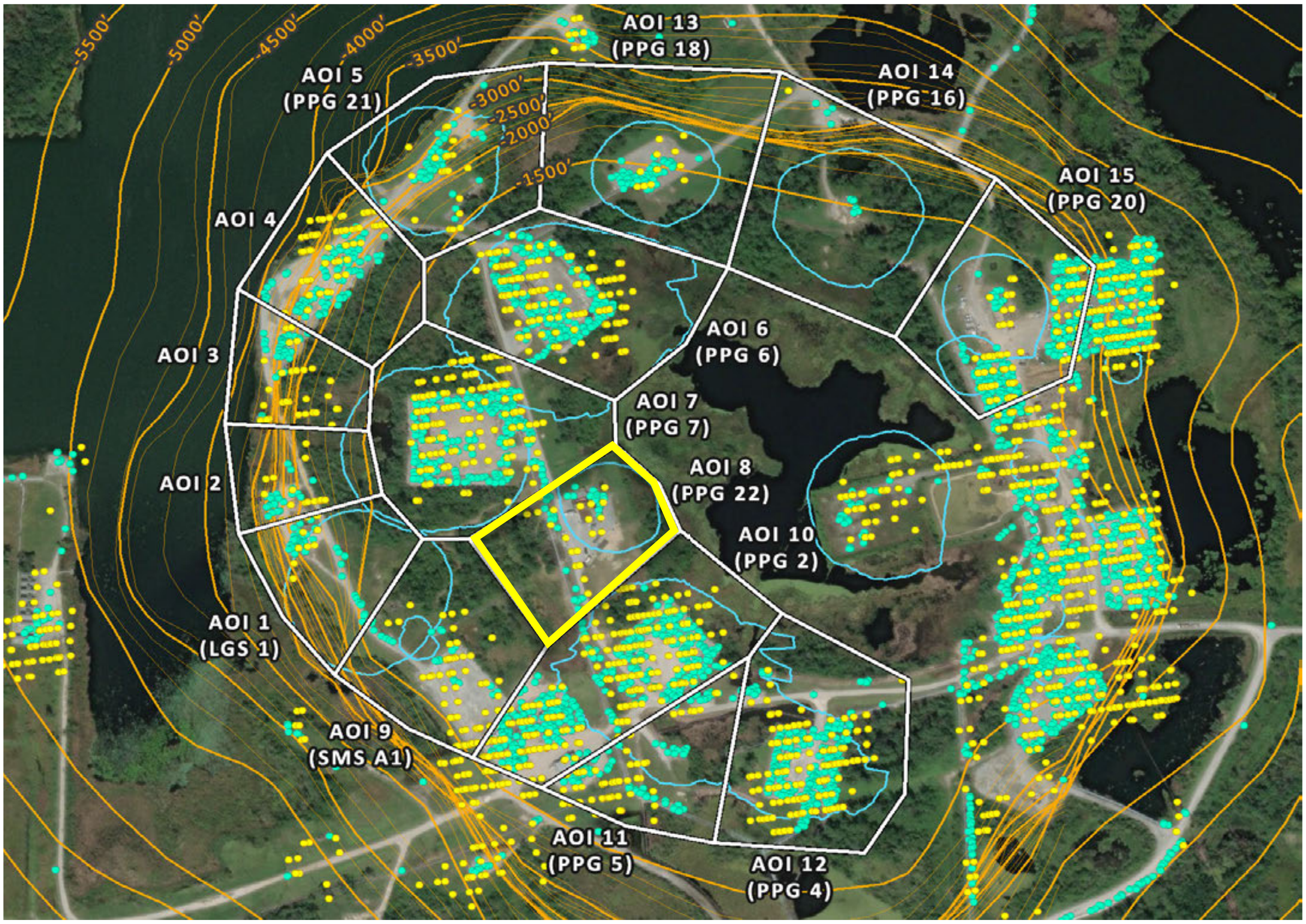
AOI 7 *(PPG 7)* - Displacement Time Series SNT (8/11/2024) Point Count: 140



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-1.00 in/yr	-1.01 in/yr	-0.01 in/yr
Acceleration:	+0.07 in/yr^2	+0.08 in/yr^2	+0.01 in/yr^2

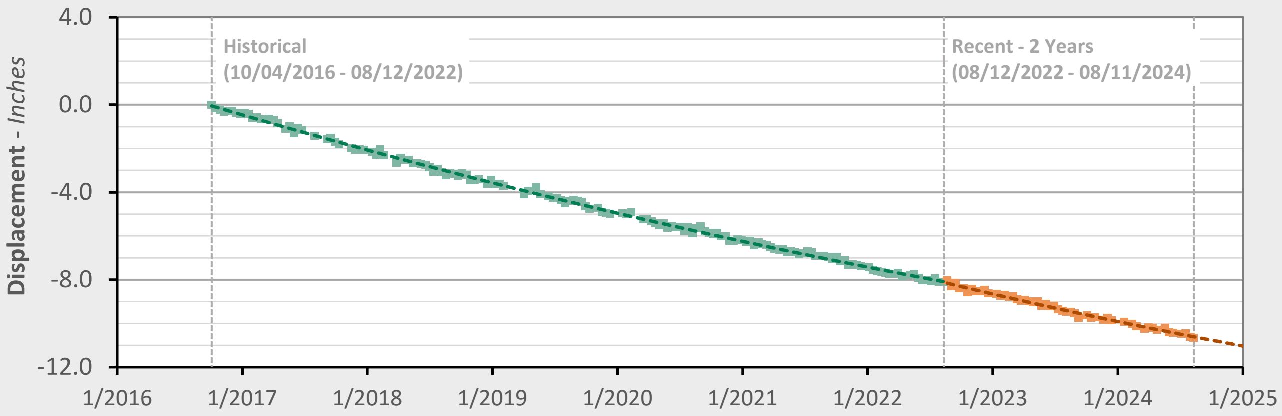
🟩 Historical LOS Displacement Measurement
---- Historical Trend Line (Quadratic Regression)
🟧 Recent LOS Displacement Measurement
---- Historical Trend Line (Quadratic Regression)

AOI 8 *(PPG 22)* - Location Map



AOI 8 *(PPG 22)* - Displacement Time Series

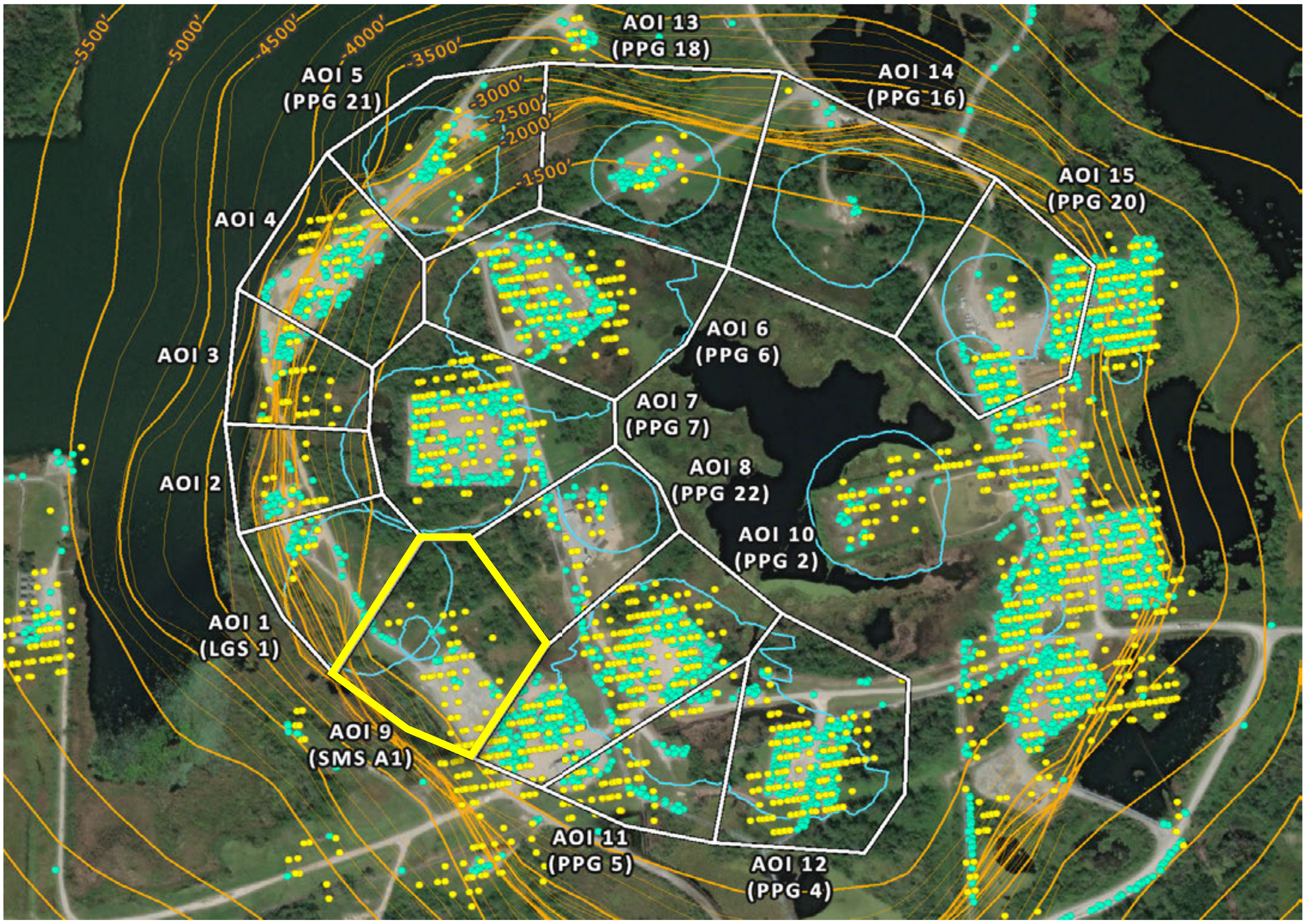
SNT (8/11/2024) Point Count: **20**



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-1.06 in/yr	-1.13 in/yr	-0.08 in/yr
Acceleration:	+0.11 in/yr^2	+0.10 in/yr^2	-0.01 in/yr^2

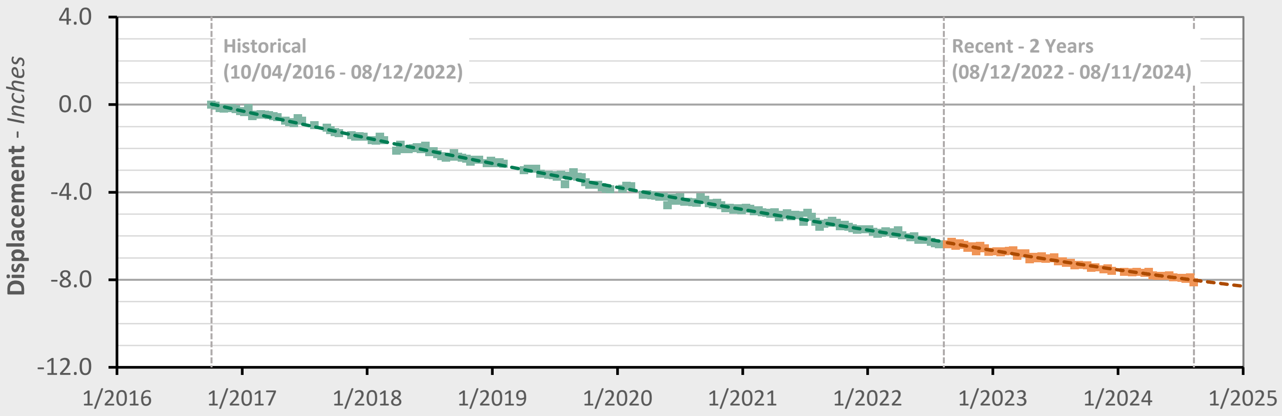
■ Historical LOS Displacement Measurement	---- Historical Trend Line (Quadratic Regression)	■ Recent LOS Displacement Measurement	---- Historical Trend Line (Quadratic Regression)

AOI 9 *(PPG A1)* - Location Map



AOI 9 *(SMS A1)* - Displacement Time Series

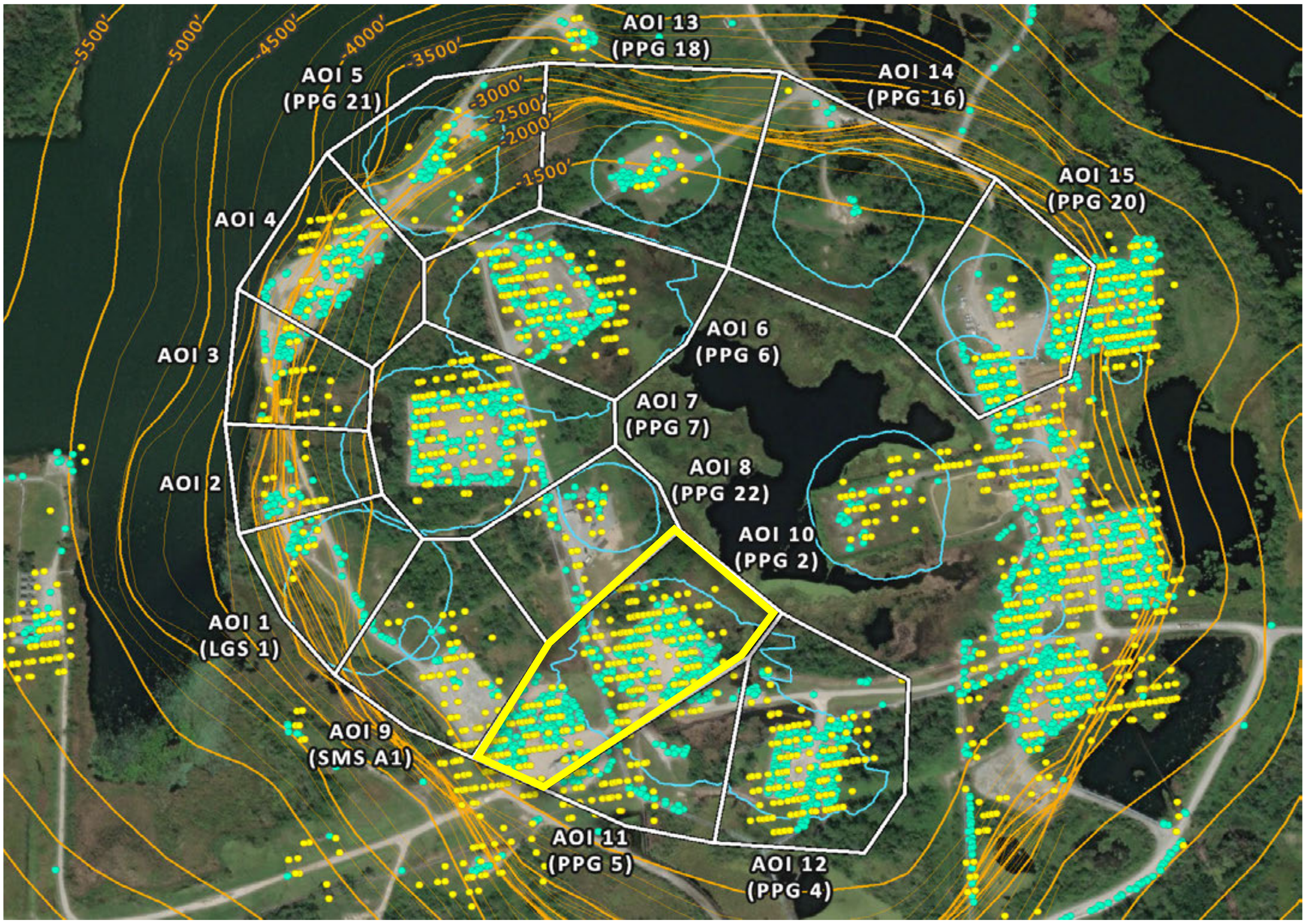
SNT (8/11/2024) Point Count: 59



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.86 in/yr	-0.72 in/yr	+0.14 in/yr
Acceleration:	+0.07 in/yr^2	+0.16 in/yr^2	+0.08 in/yr^2

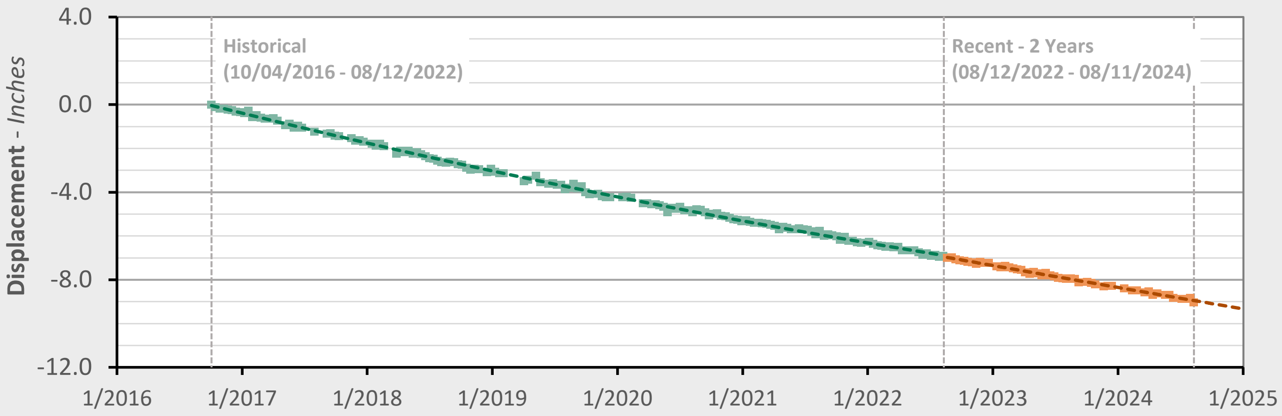
■	Historical LOS Displacement Measurement
----	Historical Trend Line (Quadratic Regression)
■	Recent LOS Displacement Measurement
----	Historical Trend Line (Quadratic Regression)

AOI 10 *(PPG 2)* - Location Map



AOI 10 *(PPG 2)* - Displacement Time Series

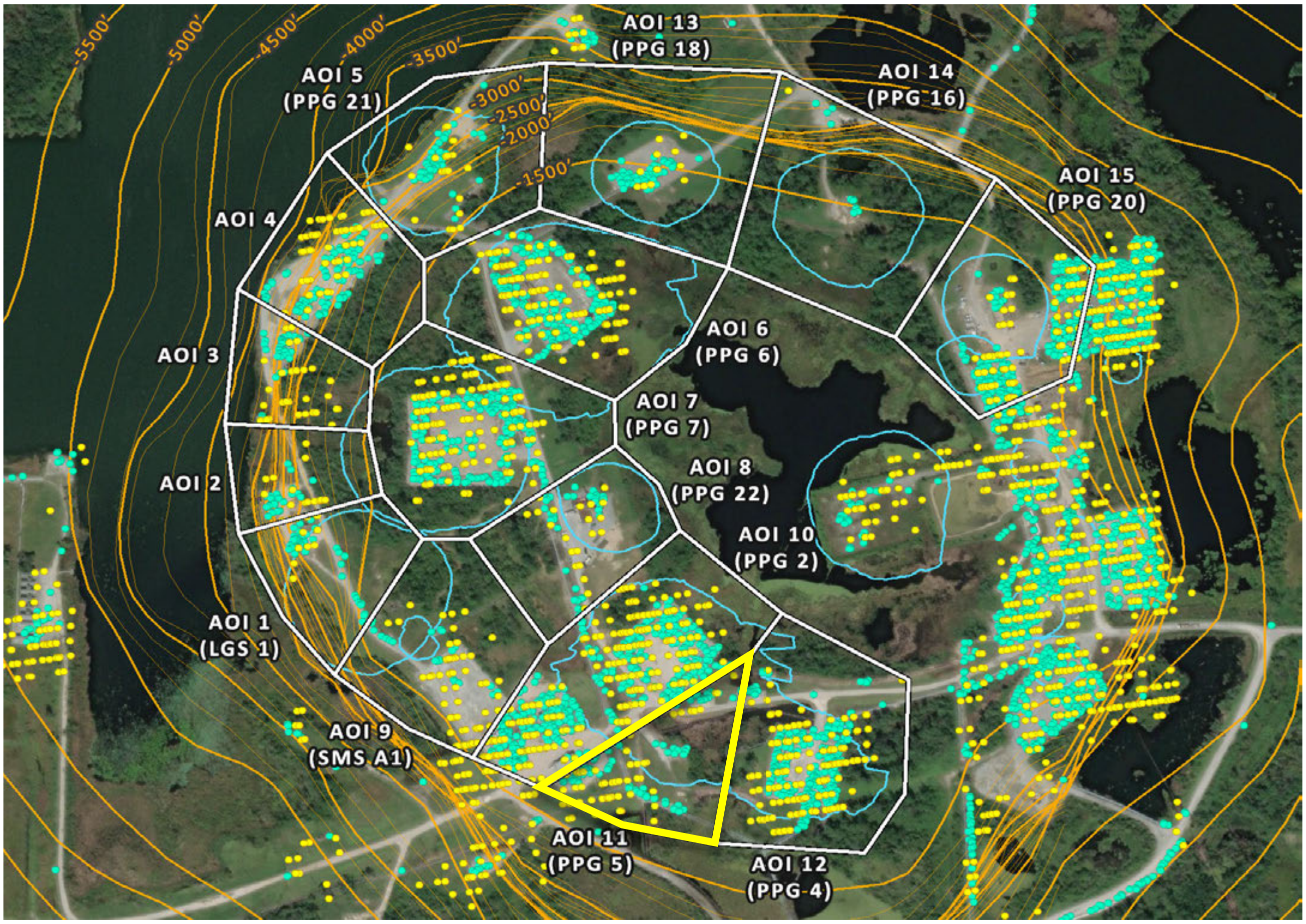
SNT (8/11/2024) Point Count: **231**



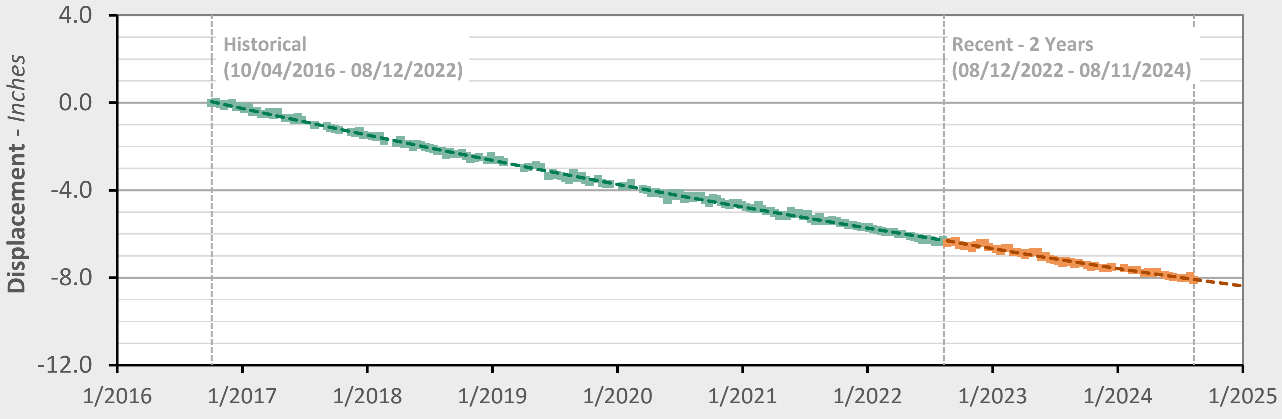
	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.90 in/yr	-0.97 in/yr	-0.06 in/yr
Acceleration:	+0.09 in/yr^2	+0.03 in/yr^2	-0.06 in/yr^2

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

AOI 11 *(PPG 5)* - Location Map



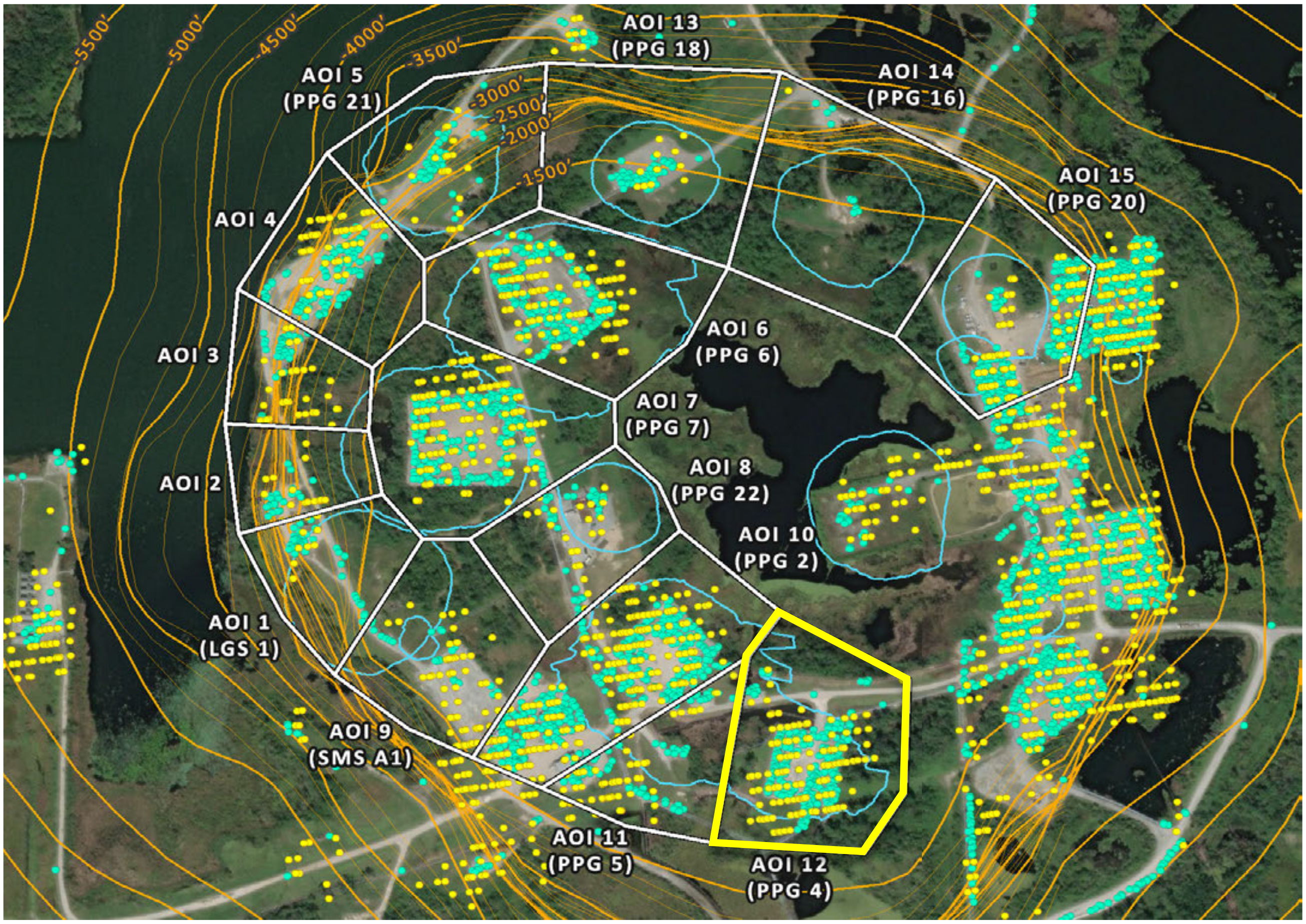
AOI 11 *(PPG 5)* - Displacement Time Series SNT (8/11/2024) Point Count: 52



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.90 in/yr	-0.76 in/yr	+0.14 in/yr
Acceleration:	+0.06 in/yr^2	+0.14 in/yr^2	+0.08 in/yr^2

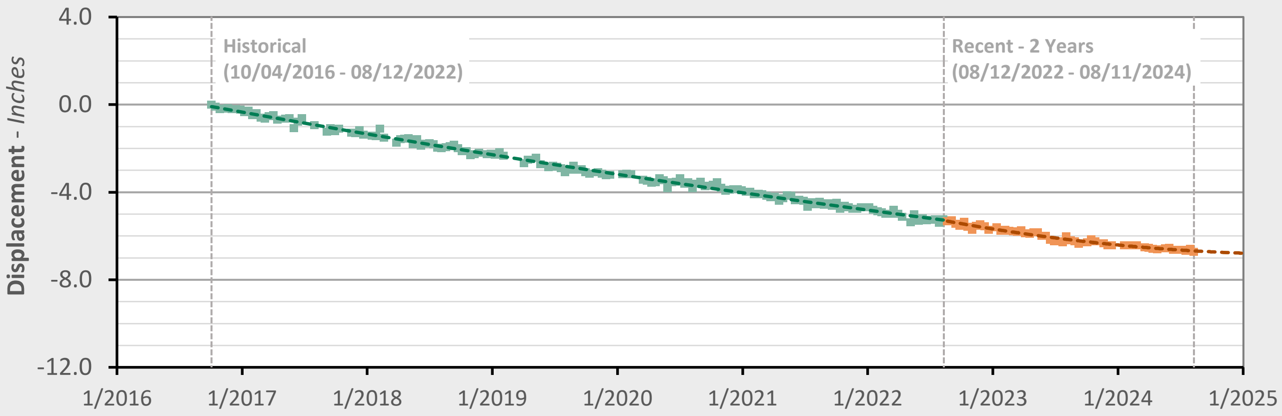
🟩 Historical LOS Displacement Measurement
---- Historical Trend Line (Quadratic Regression)
🟧 Recent LOS Displacement Measurement
---- Historical Trend Line (Quadratic Regression)

AOI 12 *(PPG 4)* - Location Map



AOI 12 *(PPG 4)* - Displacement Time Series

SNT (8/11/2024) Point Count: **120**



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.73 in/yr	-0.34 in/yr	+0.40 in/yr
Acceleration:	+0.05 in/yr^2	+0.36 in/yr^2	+0.31 in/yr^2

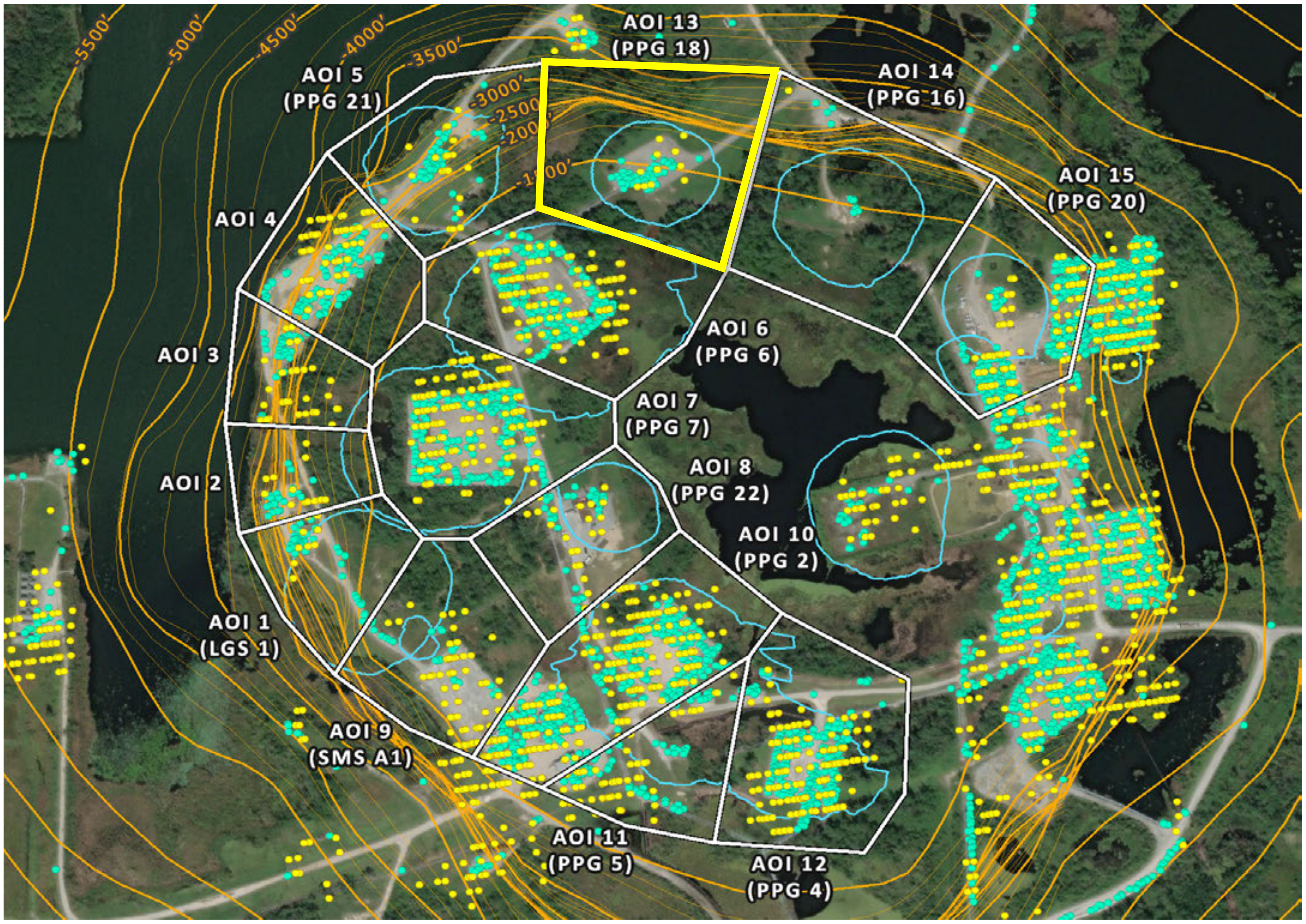
■ Historical LOS Displacement Measurement

---- Historical Trend Line (Quadratic Regression)

■ Recent LOS Displacement Measurement

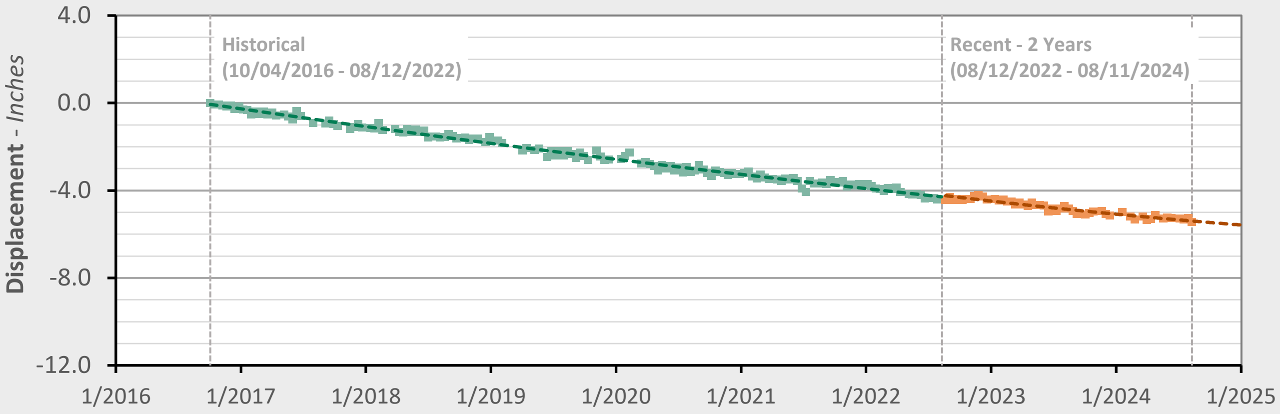
---- Historical Trend Line (Quadratic Regression)

AOI 13 *(PPG 18)* - Location Map



AOI 13 *(PPG 18)* - Displacement Time Serie

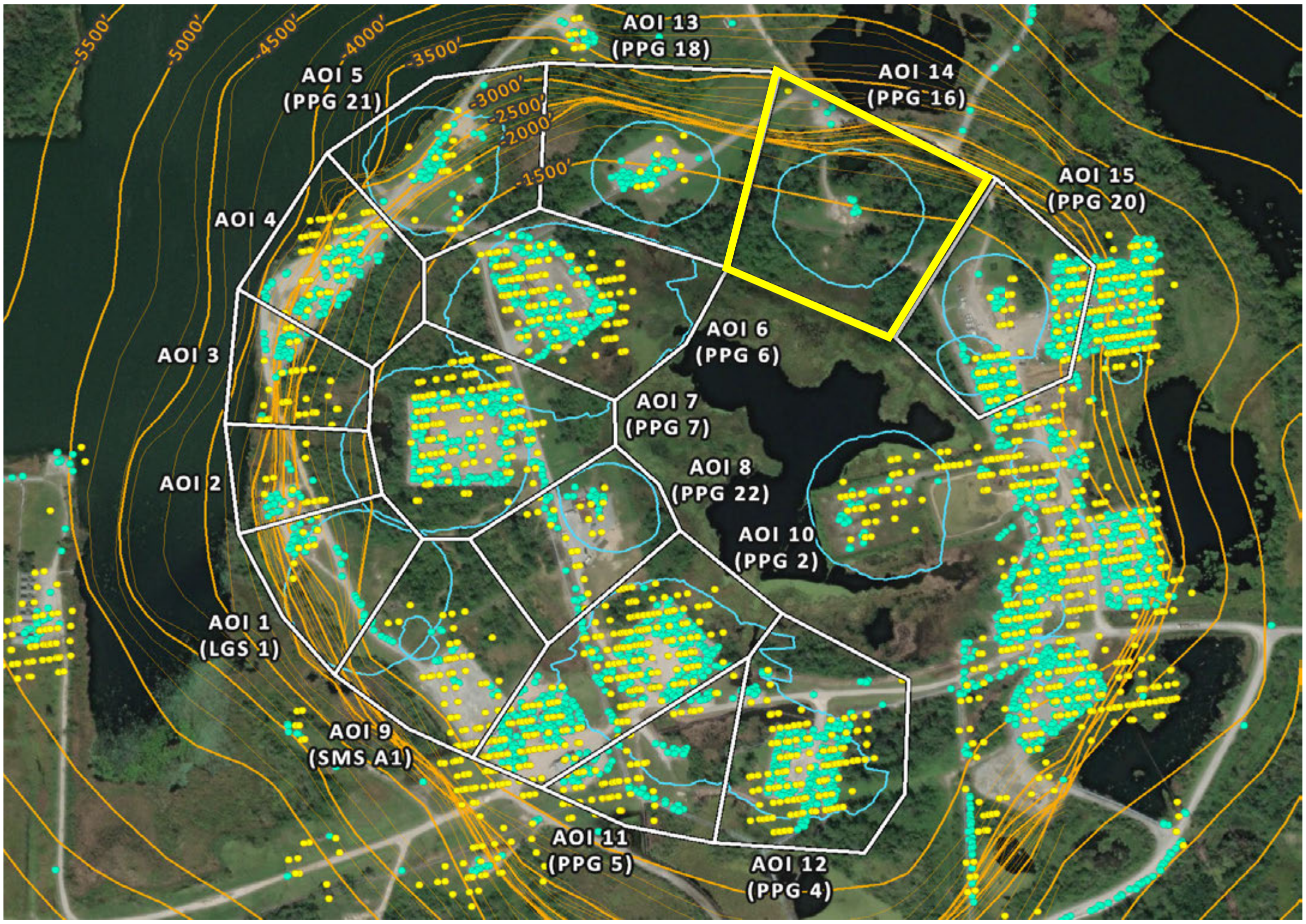
SNT (8/11/2024) Point Count: **12**



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.61 in/yr	-0.44 in/yr	+0.17 in/yr
Acceleration:	+0.04 in/yr^2	+0.16 in/yr^2	+0.13 in/yr^2

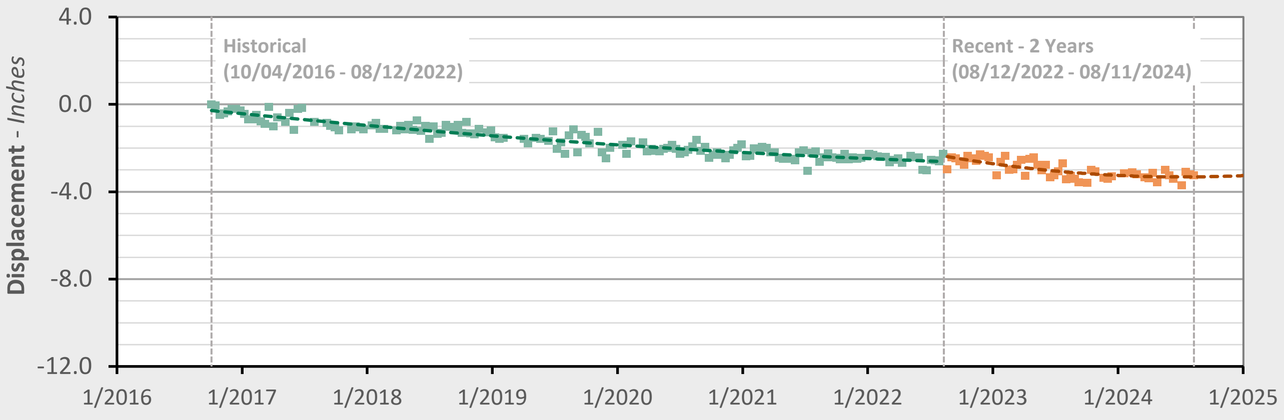
🟩	Historical LOS Displacement Measurement
----	Historical Trend Line (Quadratic Regression)
🟧	Recent LOS Displacement Measurement
----	Historical Trend Line (Quadratic Regression)

AOI 14 *(PPG 16)* - Location Map



AOI 14 *(PPG 16)* - Displacement Time Serie

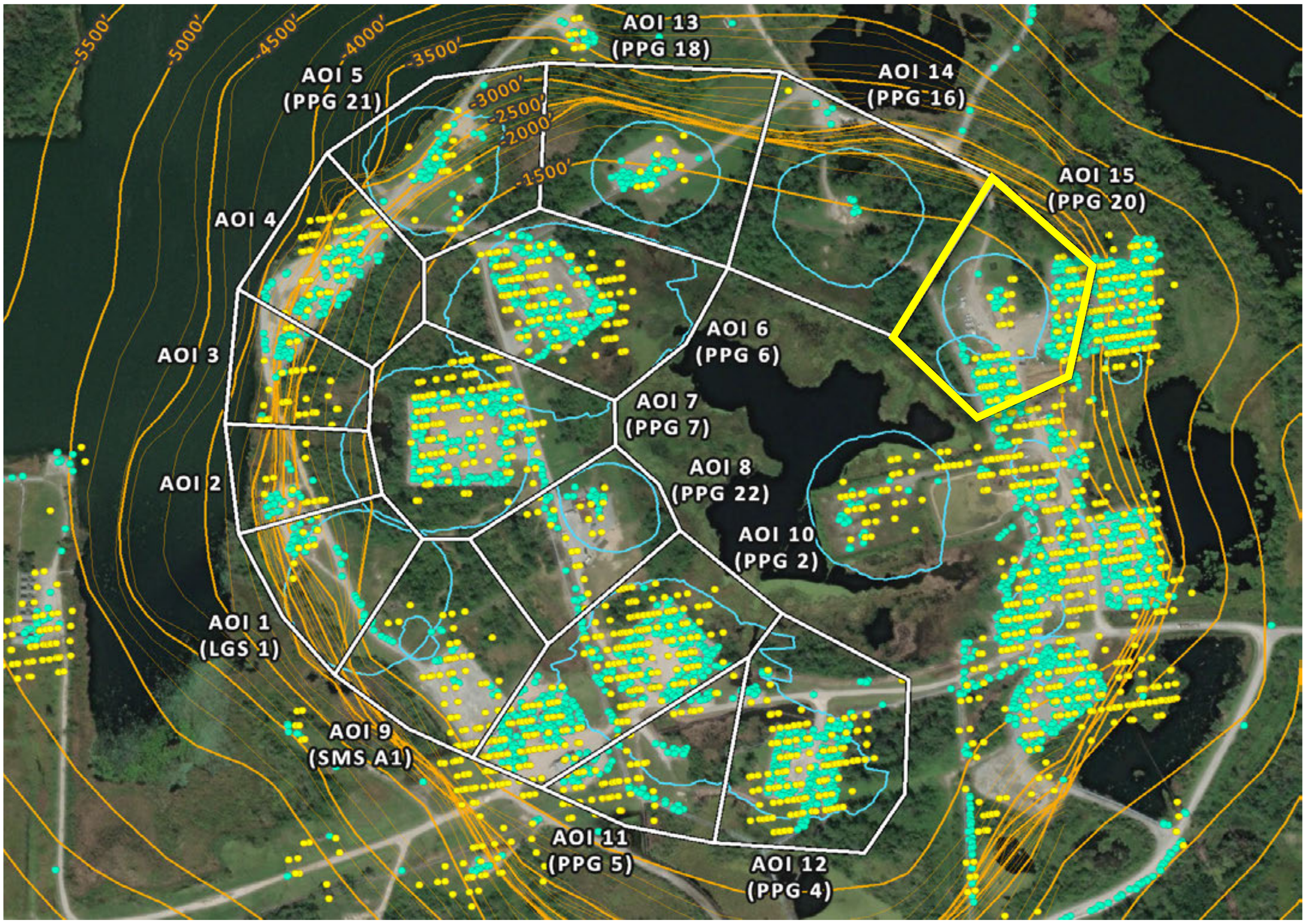
SNT (8/11/2024) Point Count: **1**



	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.21 in/yr	+0.18 in/yr	+0.39 in/yr
Acceleration:	+0.07 in/yr^2	+0.69 in/yr^2	+0.63 in/yr^2

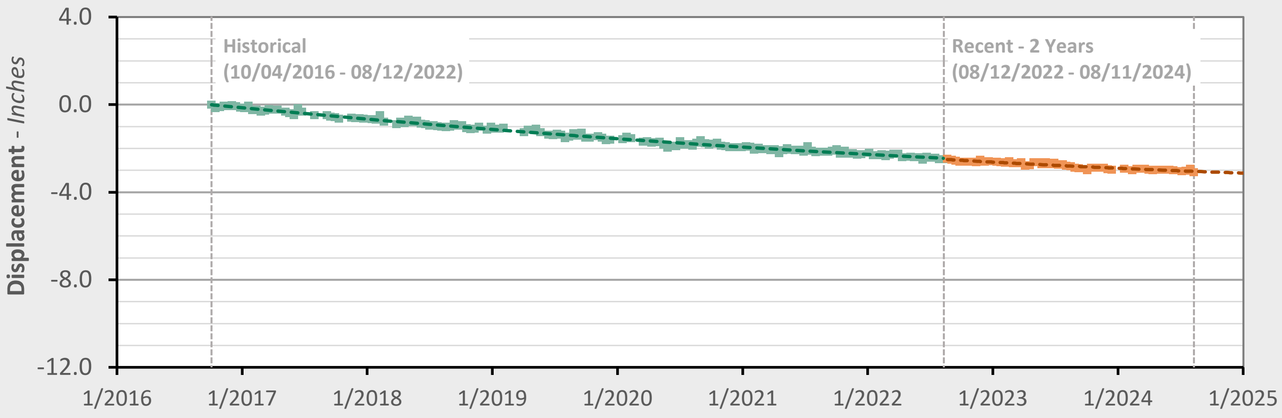
- ■ Historical LOS Displacement Measurement
- ---- Historical Trend Line (Quadratic Regression)
- ■ Recent LOS Displacement Measurement
- ---- Historical Trend Line (Quadratic Regression)

AOI 15 *(PPG 20)* - Location Map



AOI 15 *(PPG 20)* - Displacement Time Serie

SNT (8/11/2024) Point Count: 74



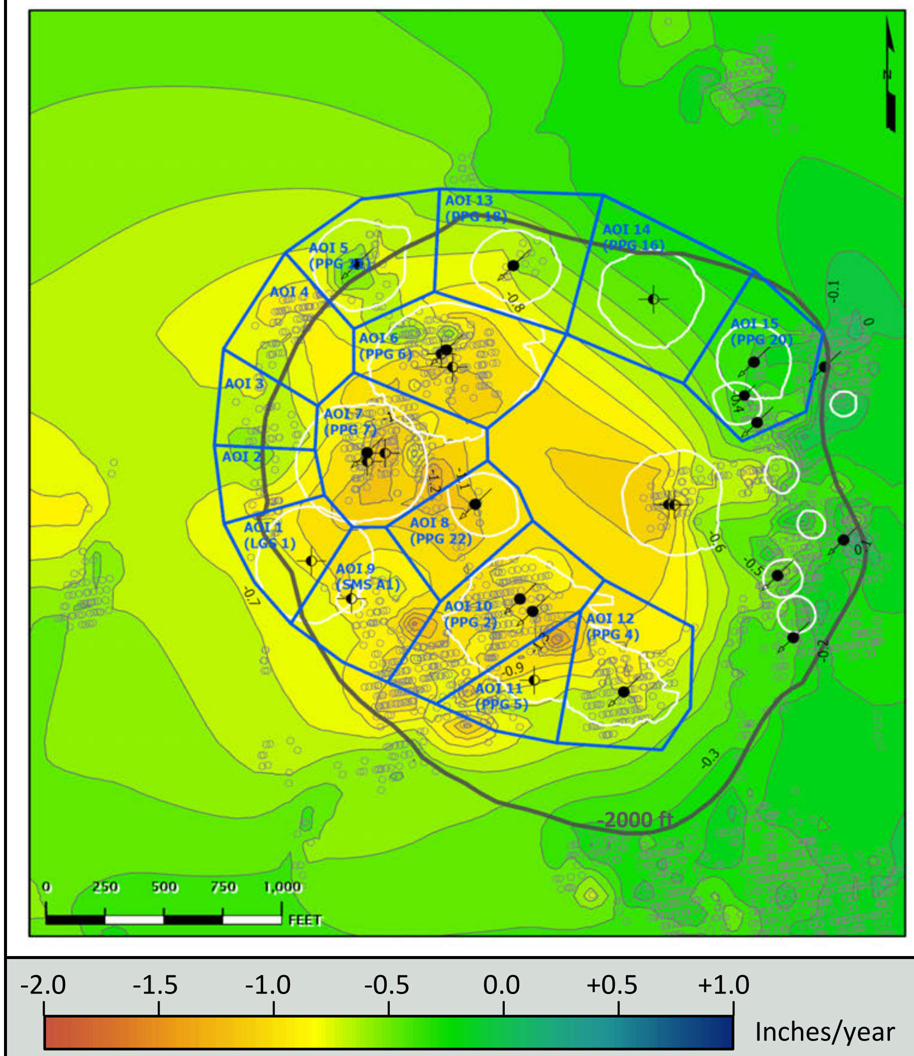
	Historical Trend Values	Recent Trend Values	Trend Change
Velocity:	-0.28 in/yr	-0.22 in/yr	+0.06 in/yr
Acceleration:	+0.05 in/yr^2	+0.05 in/yr^2	+0.00 in/yr^2

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

Historical SNT Data (10/04/2016 - 08/12/2022)

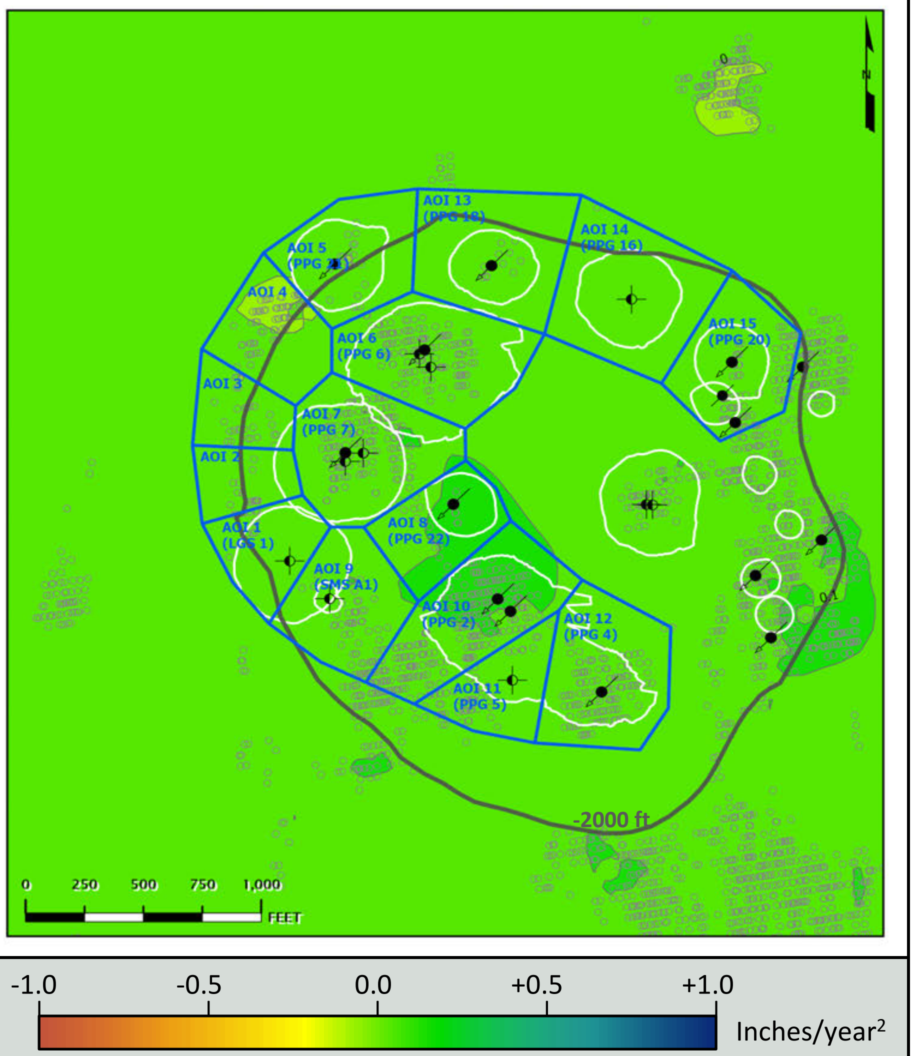
Velocity Contours

As of date: 08/12/2022



Acceleration Contours

Date range: 10/04/2016 - 08/12/2022



▭ AOI Boundary

○ InSAR LOS Measurement Point

— Contour (0.1)

▭ Historical Cavern Extent

▭ Top of Dome (-2000 ft Contour)

Cavern Well Surface Locations

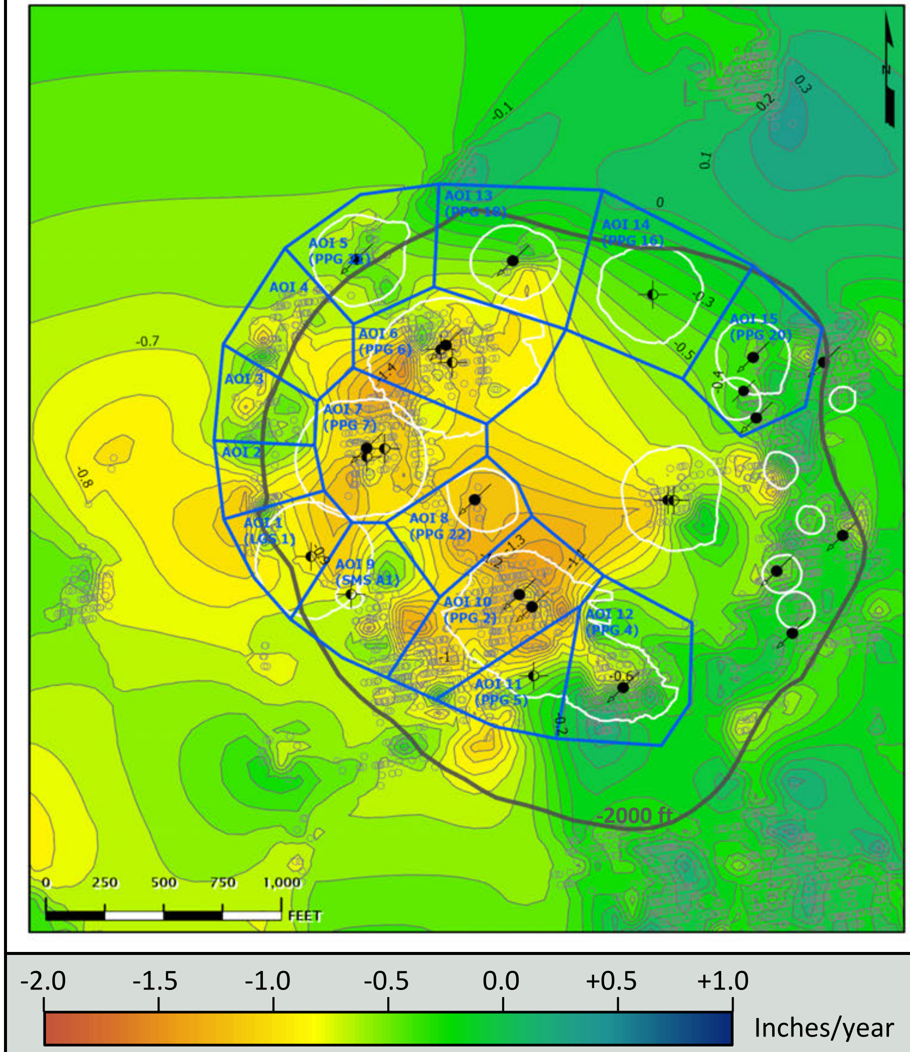
09 - Active - Injection

29 - Dry and Plugged

Recent SNT Data - 2 Years (08/12/2022 - 08/11/2024)

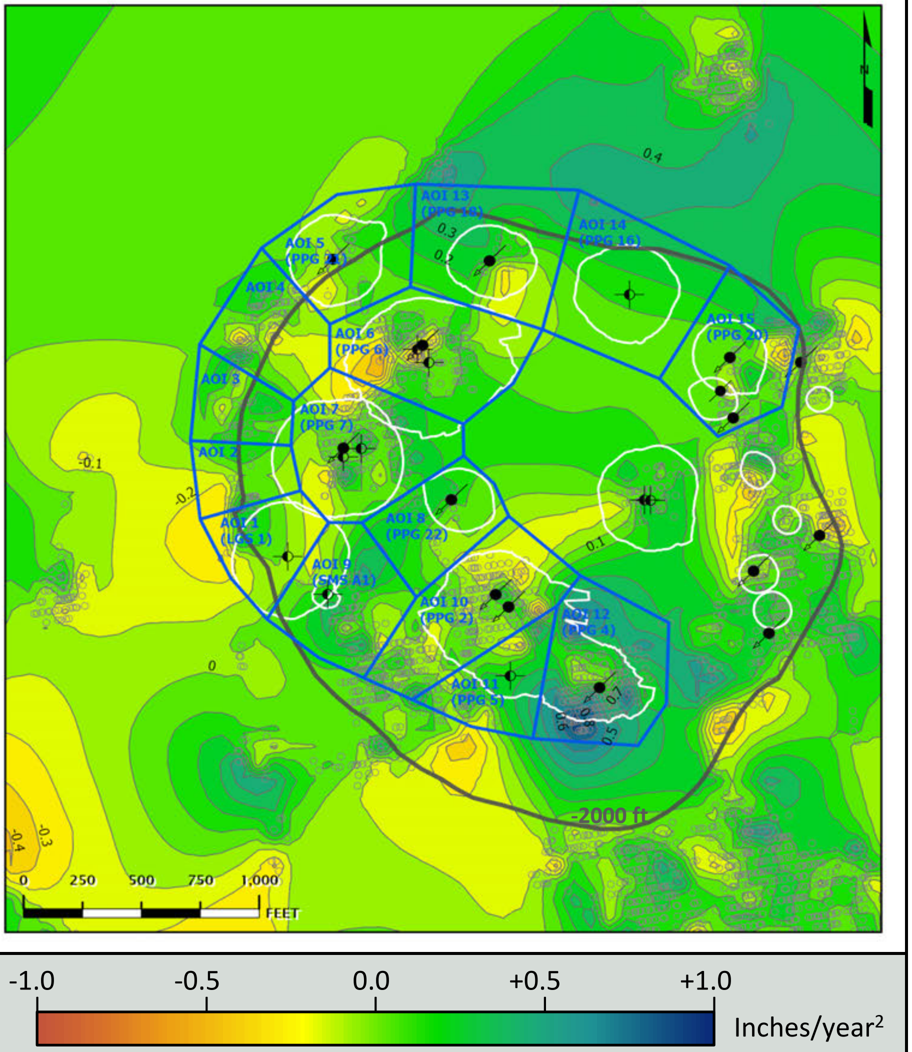
Velocity Contours

As of date: 08/11/2024



Acceleration Contours

Date range: 08/12/2022 - 08/11/2024



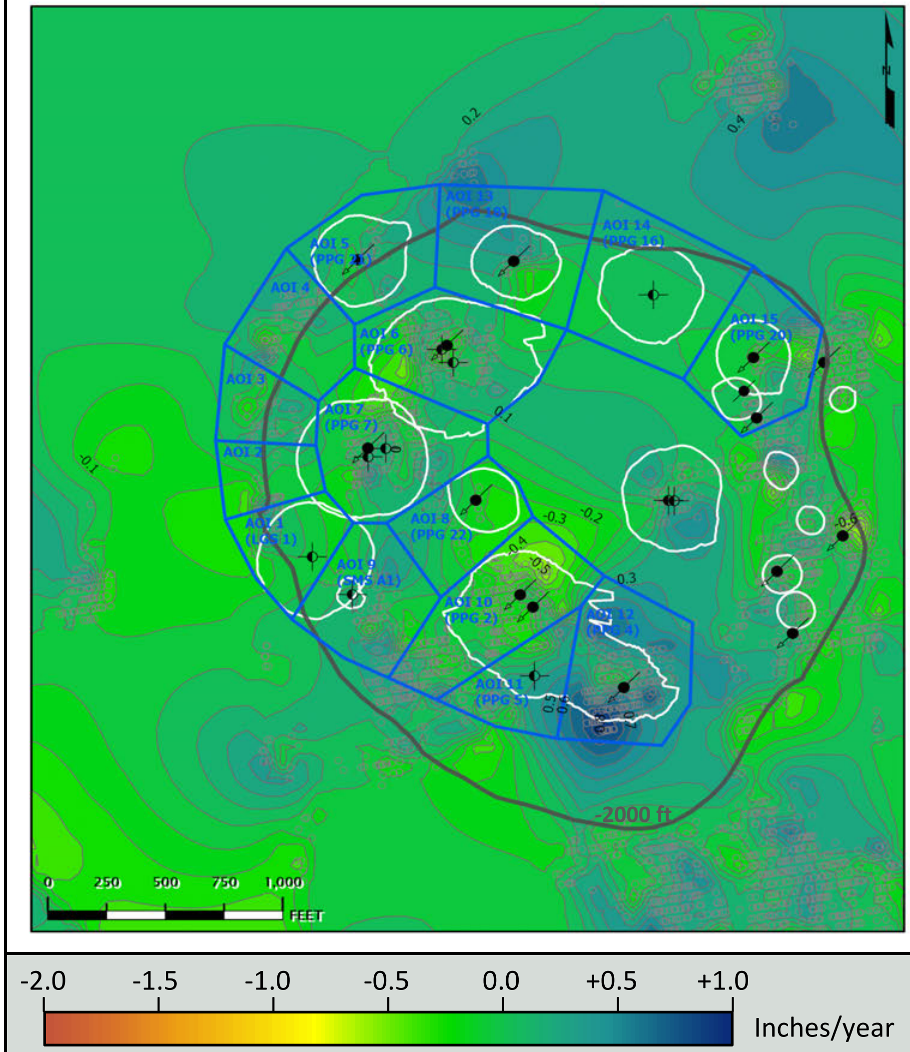
🟦 AOI Boundary
○ InSAR LOS Measurement Point
— Contour (0.1)
⬜ Historical Cavern Extent
▭ Top of Dome (-2000 ft Contour)

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

Change from Historical to Recent SNT Data

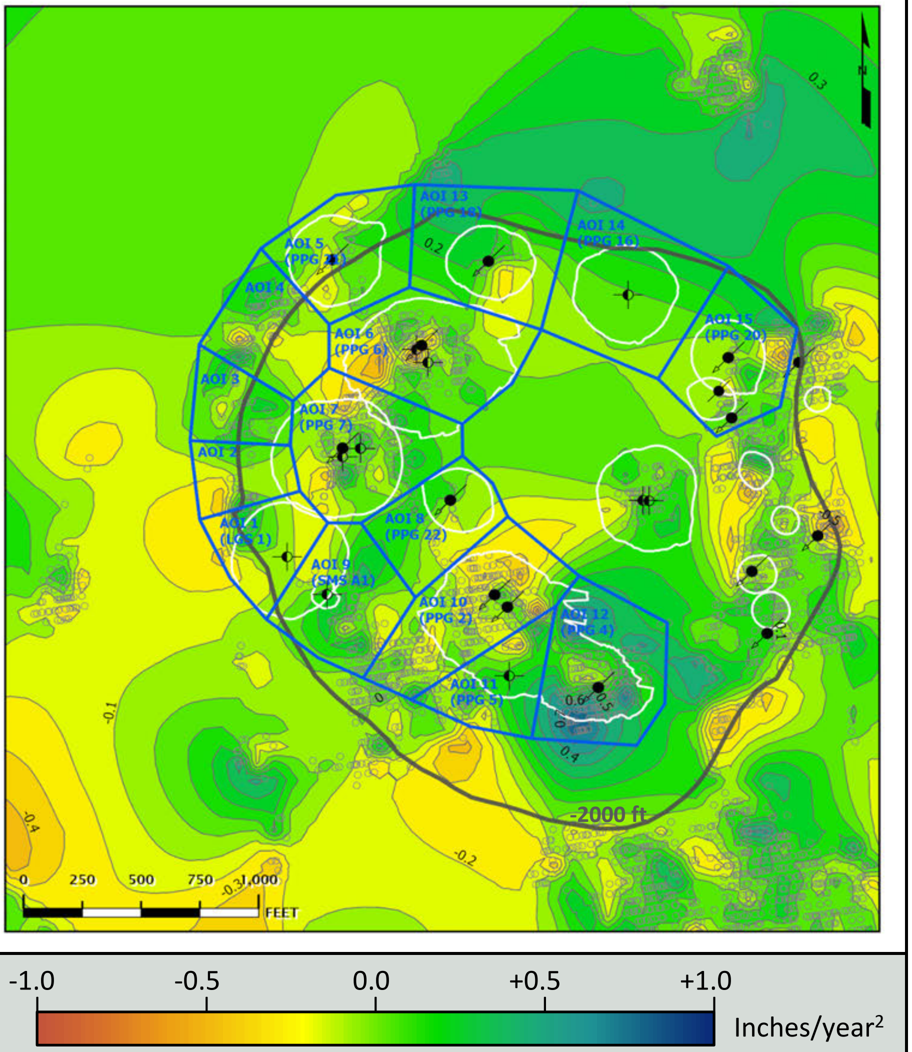
Velocity Contours

Historical Velocity subtracted from Recent Velocity



Acceleration Contours

Historical Acceleration subtracted from Recent Acceleration



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

ATTACHMENT C

TSX/PAZ InSAR report - August 29, 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
Thursday, August 29, 2024

Analysis Report Date:

September 5, 2024

Dataset Information

Satellite Source	TerraSAR-X - PAZ Constellation
Revisit Frequency	4 and 7 days
Most Recent Image Date	Thursday, August 29, 2024
Dataset Image Count	103
Dataset Time Range	January 24, 2023 - August 29, 2024
Dataset Length	1.60 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 occuring 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.

NATHANIEL L. BYARS
License No. 40697

Nathaniel Byars

Date Signed: September 5, 2024
Austin, Texas

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Principal Engineer
Louisiana License No. 40697

InSAR Data Sources

InSAR Data

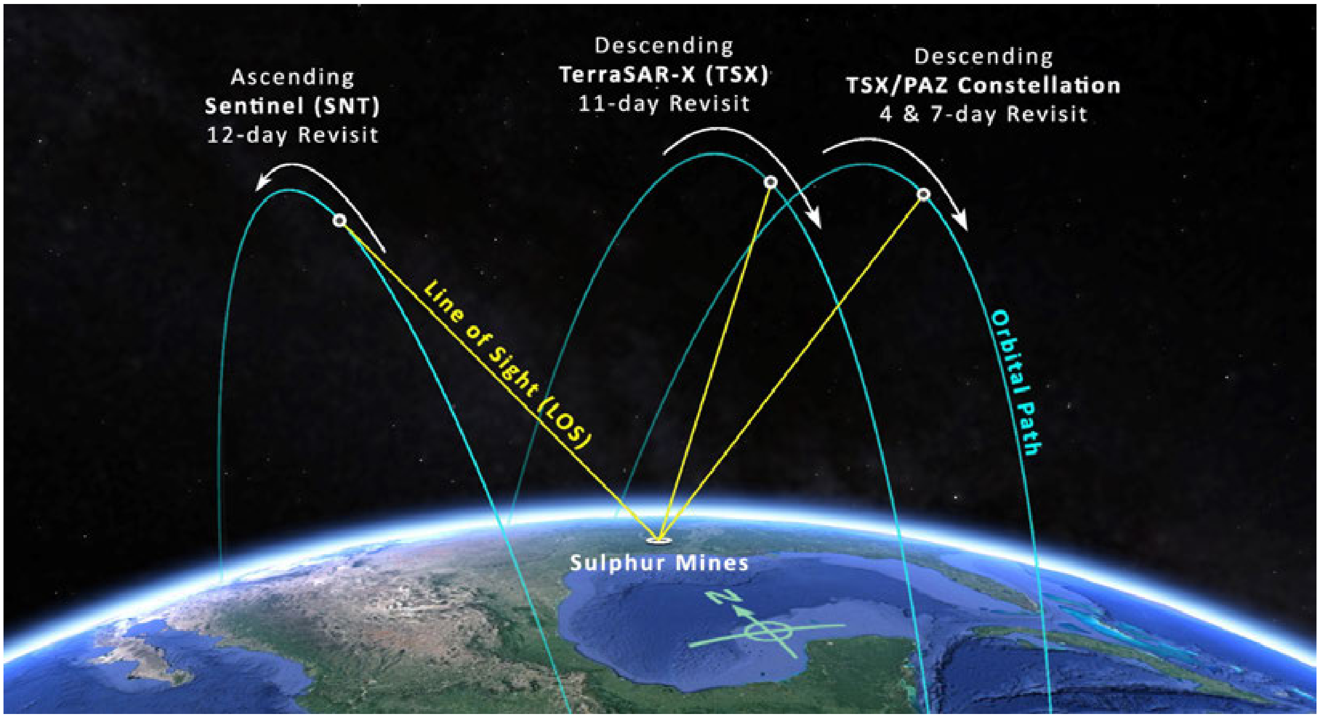
Interferometric Synthetic Aperture Radar (InSAR) is the most well established method to continually evaluate small, normally undetectable, ground movement over a large area. Radar imagery collected via satellites over successive orbital passes is used to identify and define measurement points on the 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) displacment 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 desceding orbit denotes the satellite is moving from north to south.

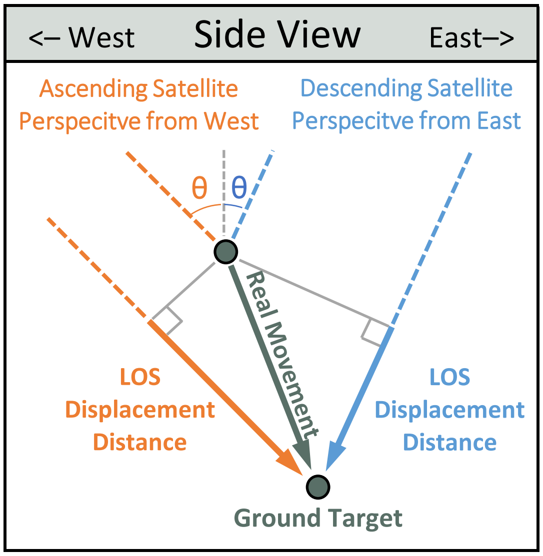
The first dataset comes from a low-resolution Sentinel-1 (SNT) satellite on an ascending orbit that captures data from the west of the site on a 12-day frequency. The second comes from a pair of high resolution satellites that share the same descending orbit and capture data from east of the site. These 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

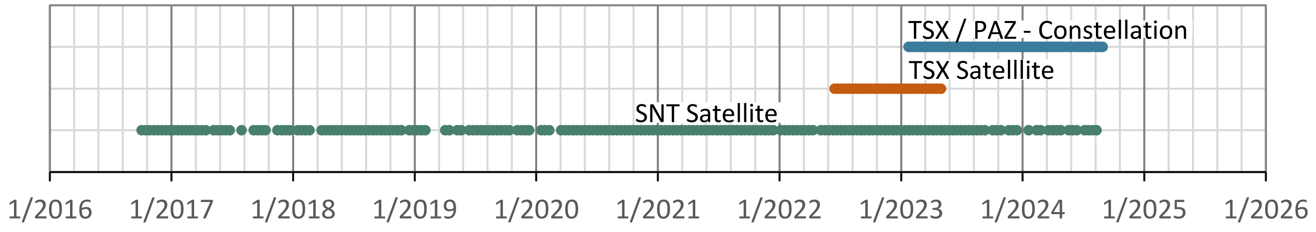
LOS displacement measurements refer to a change in distance between the satellite sensor and the ground target. Measurement positions on the west side of the Sulphur Dome are are known to be experiencing some eastward movement toward the dome center due to the geometry of the subsidence basin. The InSAR 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.



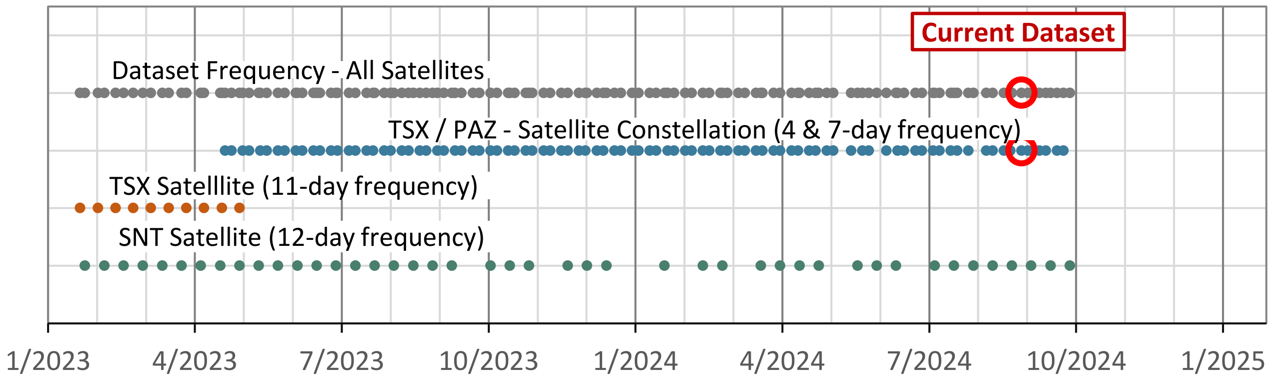
Satellite Properties & Image Frequency

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^o)	Descending (17^o)	Descending (37^o)
Data Start Date	10/4/2016	6/16/2022	1/24/2023
Measurement error range	± 0.20 in	± 0.03 in	± 0.03 in

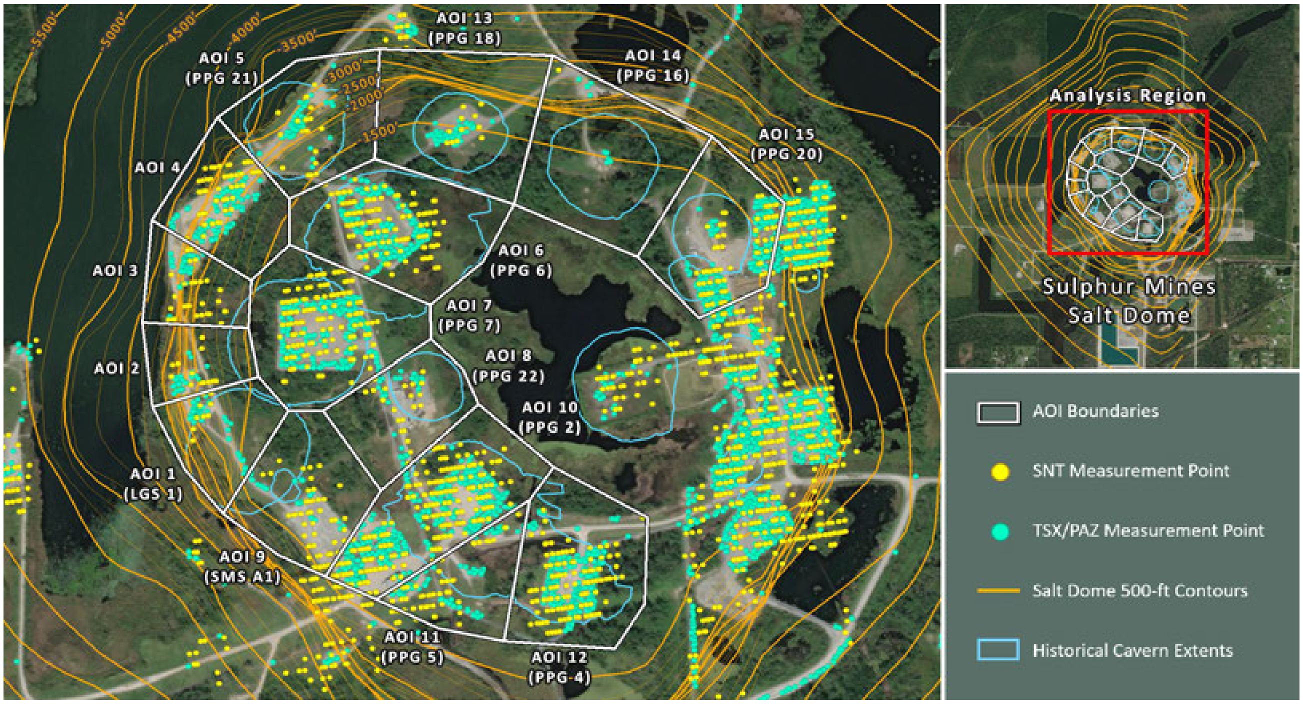
Dataset Measurement History



Dataset Update Frequency



AOI Boundaries & InSAR Measurement Points

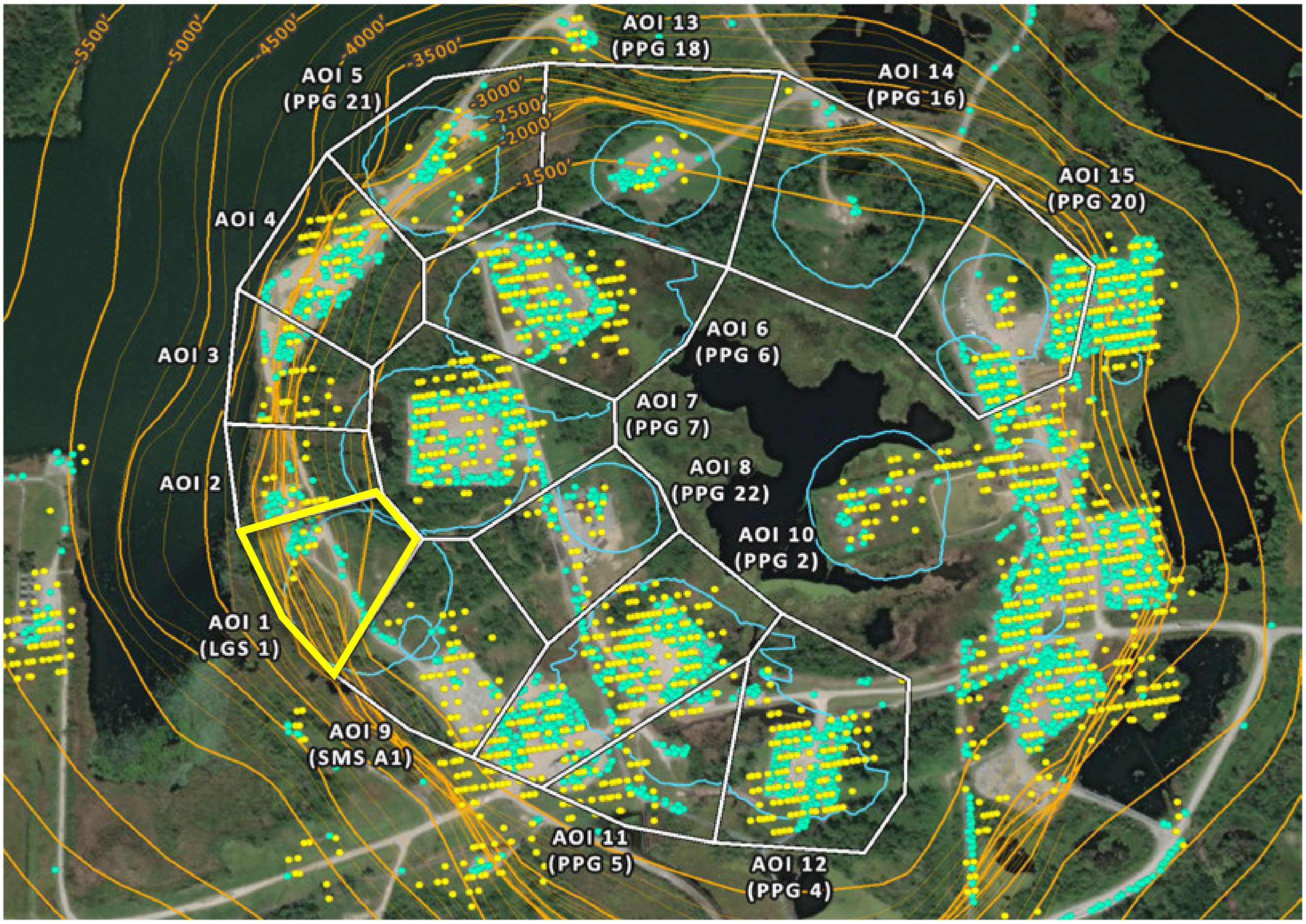


Subsidence Monitoring Areas of Interest (AOIs)

To visually convey and evaluate trend consistency for the displacement time series of each ground target, measurment 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.

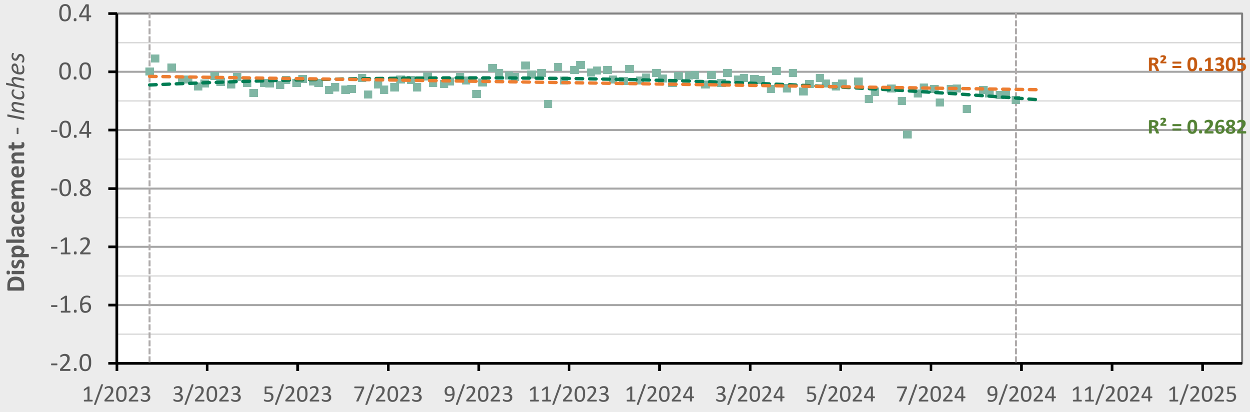
AOI Name	TSX/PAZ (8/29/2024)	LOS Velocity (in/yr)		LOS Acceleration (in/yr^2)	
	Point Count	Nonlinear	Linear	Nonlinear	Linear
AOI 1 *(LGS 1)*	42	-0.27	-0.06	-0.27	0.00
AOI 2	24	-0.38	-0.05	-0.41	0.00
AOI 3	40	-0.35	-0.03	-0.39	0.00
AOI 4	102	-0.23	+0.02	-0.30	0.00
AOI 5 *(PPG 21)*	47	-0.21	-0.17	-0.05	0.00
AOI 6 *(PPG 6)*	212	-0.59	-0.42	-0.21	0.00
AOI 7 *(PPG 7)*	216	-0.52	-0.30	-0.28	0.00
AOI 8 *(PPG 22)*	36	-0.69	-0.58	-0.14	0.00
AOI 9 *(SMS A1)*	23	-0.18	-0.24	+0.08	0.00
AOI 10 *(PPG 2)*	404	-0.70	-0.56	-0.18	0.00
AOI 11 *(PPG 5)*	85	-0.61	-0.46	-0.18	0.00
AOI 12 *(PPG 4)*	262	-0.96	-0.82	-0.17	0.00
AOI 13 *(PPG 18)*	52	-0.55	-0.43	-0.15	0.00
AOI 14 *(PPG 16)*	11	-0.36	-0.62	+0.33	0.00
AOI 15 *(PPG 20)*	224	-0.98	-0.95	-0.03	0.00

AOI 1 *(LGS 1)* - Location Map



AOI 1 *(LGS 1)* - Displacement Time Series

TSX/PAZ (8/29/2024) Point Count: **42**



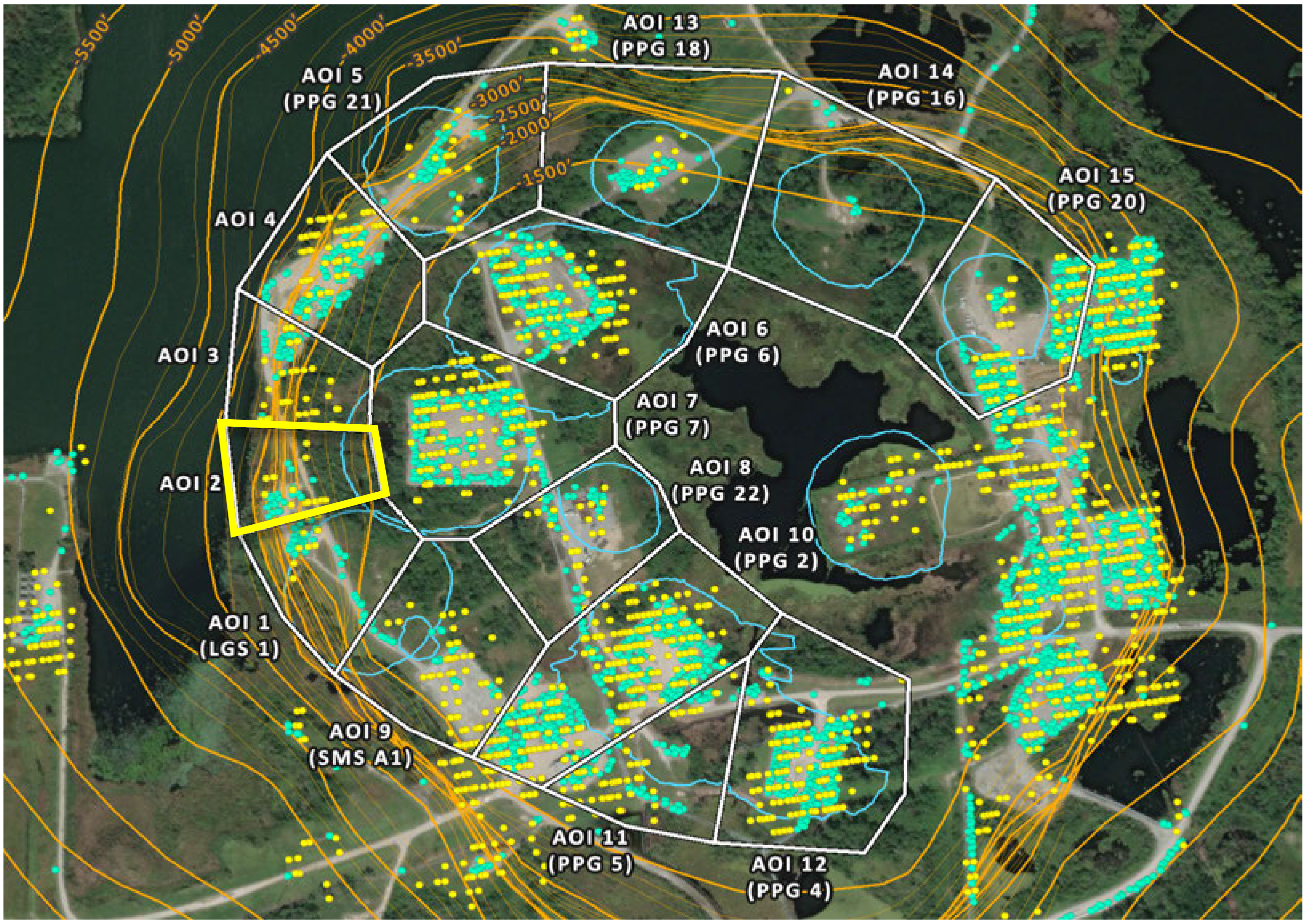
	Nonlinear Trend		Linear Trend	
Velocity:	-0.27	in/yr	-0.06	in/yr
Acceleration:	-0.27	in/yr^2	0.00	in/yr^2

🟩 LOS Displacement Measurement

- - - - Nonlinear Trend Line (Quadratic Regression)

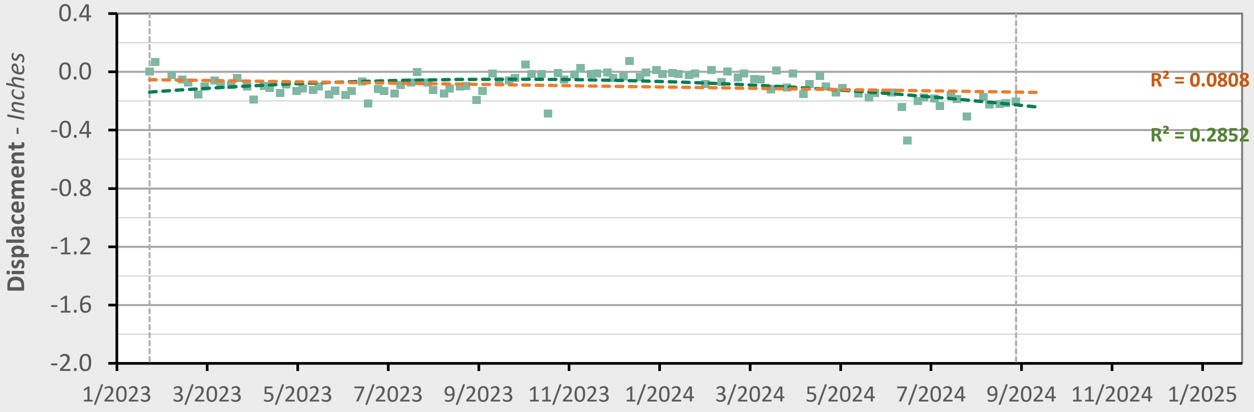
- - - - Linear Trend Line (Linear Regression)

AOI 2 - Location Map



AOI 2 - Displacement Time Series

TSX/PAZ (8/29/2024) Point Count: **24**



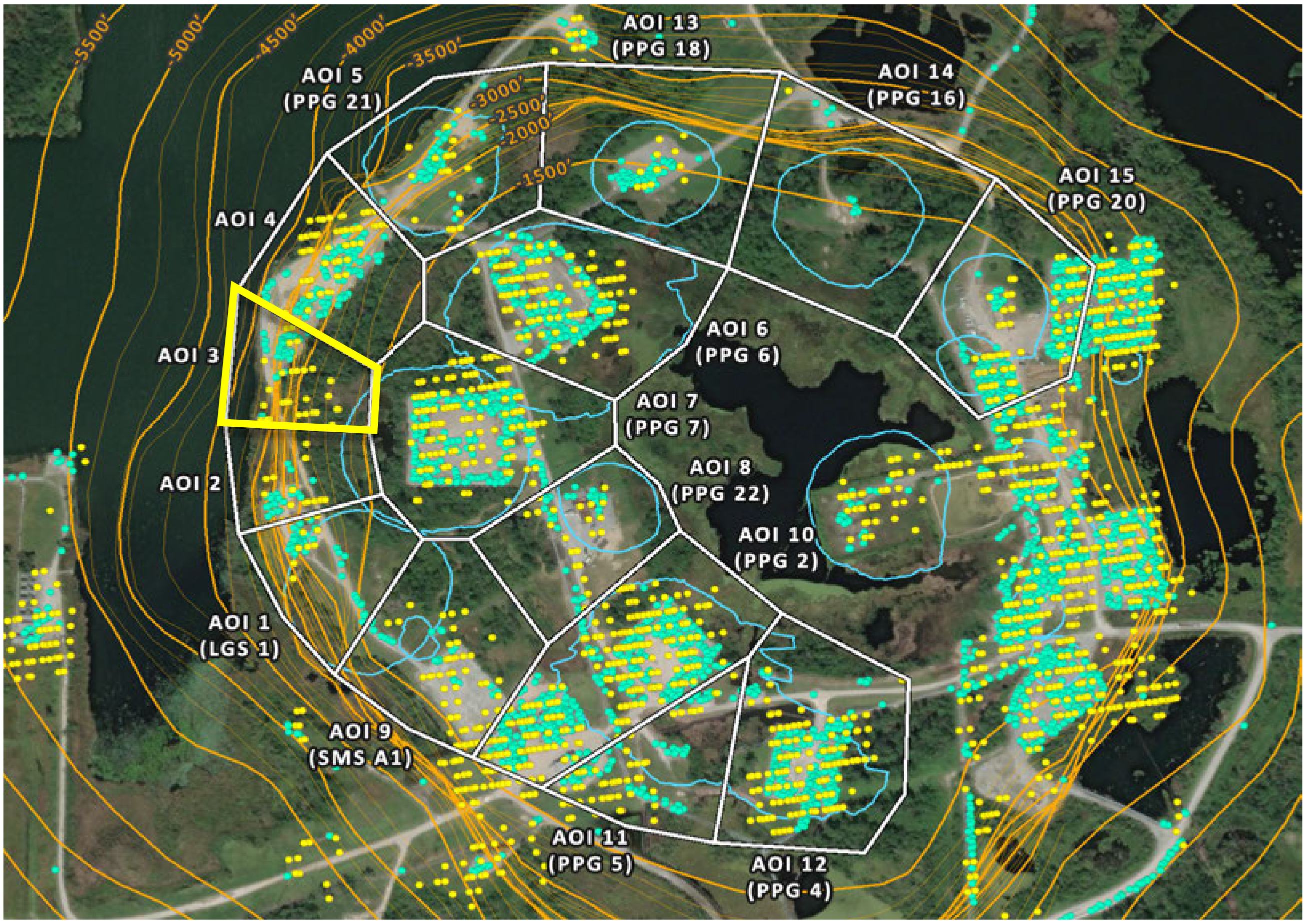
	Nonlinear Trend	Linear Trend
Velocity:	-0.38 in/yr	-0.05 in/yr
Acceleration:	-0.41 in/yr^2	0.00 in/yr^2

■ LOS Displacement Measurement

- - - - Nonlinear Trend Line (Quadratic Regression)

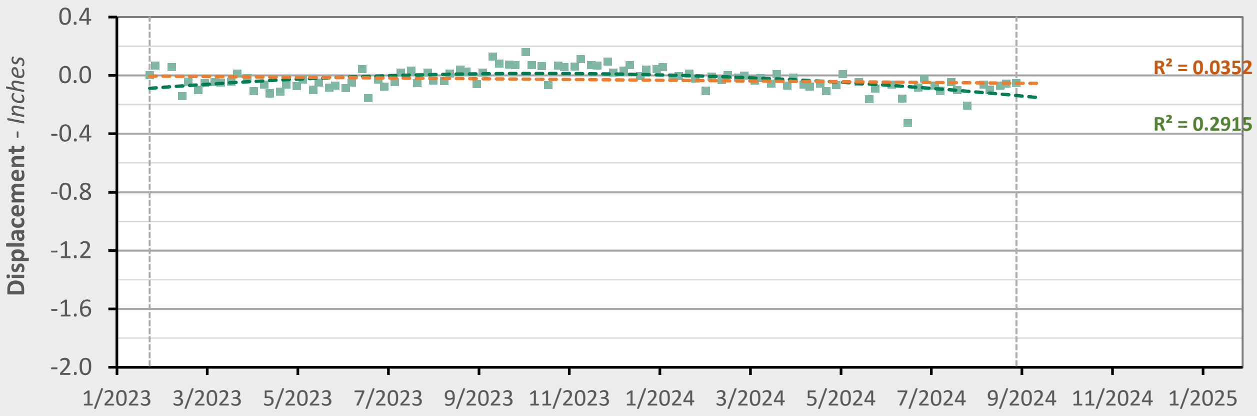
- - - - Linear Trend Line (Linear Regression)

AOI 3 - Location Map



AOI 3 - Displacement Time Series

TSX/PAZ (8/29/2024) Point Count: **40**



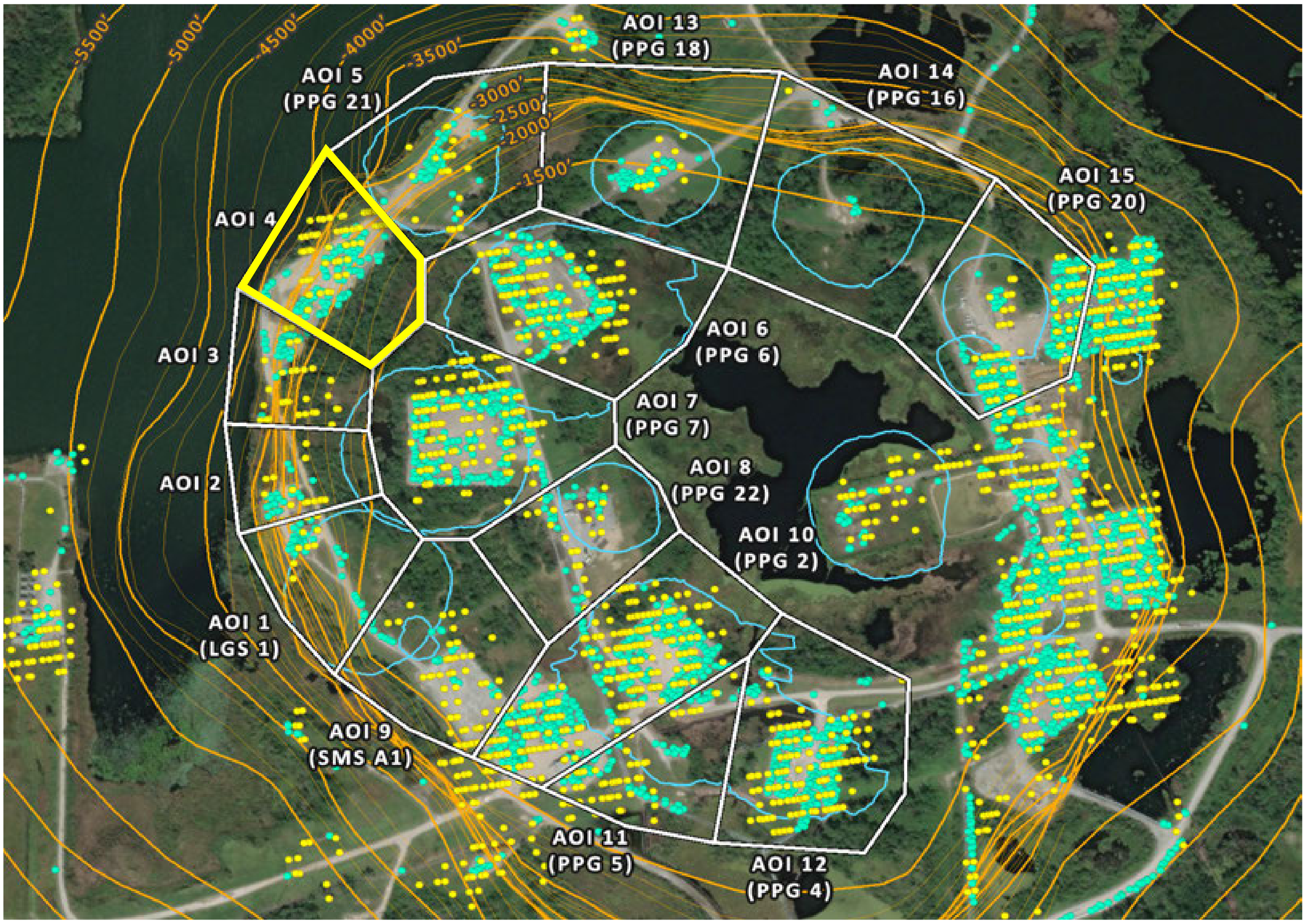
	Nonlinear Trend	Linear Trend
Velocity:	-0.35 in/yr	-0.03 in/yr
Acceleration:	-0.39 in/yr^2	0.00 in/yr^2

🟩 LOS Displacement Measurement

- - - - Nonlinear Trend Line (Quadratic Regression)

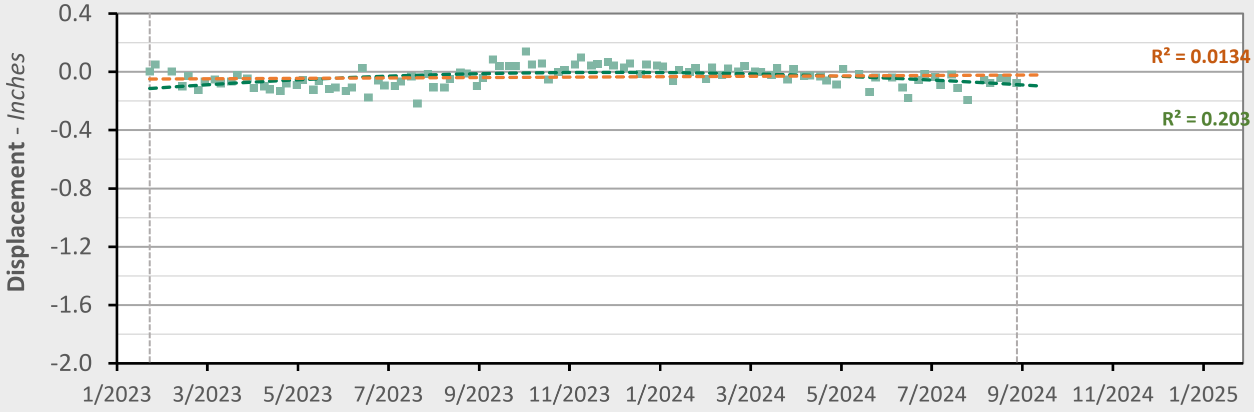
- - - - Linear Trend Line (Linear Regression)

AOI 4 - Location Map



AOI 4 - Displacement Time Series

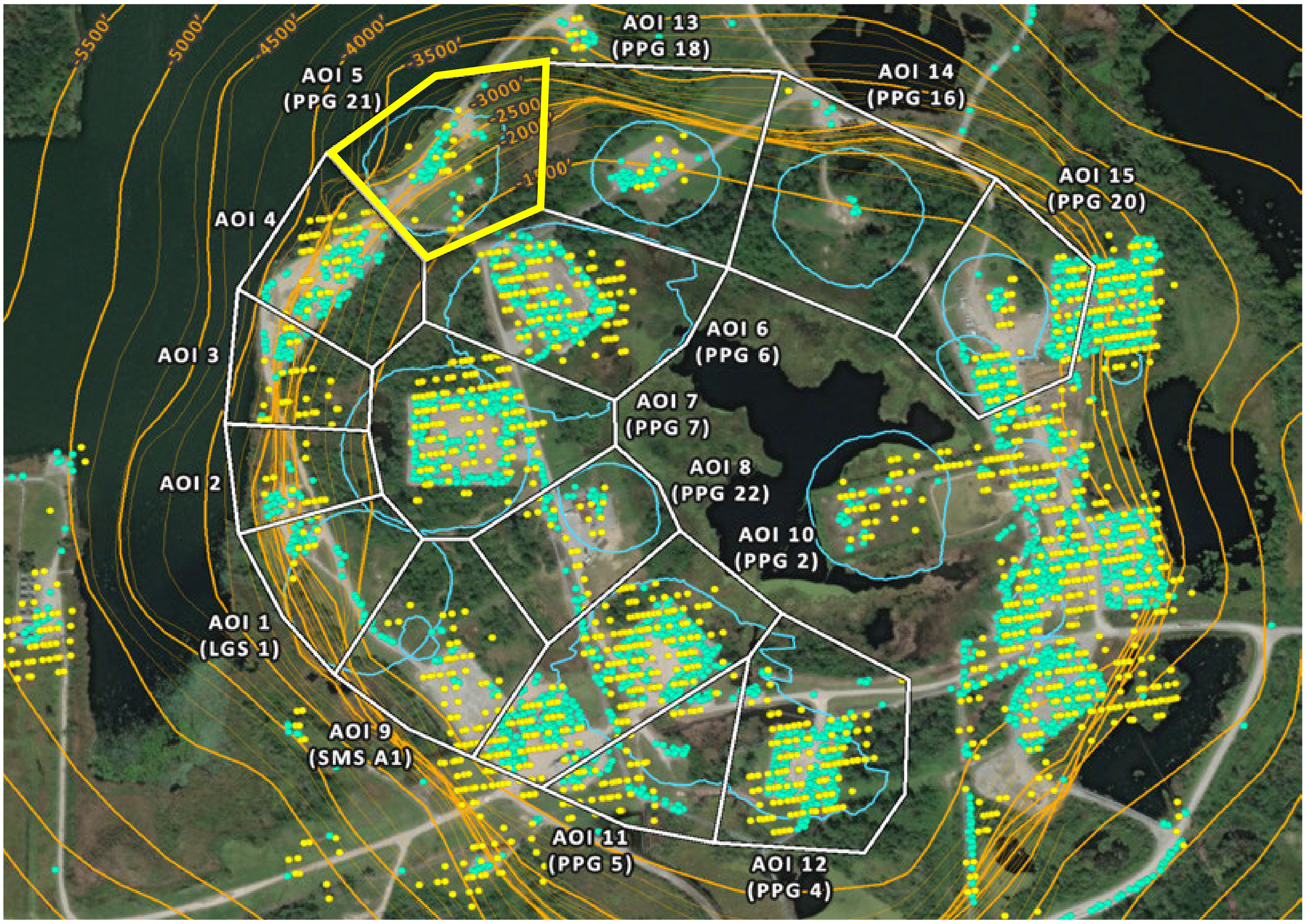
TSX/PAZ (8/29/2024) Point Count: **102**



	Nonlinear Trend		Linear Trend	
Velocity:	-0.23	in/yr	+0.02	in/yr
Acceleration:	-0.30	in/yr^2	0.00	in/yr^2

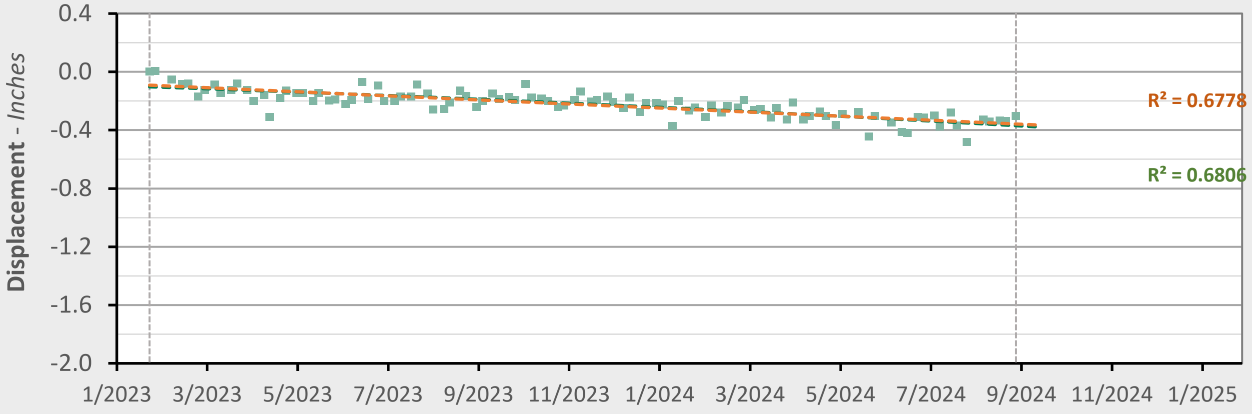
🟩 LOS Displacement Measurement — Nonlinear Trend Line (Quadratic Regression) — Linear Trend Line (Linear Regression)

AOI 5 *(PPG 21)* - Location Map



AOI 5 *(PPG 21)* - Displacement Time Series

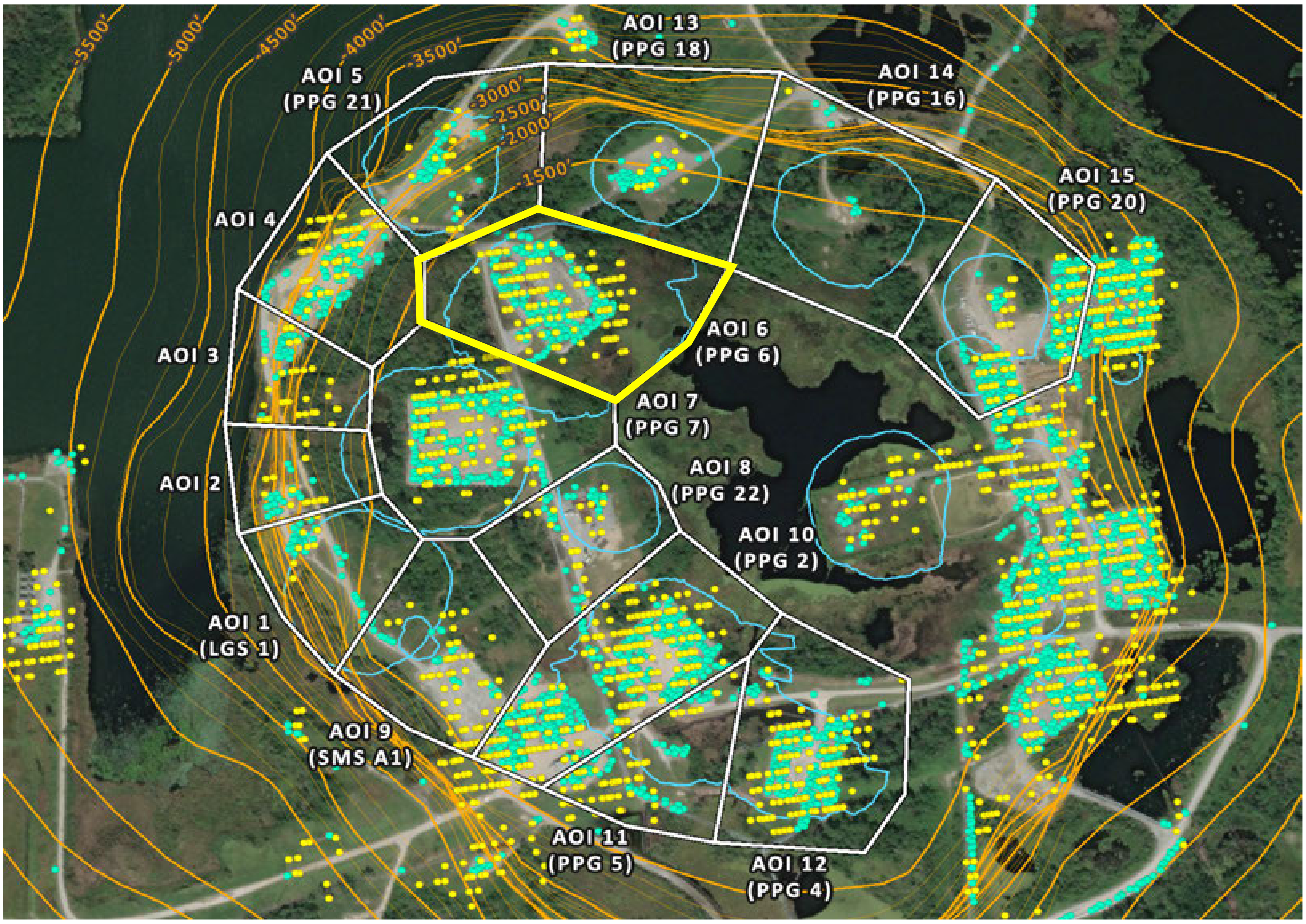
TSX/PAZ (8/29/2024) Point Count: 47



	Nonlinear Trend		Linear Trend	
Velocity:	-0.21	in/yr	-0.17	in/yr
Acceleration:	-0.05	in/yr^2	0.00	in/yr^2

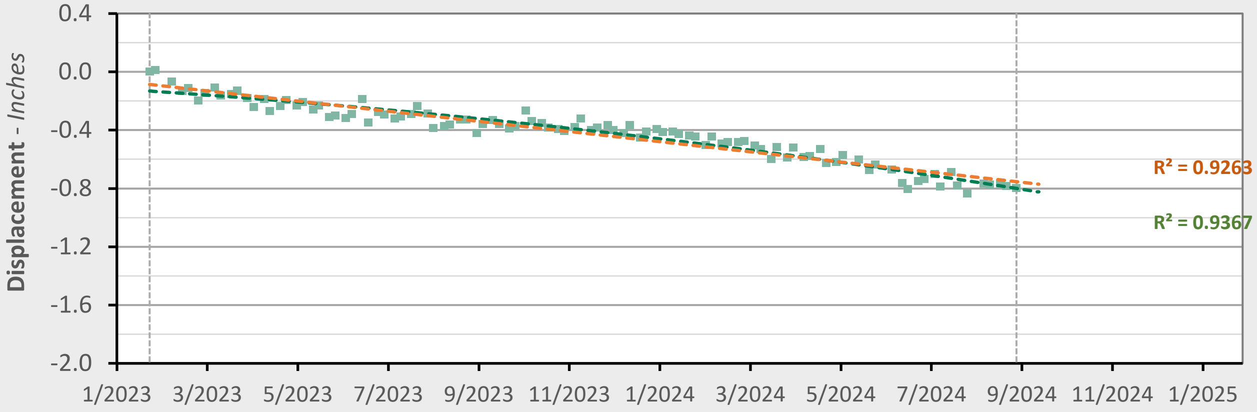
- ■ LOS Displacement Measurement
- Nonlinear Trend Line (Quadratic Regression)
- Linear Trend Line (Linear Regression)

AOI 6 *(PPG 6)* - Location Map



AOI 6 *(PPG 6)* - Displacement Time Series

TSX/PAZ (8/29/2024) Point Count: **212**



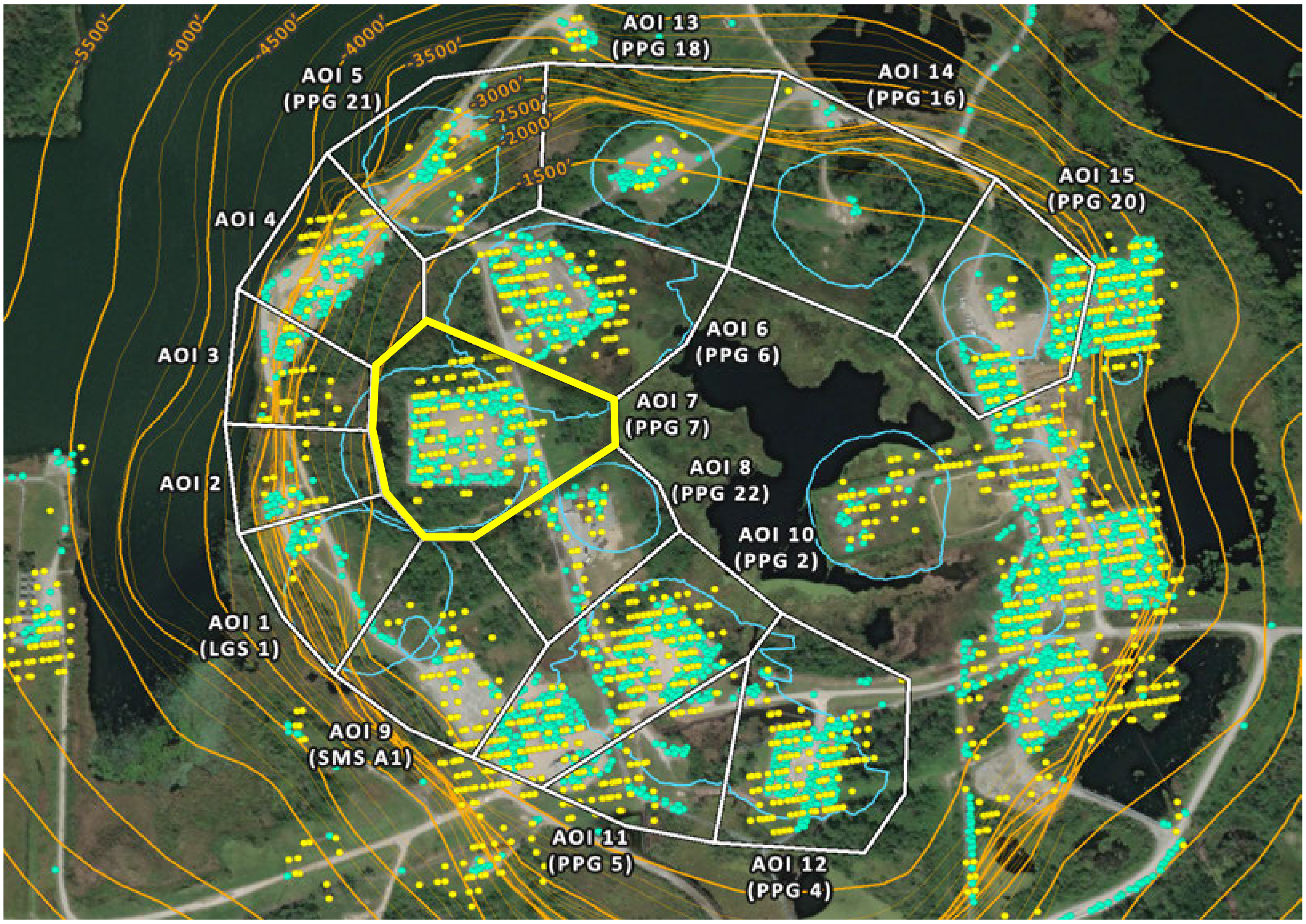
	Nonlinear Trend		Linear Trend	
Velocity:	-0.59	in/yr	-0.42	in/yr
Acceleration:	-0.21	in/yr^2	0.00	in/yr^2

■ LOS Displacement Measurement

- - - Nonlinear Trend Line (Quadratic Regression)

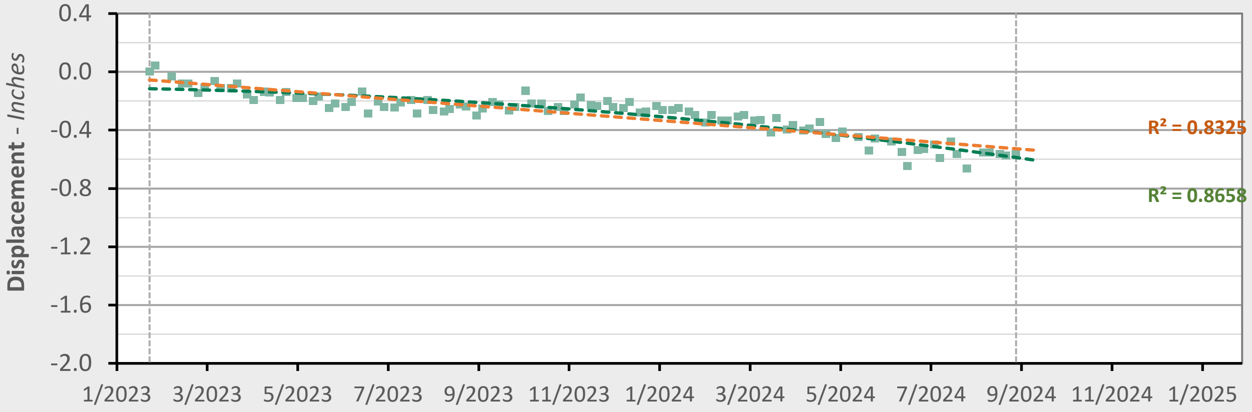
- - - Linear Trend Line (Linear Regression)

AOI 7 *(PPG 7)* - Location Map



AOI 7 *(PPG 7)* - Displacement Time Series

TSX/PAZ (8/29/2024) Point Count: **216**



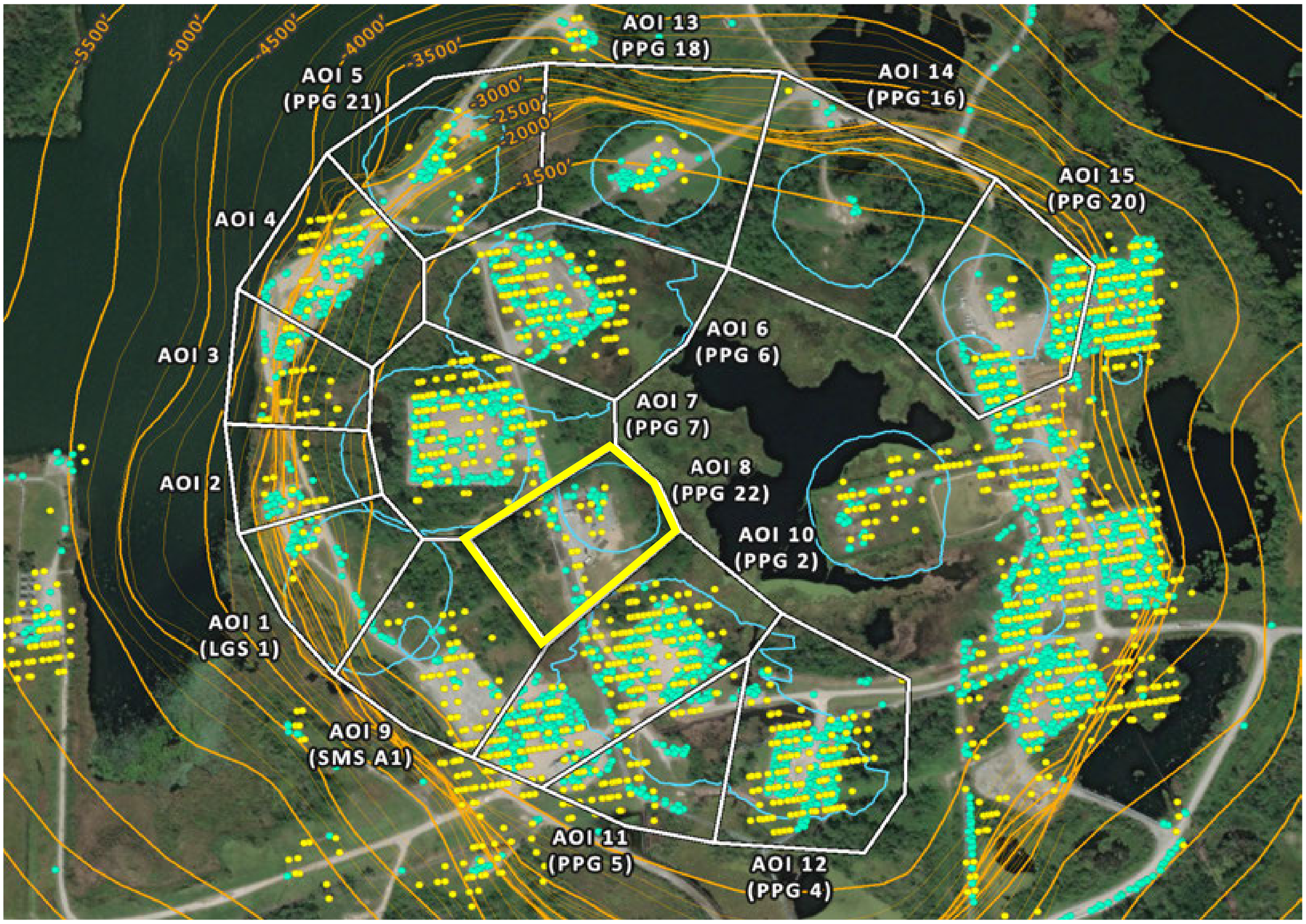
	Nonlinear Trend	Linear Trend
Velocity:	-0.52 in/yr	-0.30 in/yr
Acceleration:	-0.28 in/yr^2	0.00 in/yr^2

■ LOS Displacement Measurement

- - - Nonlinear Trend Line (Quadratic Regression)

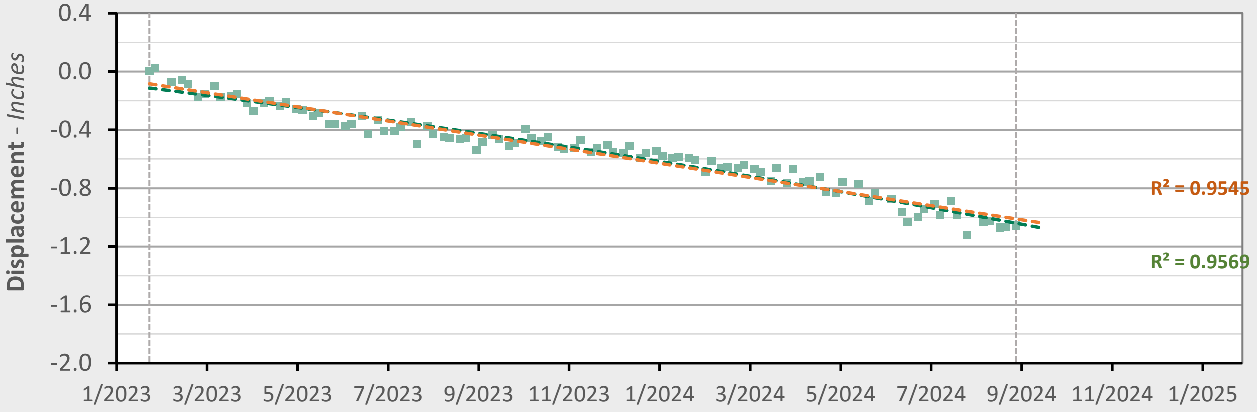
- - - Linear Trend Line (Linear Regression)

AOI 8 *(PPG 22)* - Location Map



AOI 8 *(PPG 22)* - Displacement Time Series

TSX/PAZ (8/29/2024) Point Count: **36**



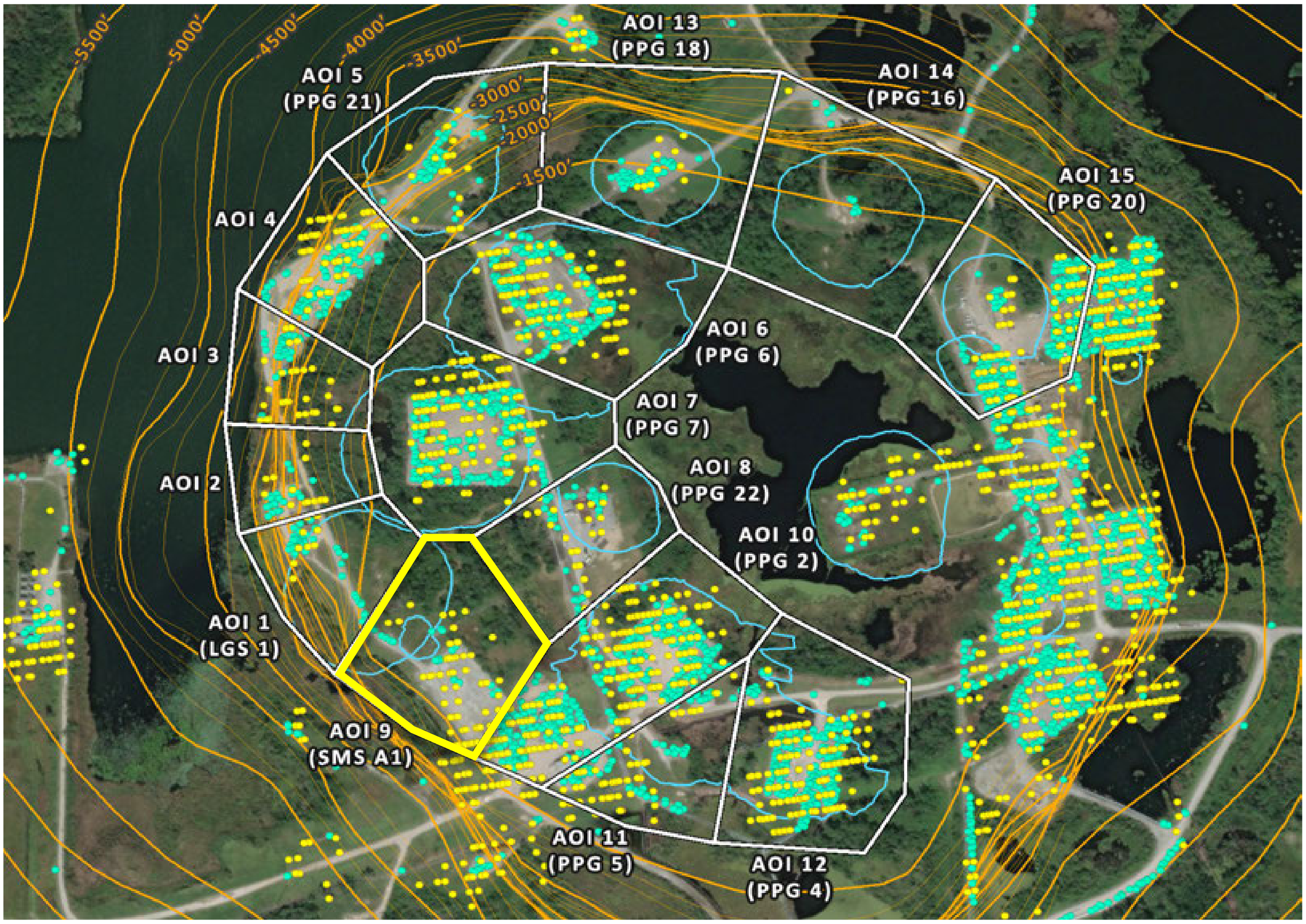
	Nonlinear Trend		Linear Trend	
Velocity:	-0.69	in/yr	-0.58	in/yr
Acceleration:	-0.14	in/yr^2	0.00	in/yr^2

🟩 LOS Displacement Measurement

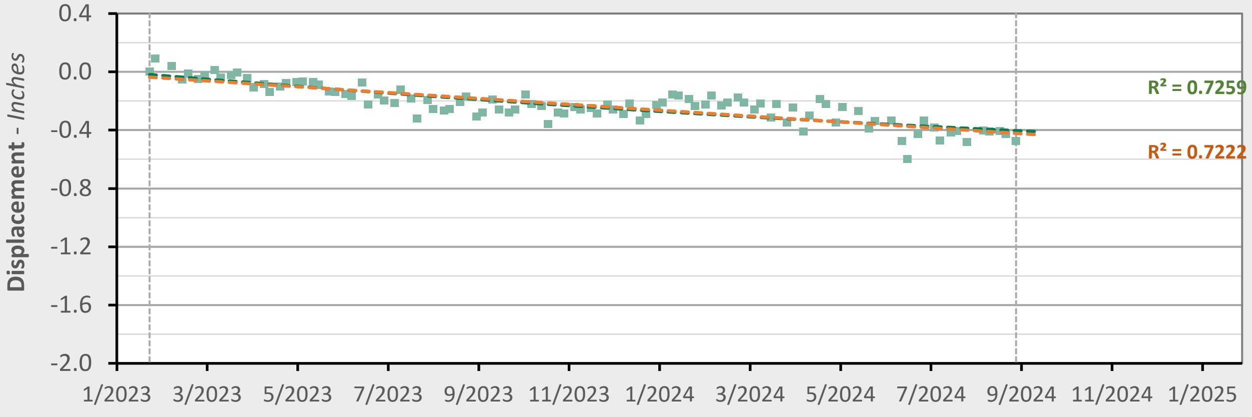
Nonlinear Trend Line (Quadratic Regression)

Linear Trend Line (Linear Regression)

AOI 9 *(PPG A1)* - Location Map



AOI 9 *(SMS A1)* - Displacement Time Series TSX/PAZ (8/29/2024) Point Count: 23



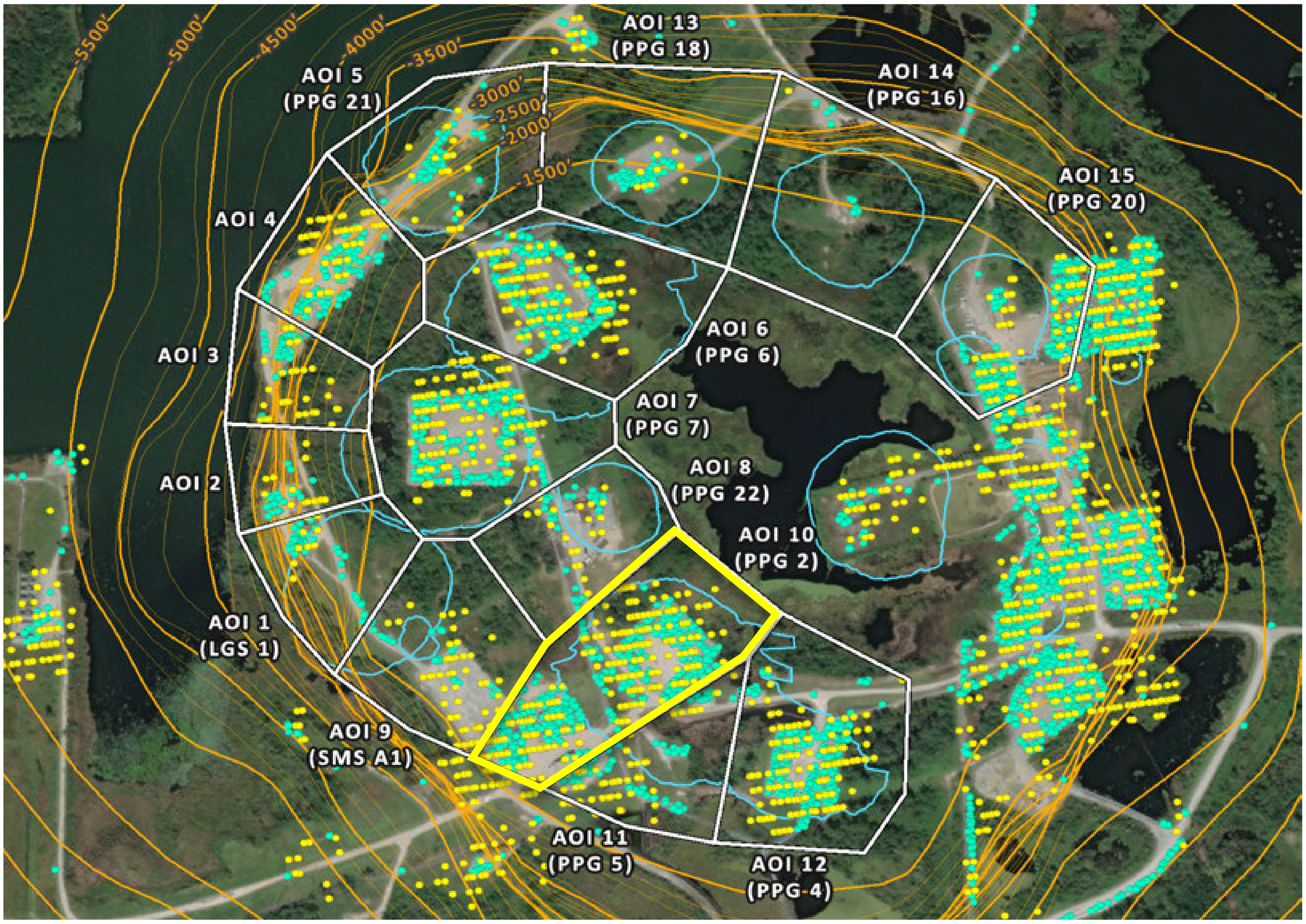
	Nonlinear Trend		Linear Trend	
Velocity:	-0.18	in/yr	-0.24	in/yr
Acceleration:	+0.08	in/yr^2	0.00	in/yr^2

■ LOS Displacement Measurement

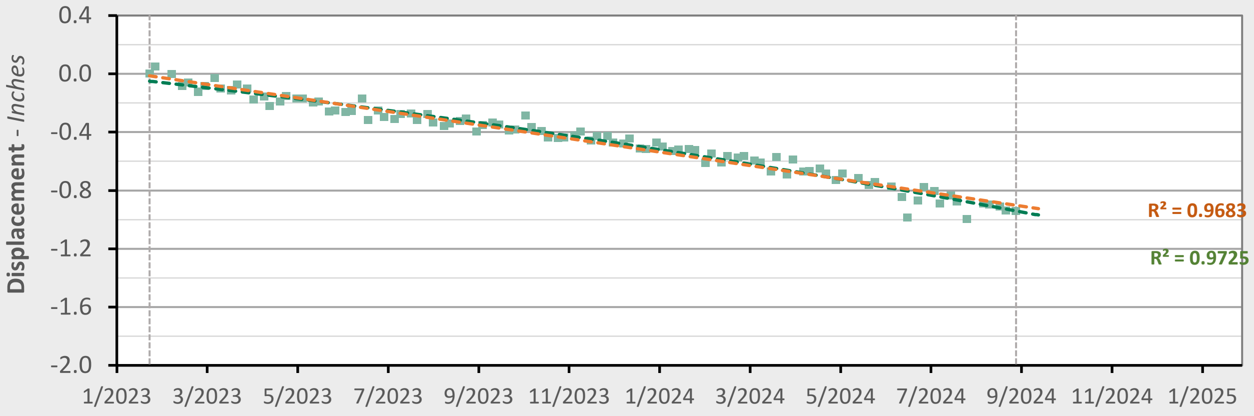
- - - - Nonlinear Trend Line (Quadratic Regression)

- - - - Linear Trend Line (Linear Regression)

AOI 10 *(PPG 2)* - Location Map



AOI 10 *(PPG 2)* - Displacement Time Series TSX/PAZ (8/29/2024) Point Count: 404



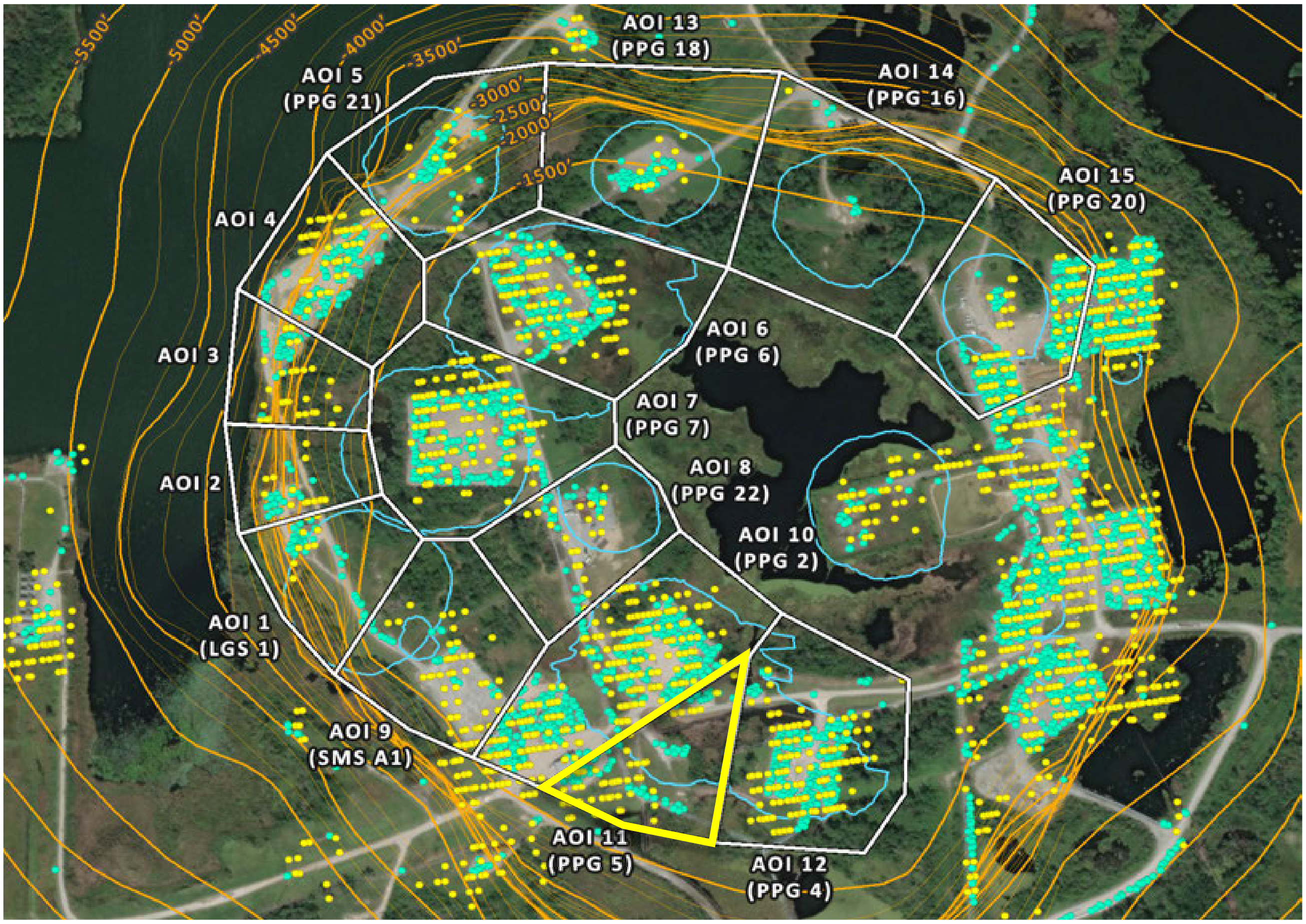
	Nonlinear Trend	Linear Trend
Velocity:	-0.70 in/yr	-0.56 in/yr
Acceleration:	-0.18 in/yr^2	0.00 in/yr^2

🟩 LOS Displacement Measurement

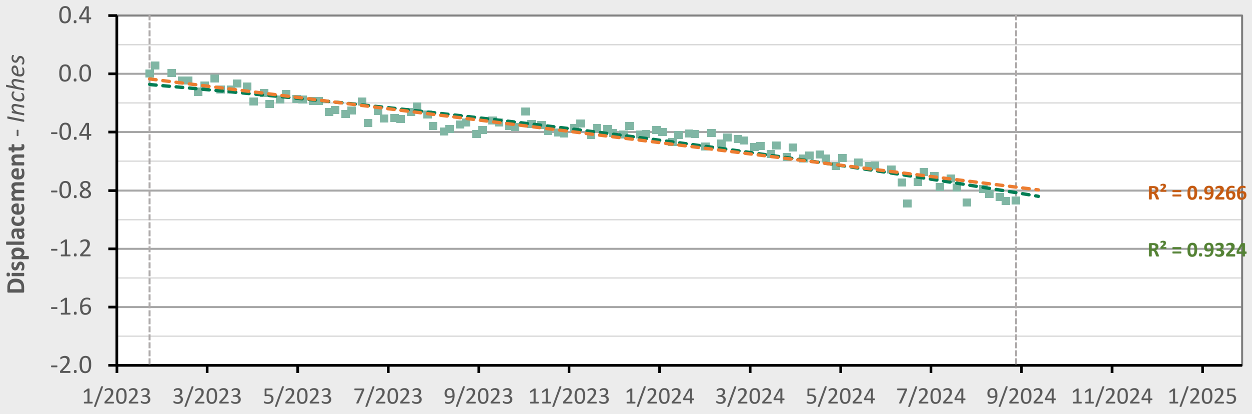
---- Nonlinear Trend Line (Quadratic Regression)

---- Linear Trend Line (Linear Regression)

AOI 11 *(PPG 5)* - Location Map



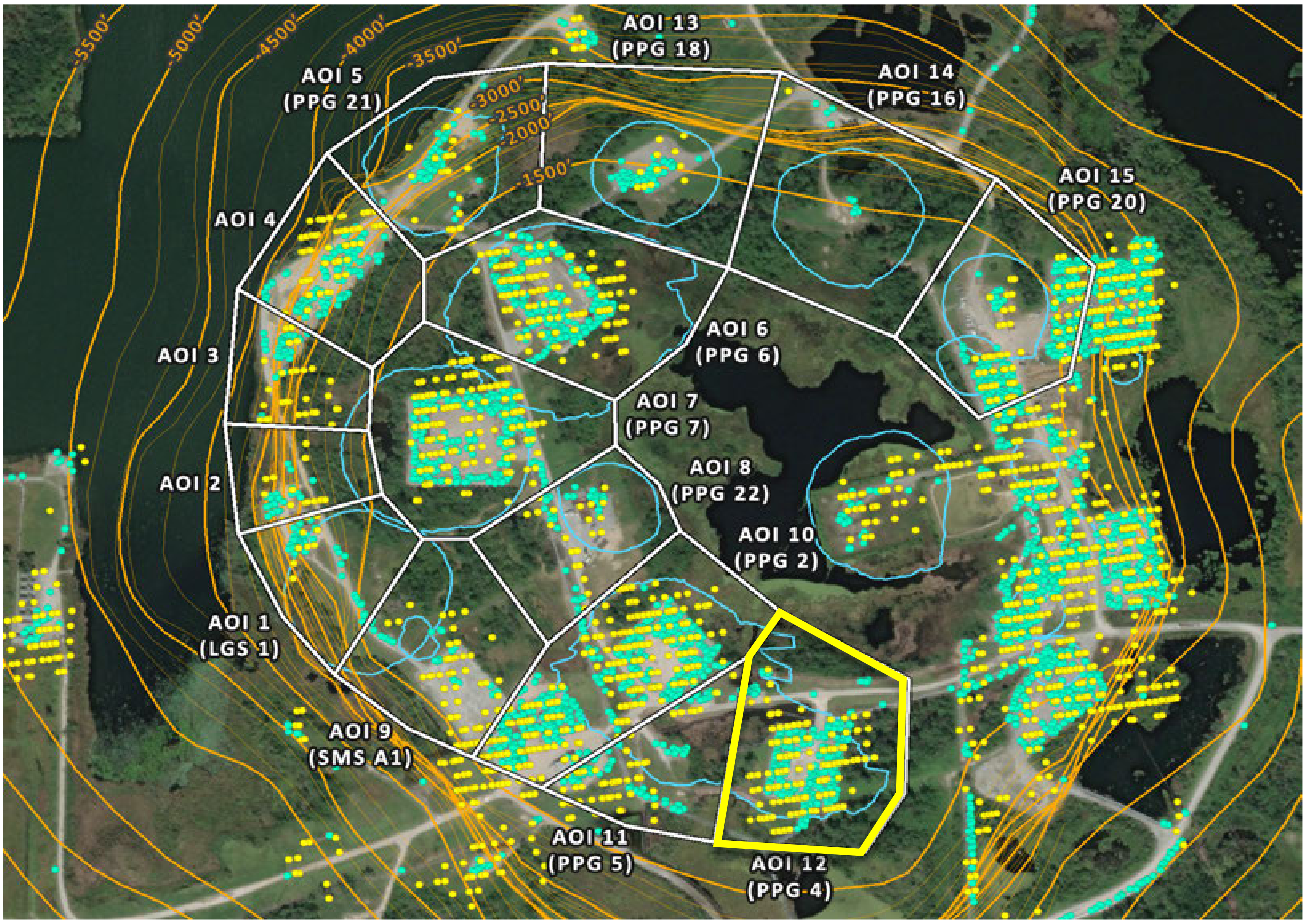
AOI 11 *(PPG 5)* - Displacement Time Series TSX/PAZ (8/29/2024) Point Count: 85



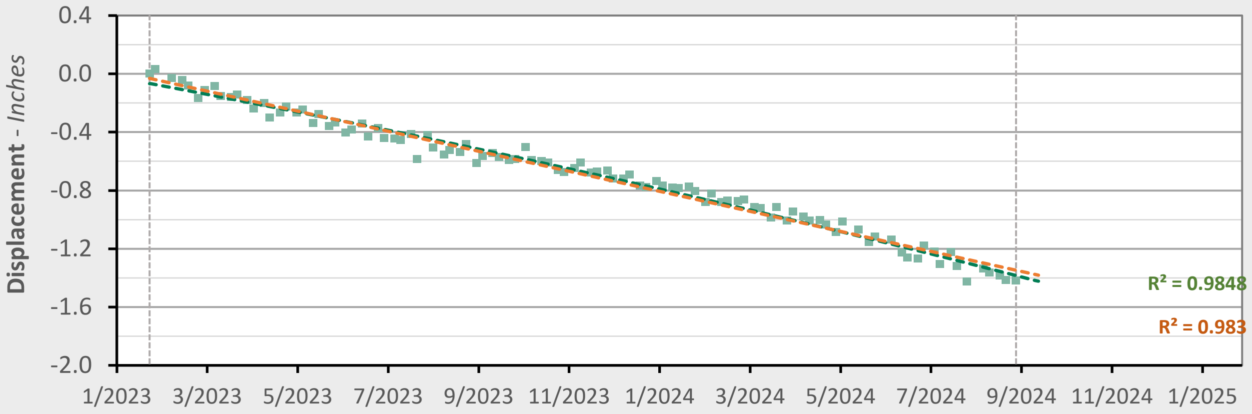
	Nonlinear Trend		Linear Trend	
Velocity:	-0.61	in/yr	-0.46	in/yr
Acceleration:	-0.18	in/yr^2	0.00	in/yr^2

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

AOI 12 *(PPG 4)* - Location Map



AOI 12 *(PPG 4)* - Displacement Time Series TSX/PAZ (8/29/2024) Point Count: 262



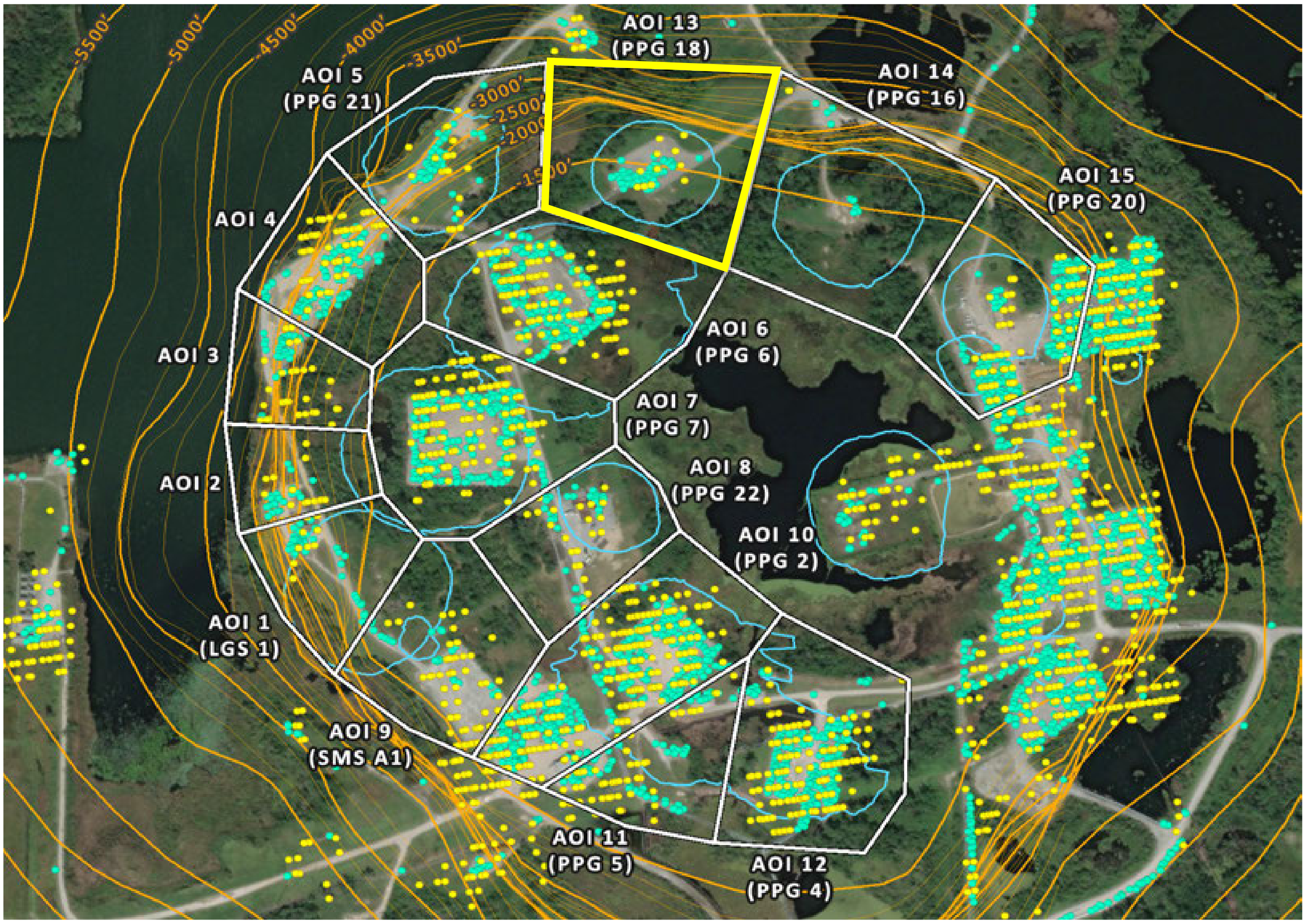
	Nonlinear Trend	Linear Trend
Velocity:	-0.96 in/yr	-0.82 in/yr
Acceleration:	-0.17 in/yr^2	0.00 in/yr^2

■ LOS Displacement Measurement

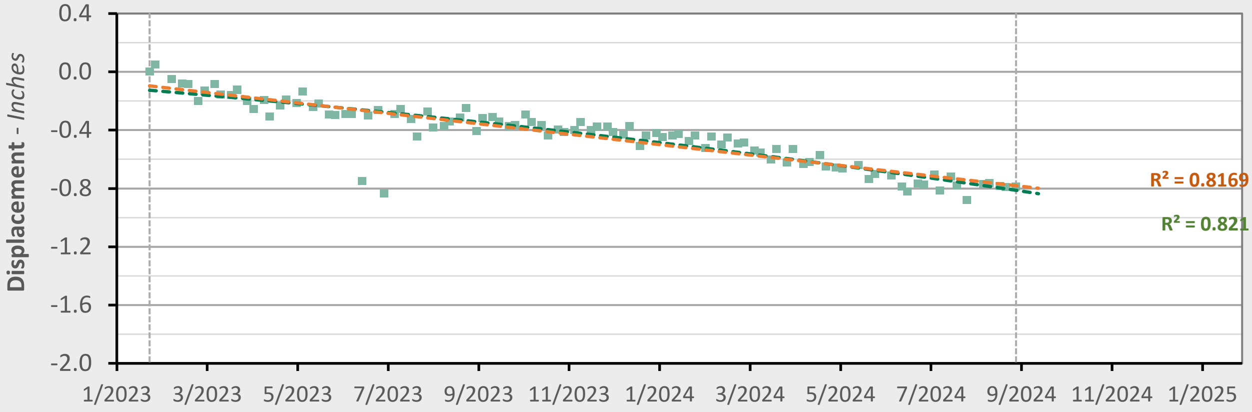
--- Nonlinear Trend Line (Quadratic Regression)

--- Linear Trend Line (Linear Regression)

AOI 13 *(PPG 18)* - Location Map



AOI 13 *(PPG 18)* - Displacement Time Series TSX/PAZ (8/29/2024) Point Count: 52



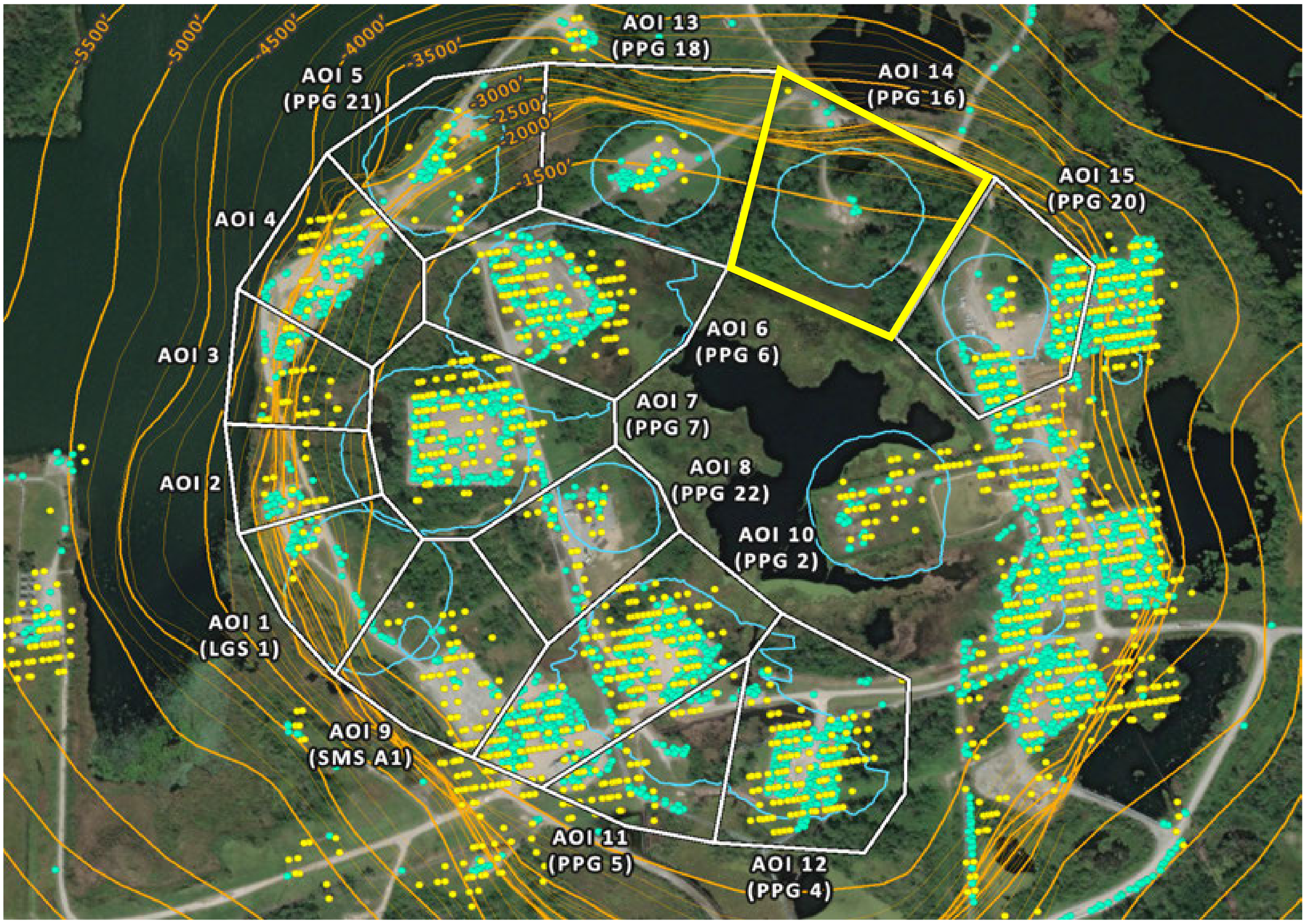
	Nonlinear Trend	Linear Trend
Velocity:	-0.55 in/yr	-0.43 in/yr
Acceleration:	-0.15 in/yr^2	0.00 in/yr^2

🟩 LOS Displacement Measurement

- - - - Nonlinear Trend Line (Quadratic Regression)

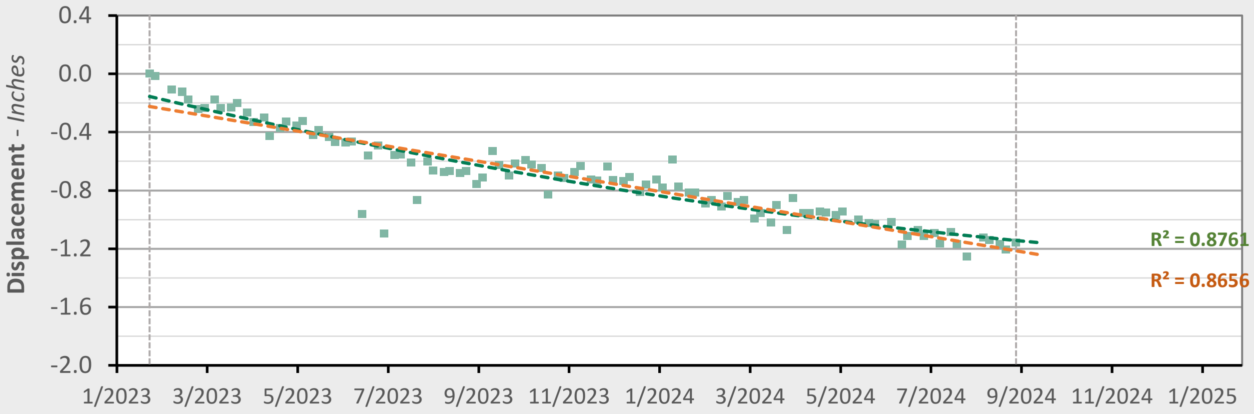
- - - - Linear Trend Line (Linear Regression)

AOI 14 *(PPG 16)* - Location Map



AOI 14 *(PPG 16)* - Displacement Time Series

TSX/PAZ (8/29/2024) Point Count: **11**



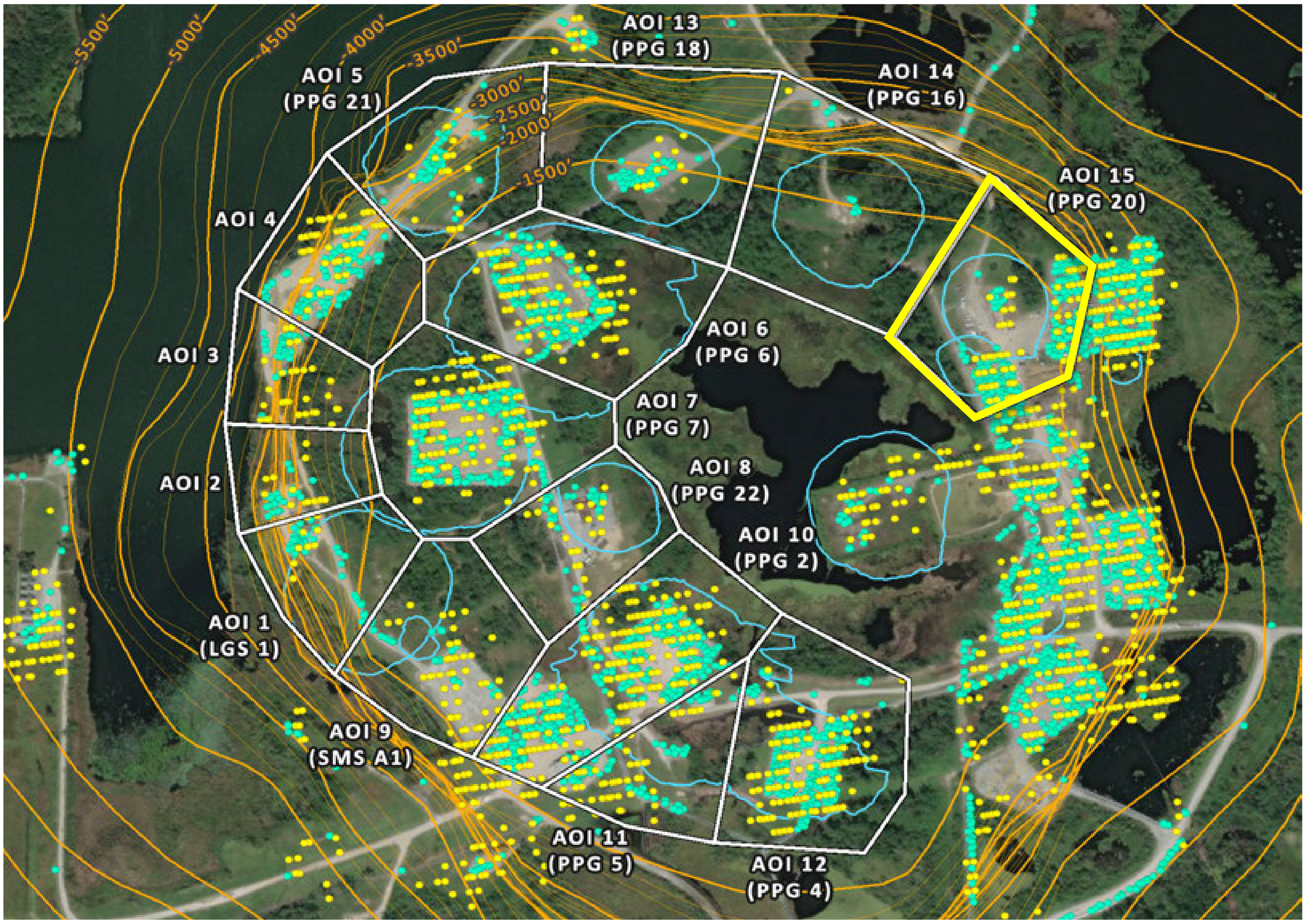
	Nonlinear Trend		Linear Trend	
Velocity:	-0.36	in/yr	-0.62	in/yr
Acceleration:	+0.33	in/yr^2	0.00	in/yr^2

■ LOS Displacement Measurement

- - - Nonlinear Trend Line (Quadratic Regression)

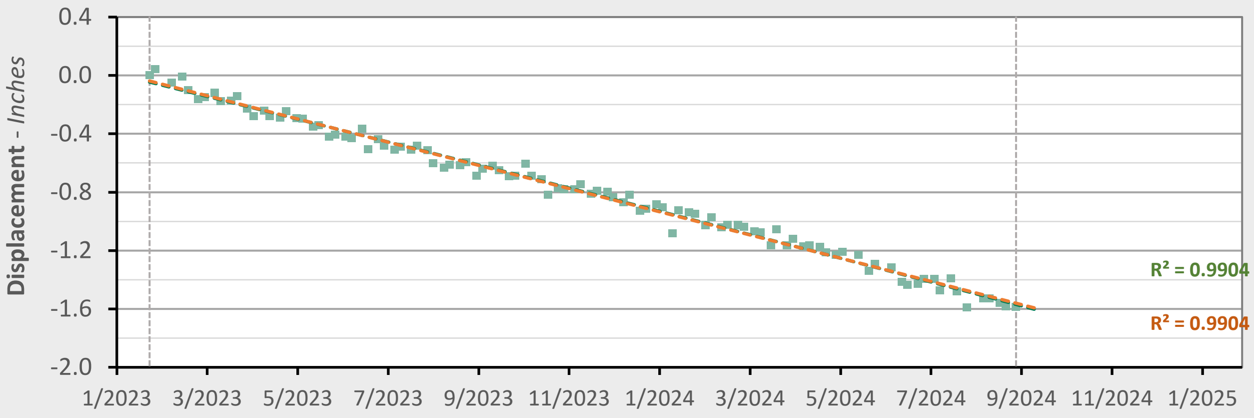
- - - Linear Trend Line (Linear Regression)

AOI 15 *(PPG 20)* - Location Map



AOI 15 *(PPG 20)* - Displacement Time Series

TSX/PAZ (8/29/2024) Point Count: **224**



	Nonlinear Trend	Linear Trend
Velocity:	-0.98 in/yr	-0.95 in/yr
Acceleration:	-0.03 in/yr^2	0.00 in/yr^2

🟩 LOS Displacement Measurement

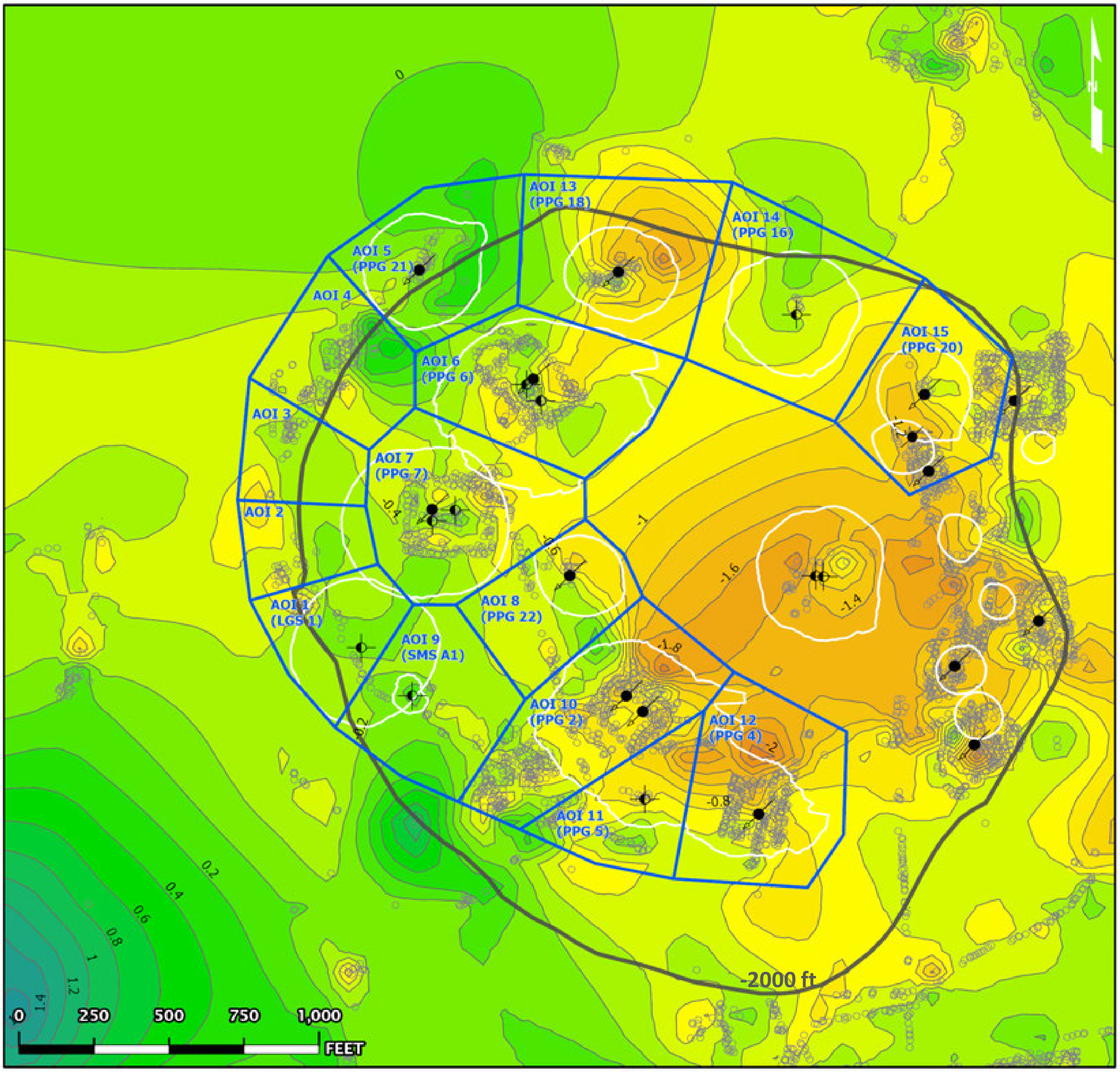
- - - - Nonlinear Trend Line (Quadratic Regression)

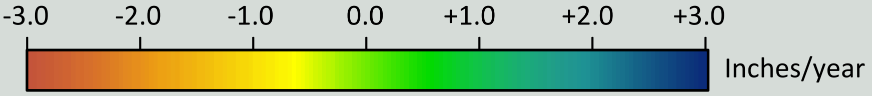
- - - - Linear Trend Line (Linear Regression)

TSX/PAZ Data (01/24/2023 - 08/29/2024)

Nonlinear Velocity Contours

As of date: 08/29/2024





▭ AOI Boundary ○ InSAR LOS Measurement Point — Contour (0.2)

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

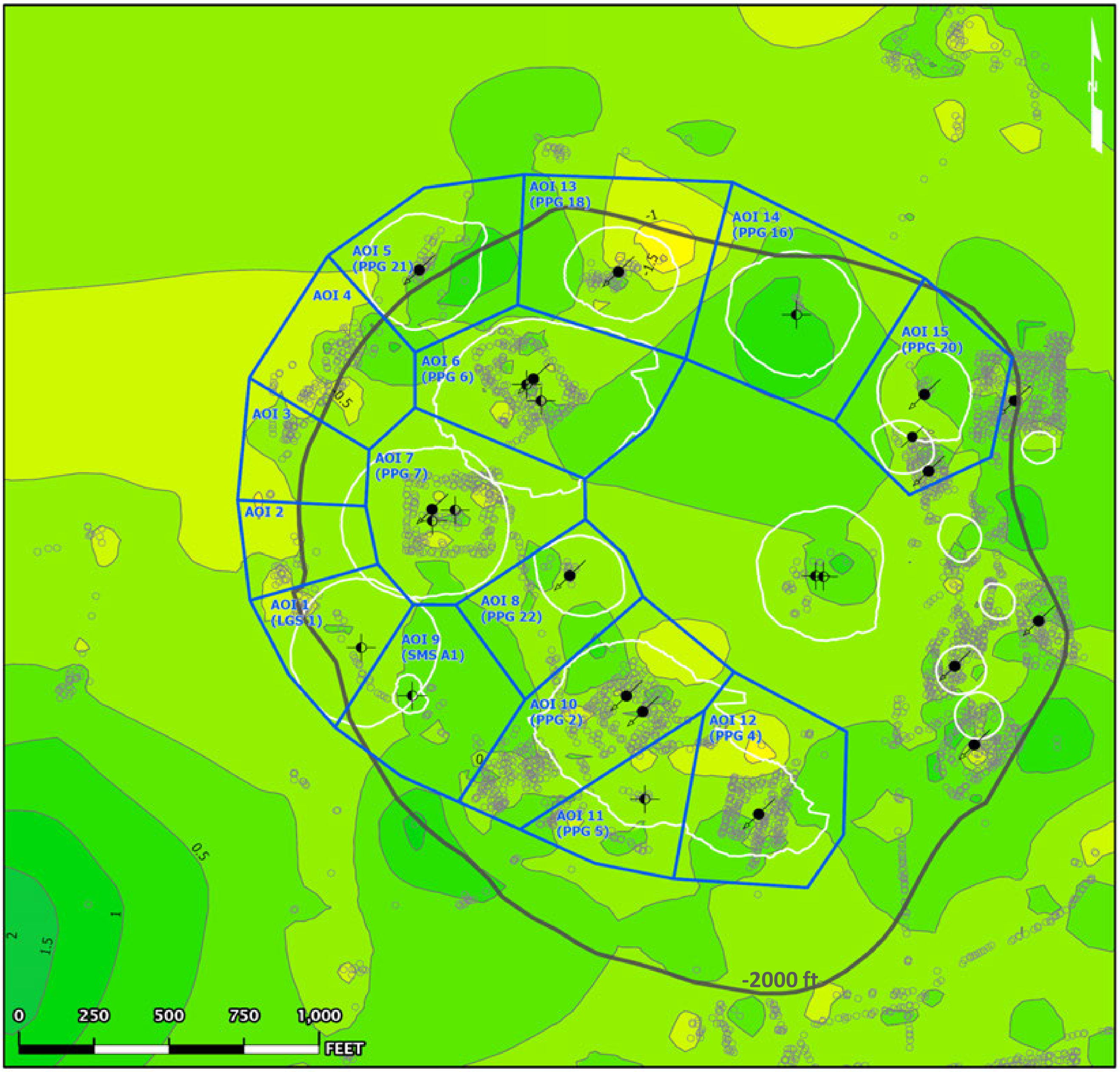
Cavern Well Surface Locations

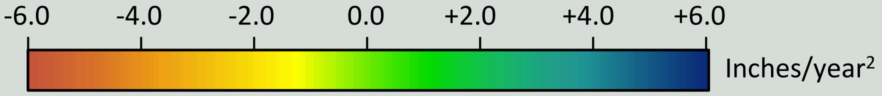
09 - Active - Injection 29 - Dry and Plugged

TSX/PAZ Data (01/24/2023 - 08/29/2024)

Nonlinear Acceleration Contours

Date range: 01/24/2023 - 08/29/2024





▭ AOI Boundary ○ InSAR LOS Measurement Point — Contour (0.5)

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

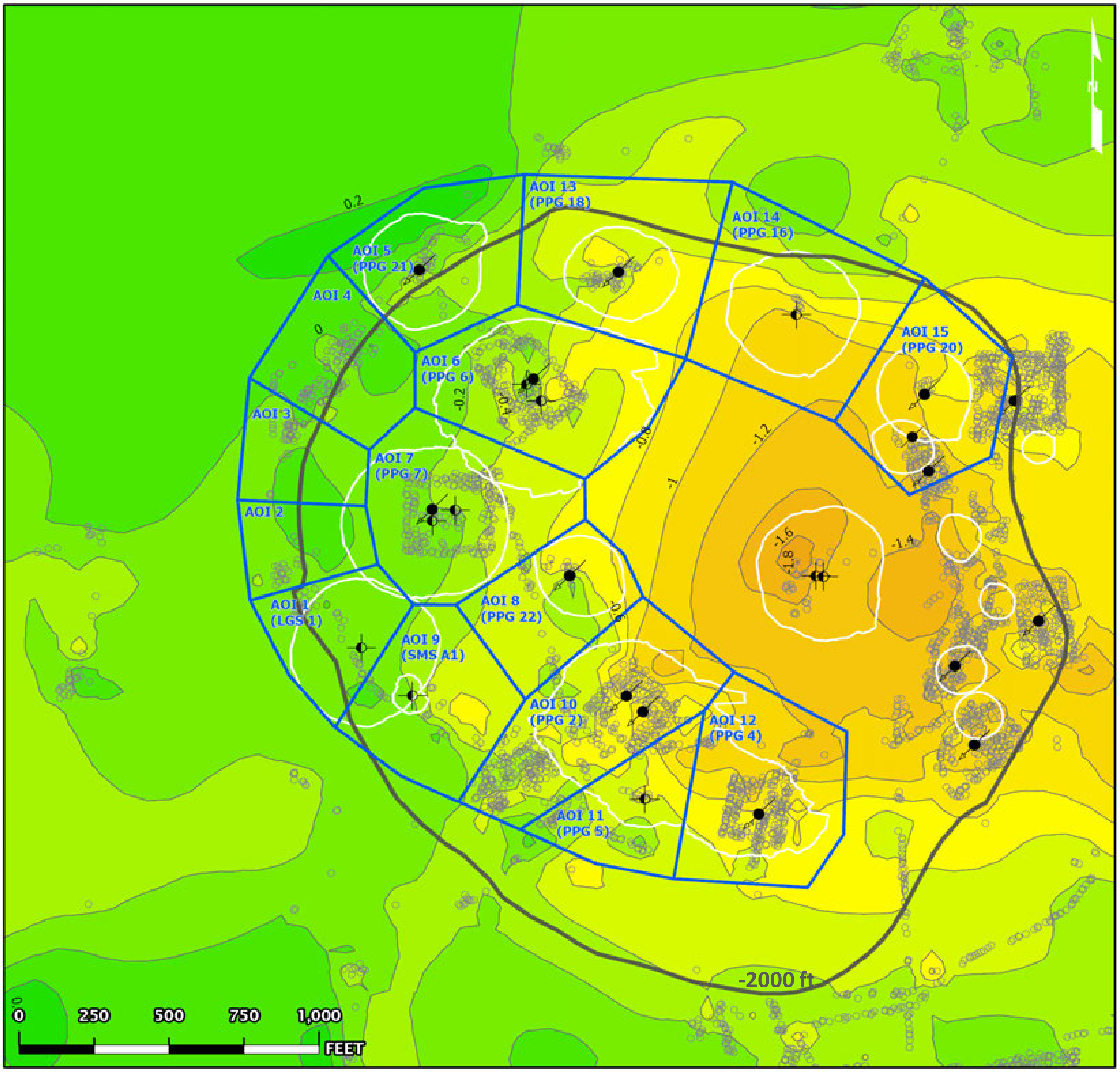
Cavern Well Surface Locations

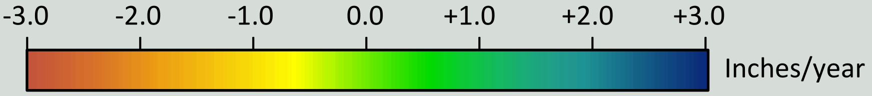
● 09 - Active - Injection ⊕ 29 - Dry and Plugged

TSX/PAZ Data (01/24/2023 - 08/29/2024)

Linear Velocity Contours

Date range: 01/24/2023 - 08/29/2024





▭ AOI Boundary ○ InSAR LOS Measurement Point — Contour (0.2)

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

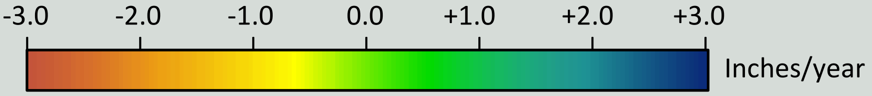
Cavern Well Surface Locations

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

TSX/PAZ Data (01/24/2023 - 08/29/2024)

Nonlinear Velocity Data Points

As of date: 08/29/2024



▭ 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 - 08/29/2024)

Nonlinear Acceleration Data Points

Date range: 01/24/2023 - 08/29/2024

-6.0 -4.0 -2.0 0.0 +2.0 +4.0 +6.0

Inches/year^2

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 - 08/29/2024)

Linear Velocity Data Points

Date range: 01/24/2023 - 08/29/2024

-3.0 -2.0 -1.0 0.0 +1.0 +2.0 +3.0

Inches/year

▭ 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 D

Vertical & East-West 2D InSAR report - August 29, 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
Thursday, August 29, 2024

Analysis Report Date:

September 12, 2024

Dataset Information

Satellite Source	Sentinel-1 & TerraSAR-X - PAZ Constellation
Update Frequency	12 days
Most Recent Image Date	Thursday, August 29, 2024
Dataset Image Count	131
Dataset Time Range	January 24, 2023 - August 29, 2024
Dataset Length	1.60 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 occuring with near-linear trends in all AOIs where data is present. Minor positive acceleration (slowing subsidence) is present all of the calculated nonlinear AOI trends.

The calculated east-west dispacement values generally indicate horizontal movement toward the dome center with the greatest rates of eastward movement occuring in the westernmost AOIs and the greatest rate of westward movement occuring in the easternmost AOI. All AOIs indicate varying amounts of negative acceleration (slower eastward or faster westward displacement) with the most pronounced values occuring 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.

NATHANIEL L. BYARS
License No. 40697

Nathaniel Byars

Date Signed: September 12, 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.

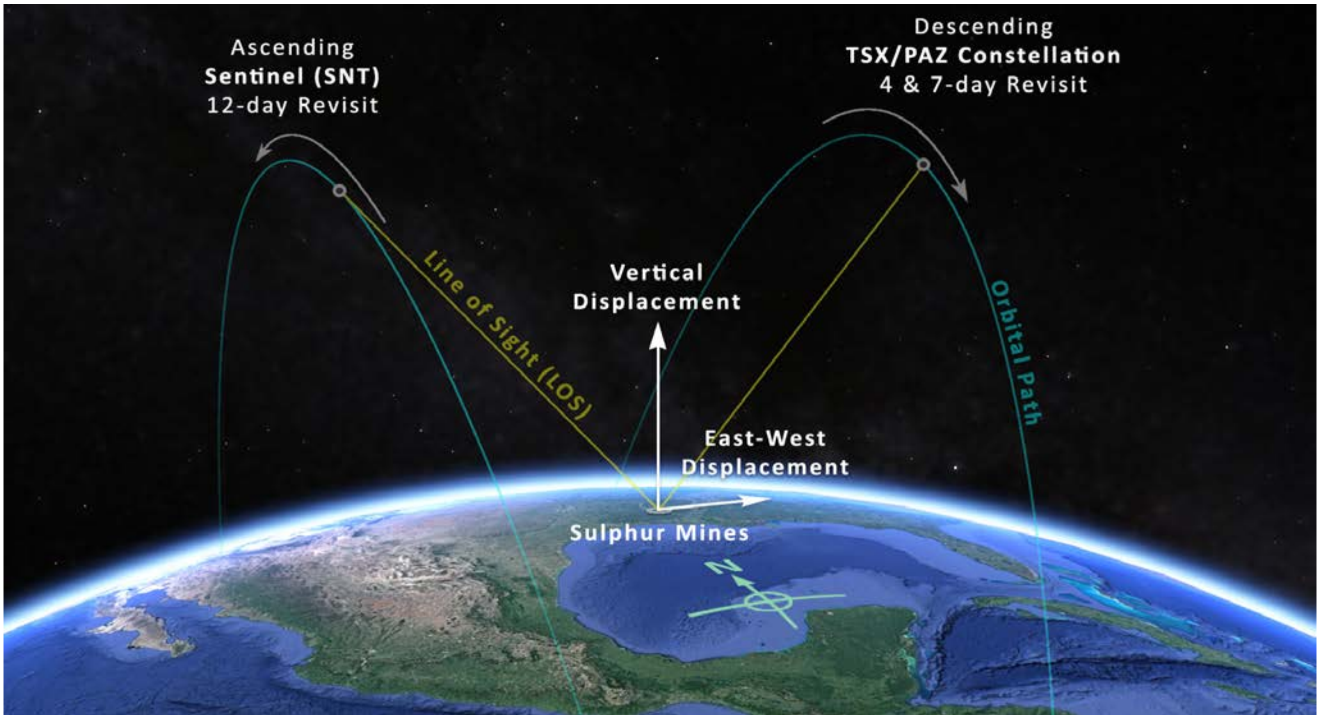
Satellite Sources

Two InSAR datasets are being used to evaluate subsidence over the Sulphur Mines Salt Dome. These datasets provide Line-of-Sight (LOS) displacment 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.

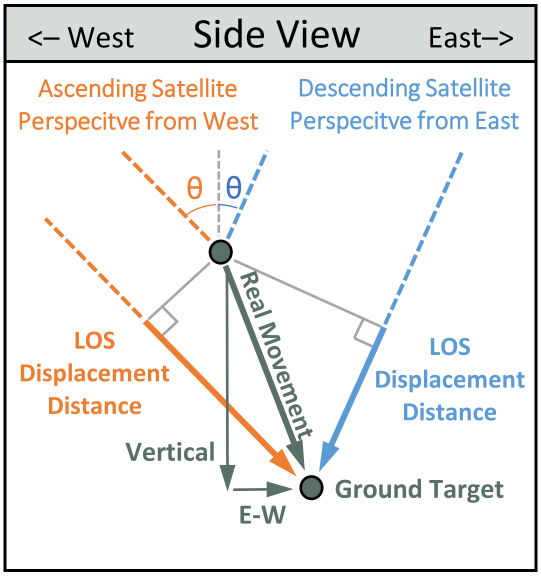
Each instance of data capture in either the SNT or TSX/PAZ constellation is used to generate 2D (two-dimensional) displacement values in the vertical and east-west directions for each measurement point within the 2D data grid. The image below depicts the orbital paths of the satellites in relation to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

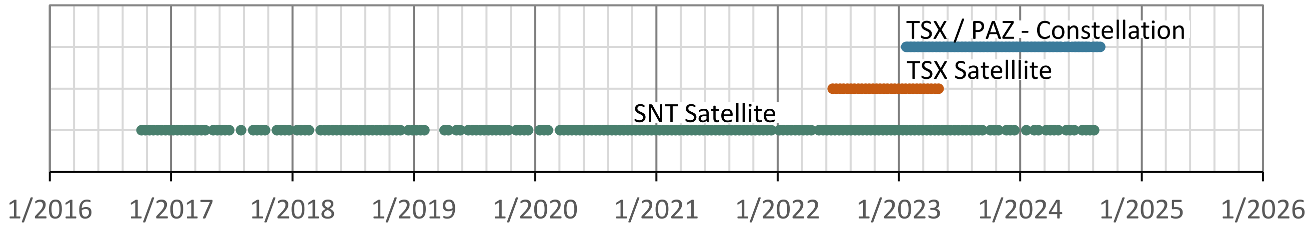
LOS (line-of-sight) displacement measurements, which refer to a change in distance between the satellite sensor and the ground target, are used to triangulate the real movement along the 2D plane defined by the satellite positions and the ground target. The diagram to the right illustrates the geometric 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.



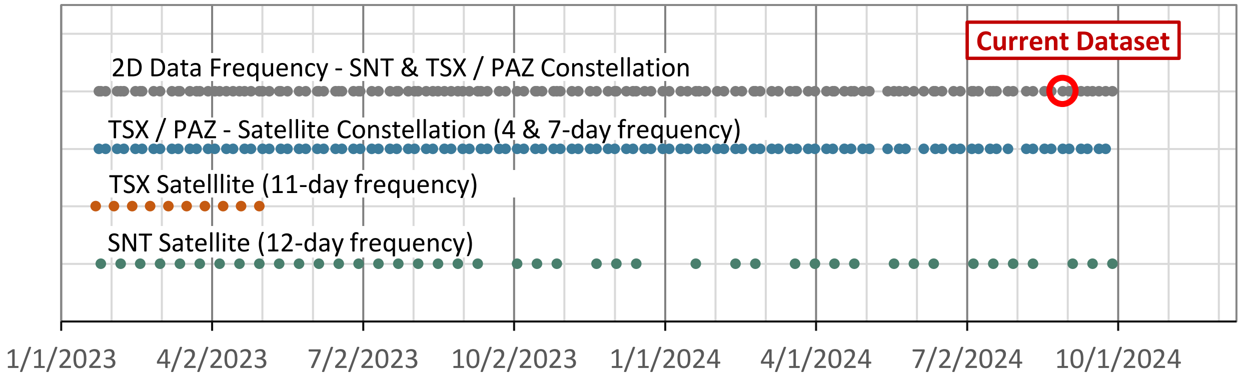
Satellite Properties & Image Frequency

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^o)	Descending (37^o)
Data Start Date	10/4/2016	1/24/2023
Measurement error range	± 0.20 in	± 0.03 in

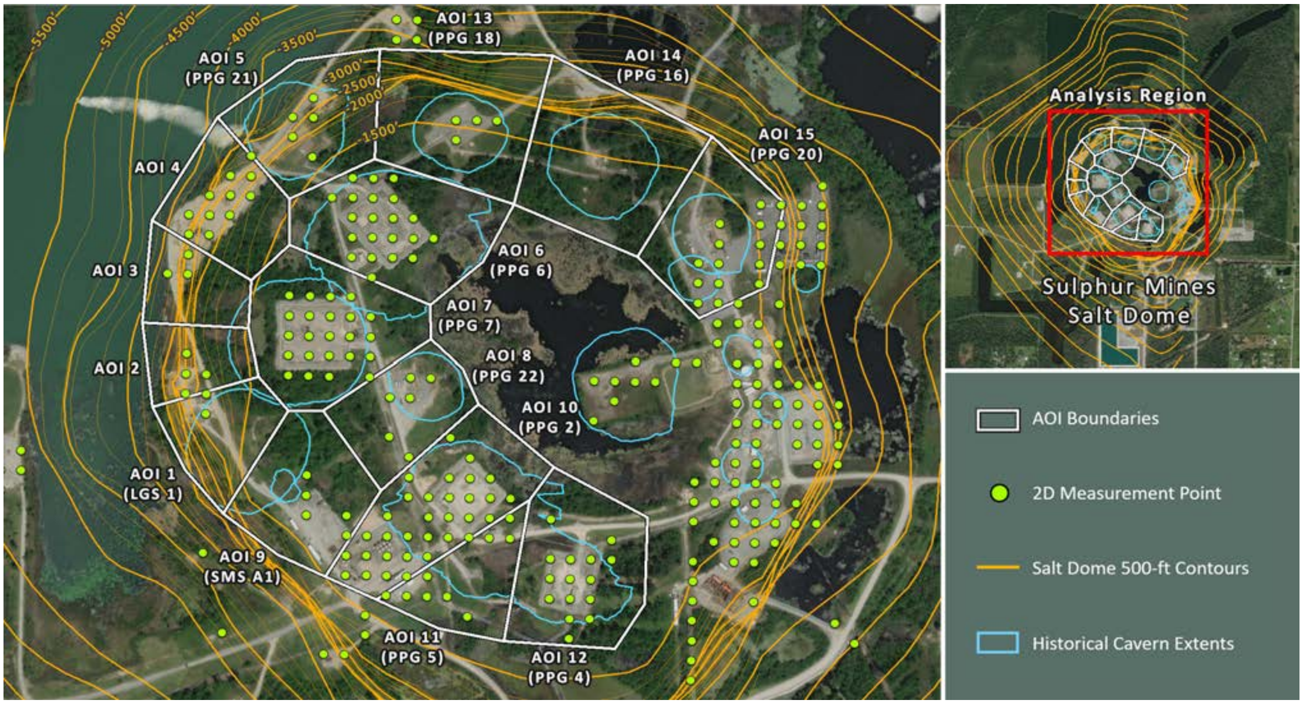
LOS Measurement History



2D Measurement Frequency



AOI Boundaries & 2D InSAR Measurement Points

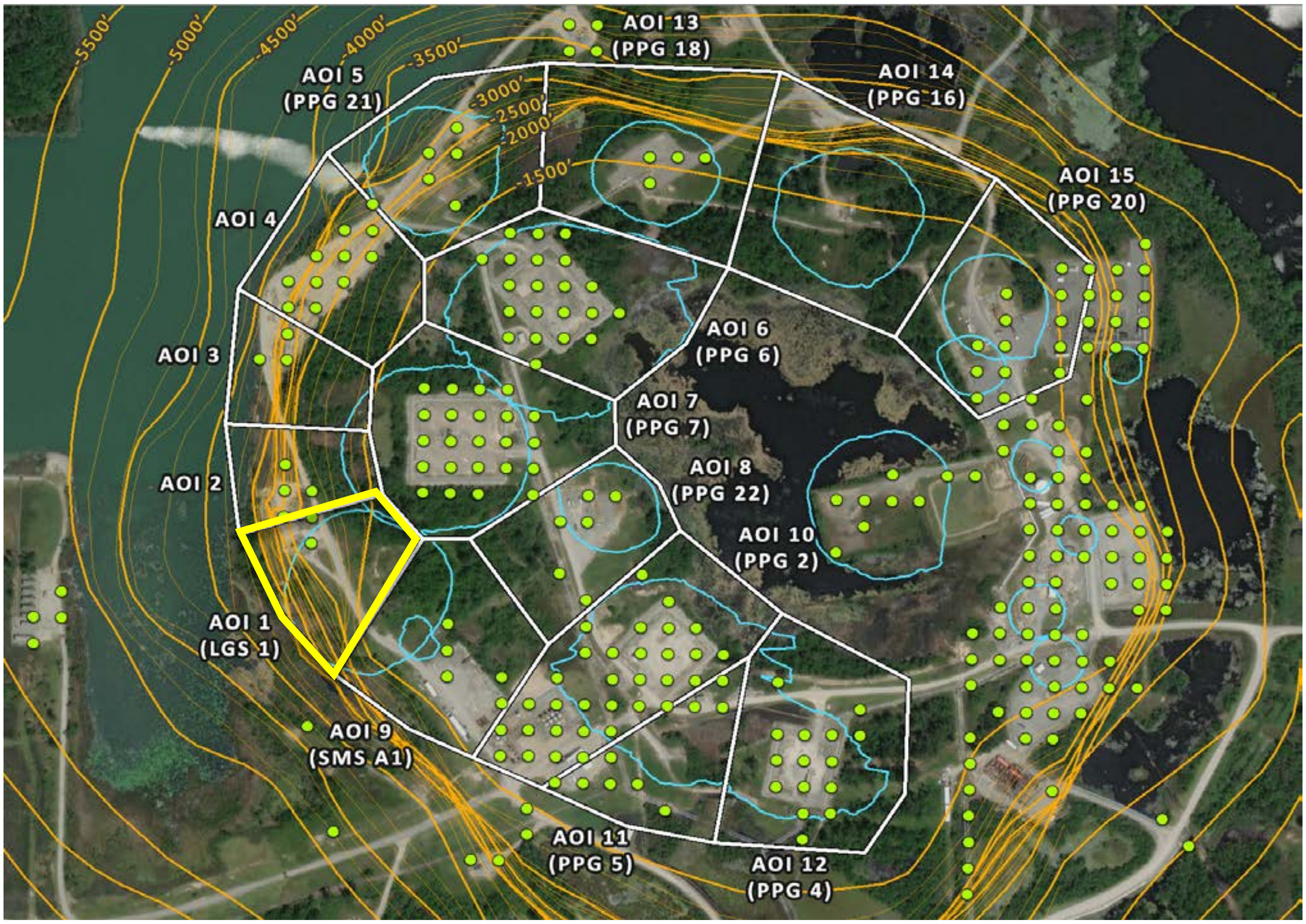


Subsidence Monitoring Areas of Interest (AOIs)

To visually convey and evaluate trend consistency for the Vertical displacement time series of each ground target, measurment 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.

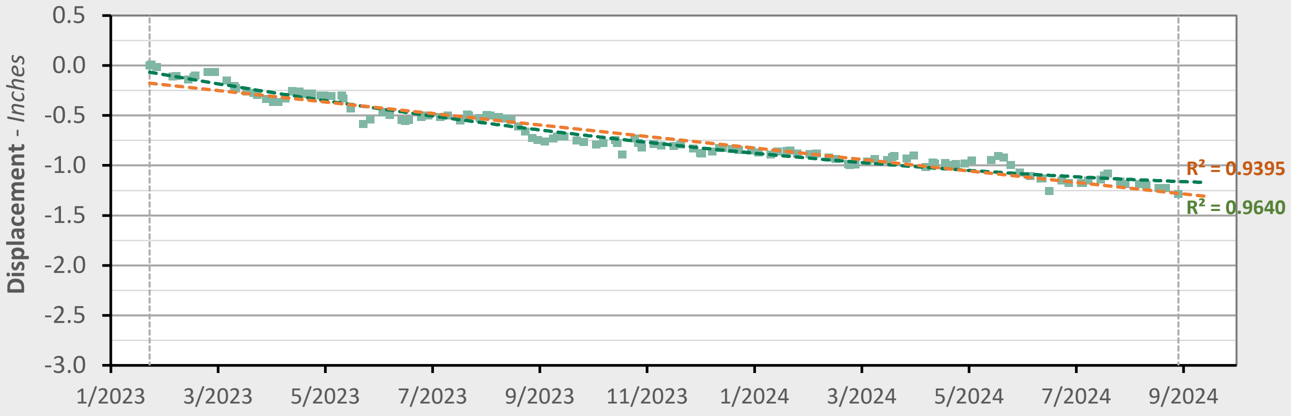
AOI Name	Vertical (8/29/2024)	Vertical Velocity (in/yr)		Vertical Acceleration (in/yr^2)	
	Point Count	Nonlinear	Linear	Nonlinear	Linear
AOI 1 *(LGS 1)*	2	-0.25	-0.69	+0.54	0.00
AOI 2	4	-0.52	-0.62	+0.12	0.00
AOI 3	3	-0.24	-0.62	+0.47	0.00
AOI 4	11	-0.25	-0.53	+0.35	0.00
AOI 5 *(PPG 21)*	5	-0.31	-0.55	+0.31	0.00
AOI 6 *(PPG 6)*	21	-0.77	-0.91	+0.16	0.00
AOI 7 *(PPG 7)*	23	-0.79	-0.96	+0.21	0.00
AOI 8 *(PPG 22)*	5	-0.94	-1.21	+0.33	0.00
AOI 9 *(SMS A1)*	5	-0.45	-0.96	+0.63	0.00
AOI 10 *(PPG 2)*	32	-0.91	-1.11	+0.25	0.00
AOI 11 *(PPG 5)*	9	-0.75	-0.95	+0.26	0.00
AOI 12 *(PPG 4)*	15	-0.78	-1.08	+0.37	0.00
AOI 13 *(PPG 18)*	4	-0.47	-0.71	+0.30	0.00
AOI 14 *(PPG 16)*	0	N/A	N/A	N/A	N/A
AOI 15 *(PPG 20)*	14	-0.64	-0.92	+0.35	0.00

AOI 1 *(LGS 1)* - Location Map



AOI 1 *(LGS 1)* - Vertical Time Series

Vertical (8/29/2024) Point Count: **2**



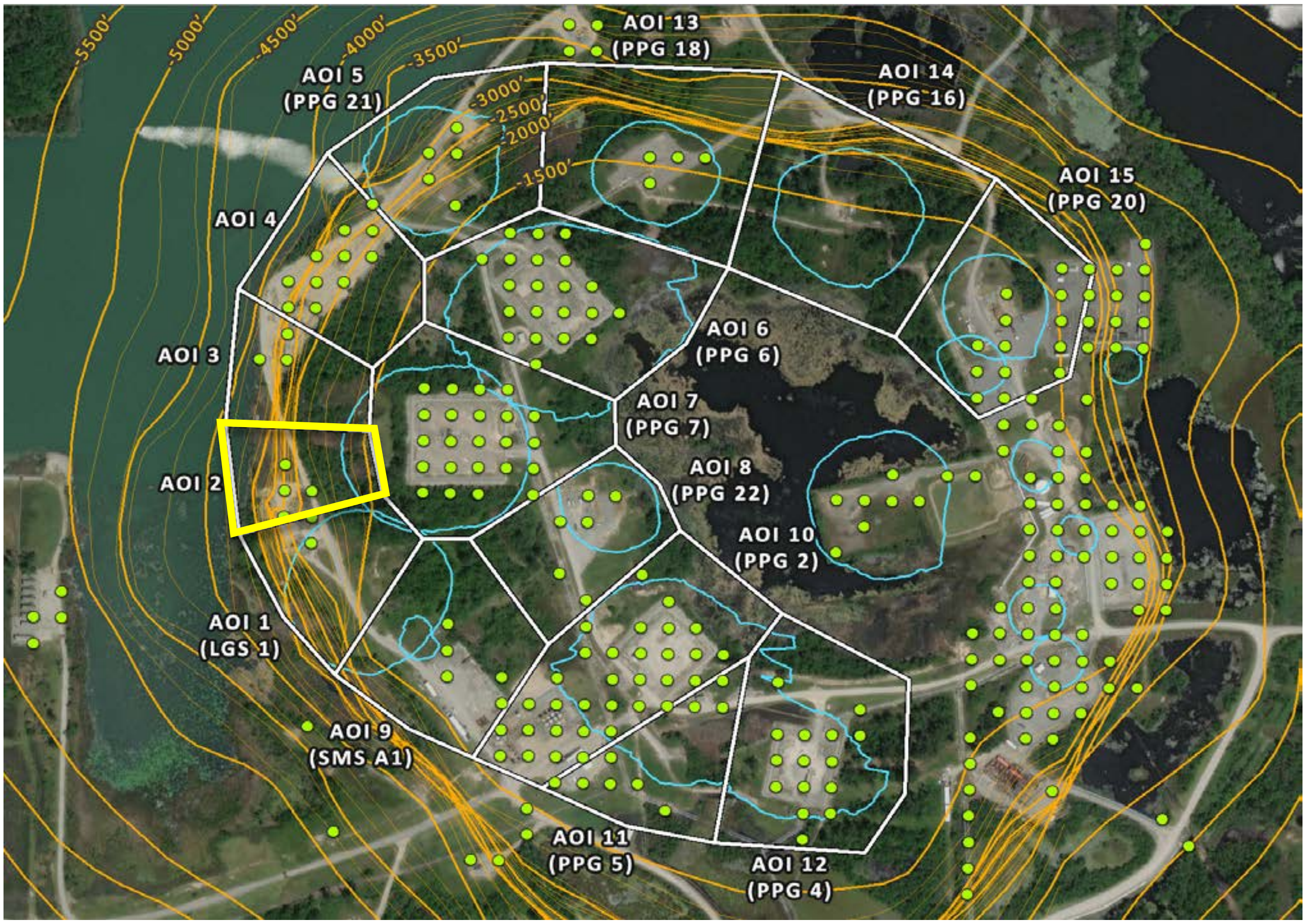
	Nonlinear Trend		Linear Trend	
Velocity:	-0.25	in/yr	-0.69	in/yr
Acceleration:	+0.54	in/yr²	0.00	in/yr²

■ 2D Displacement Measurement

- - - - Nonlinear Trend Line (Quadratic Regression)

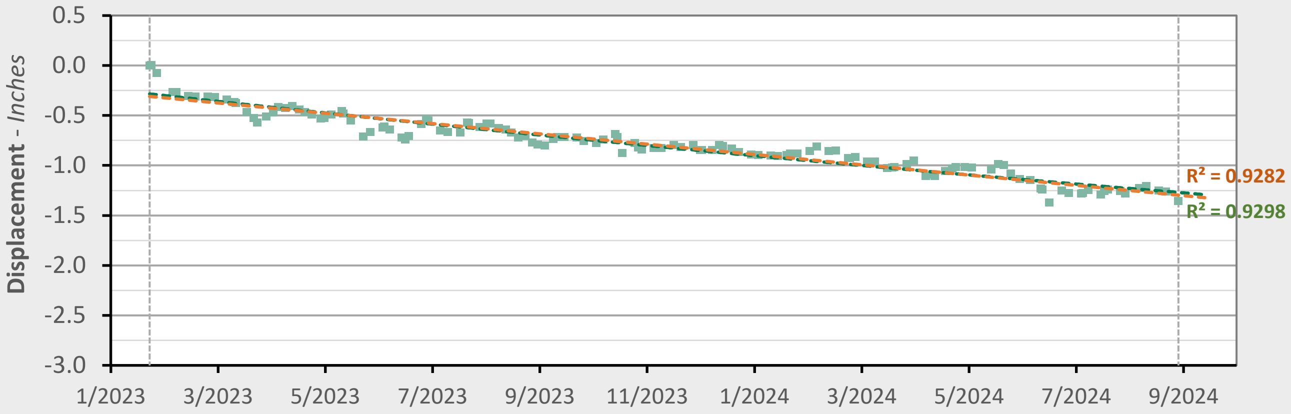
- - - - Linear Trend Line (Linear Regression)

AOI 2 - Location Map



AOI 2 - Vertical Time Series

Vertical (8/29/2024) Point Count: 4



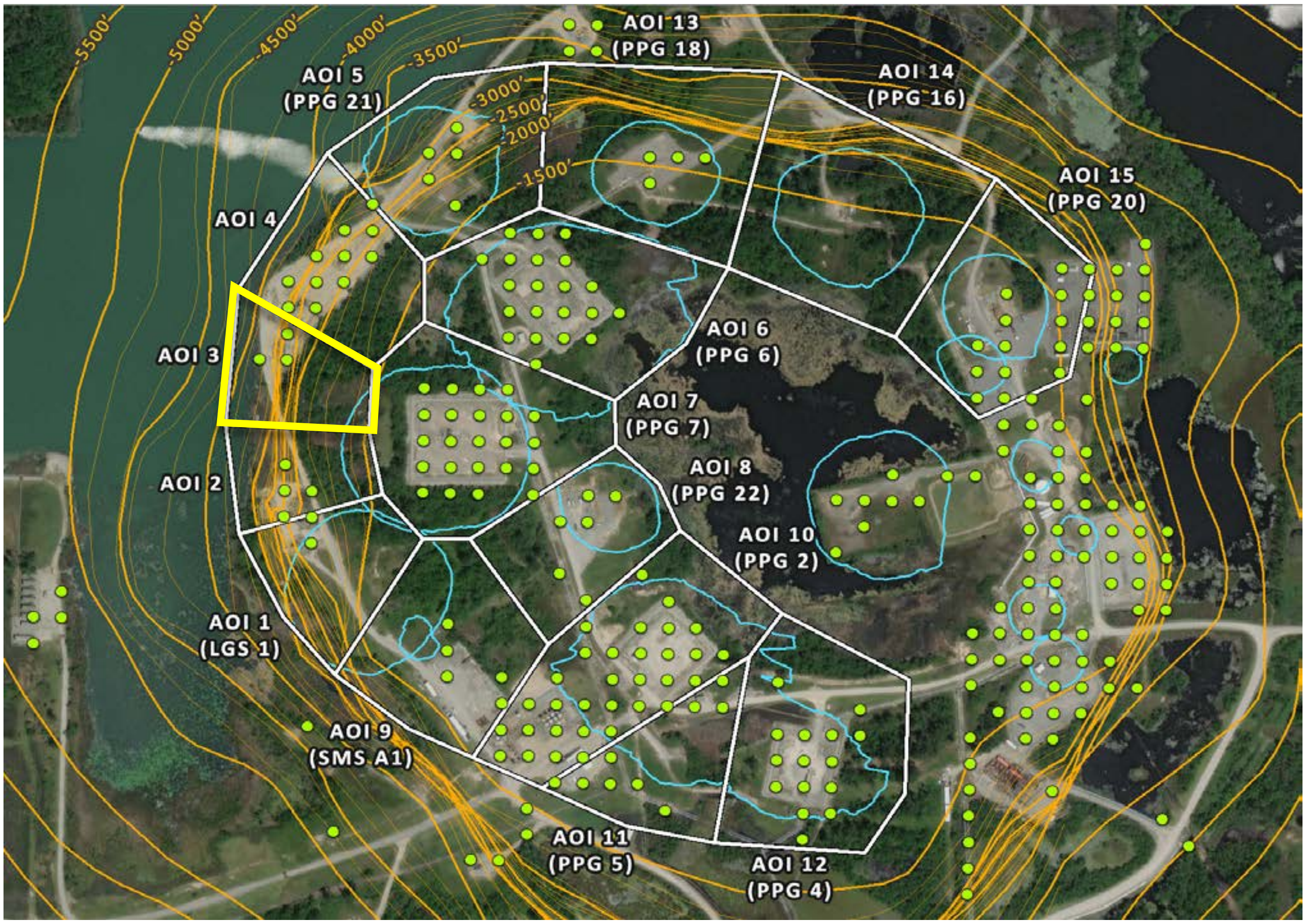
	Nonlinear Trend		Linear Trend	
Velocity:	-0.52	in/yr	-0.62	in/yr
Acceleration:	+0.12	in/yr^2	0.00	in/yr^2

■ 2D Displacement Measurement

---- Nonlinear Trend Line (Quadratic Regression)

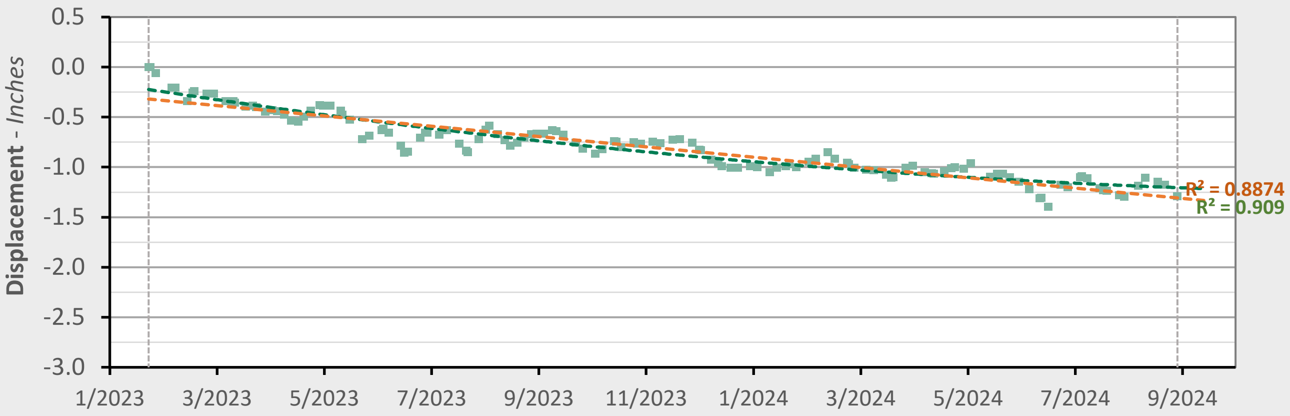
---- Linear Trend Line (Linear Regression)

AOI 3 - Location Map



AOI 3 - Vertical Time Series

Vertical (8/29/2024) Point Count: 3



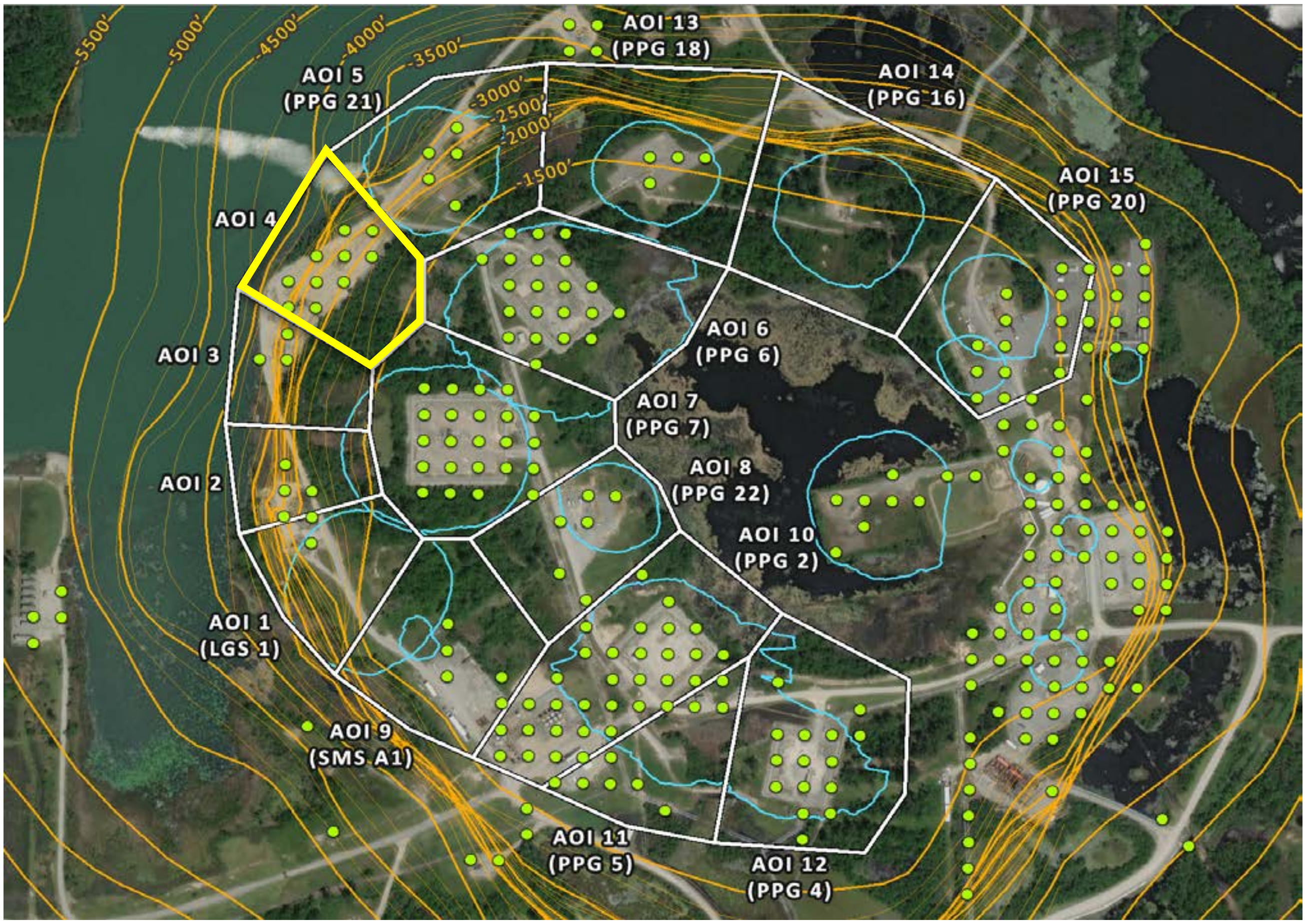
	Nonlinear Trend		Linear Trend	
Velocity:	-0.24	in/yr	-0.62	in/yr
Acceleration:	+0.47	in/yr^2	0.00	in/yr^2

■ 2D Displacement Measurement

--- Nonlinear Trend Line (Quadratic Regression)

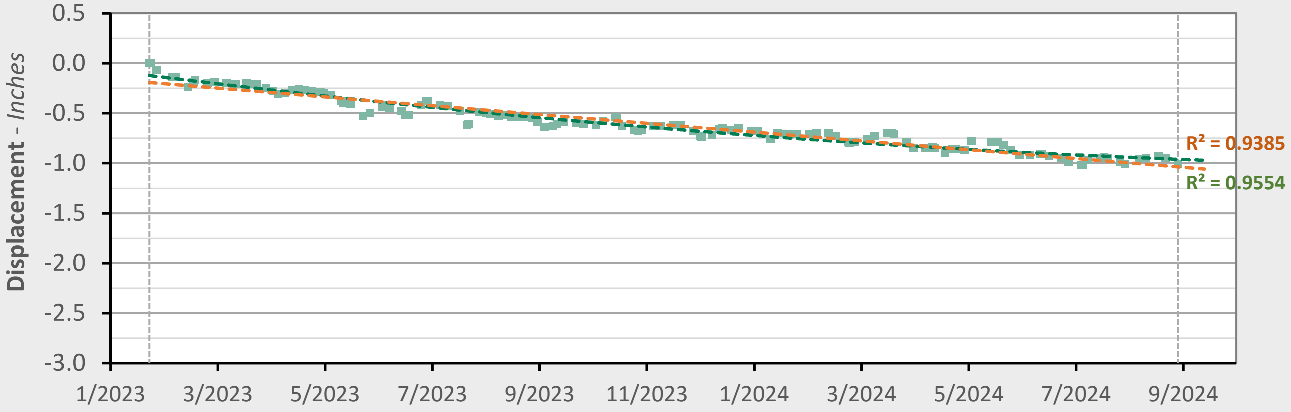
--- Linear Trend Line (Linear Regression)

AOI 4 - Location Map



AOI 4 - Vertical Time Series

Vertical (8/29/2024) Point Count: **11**



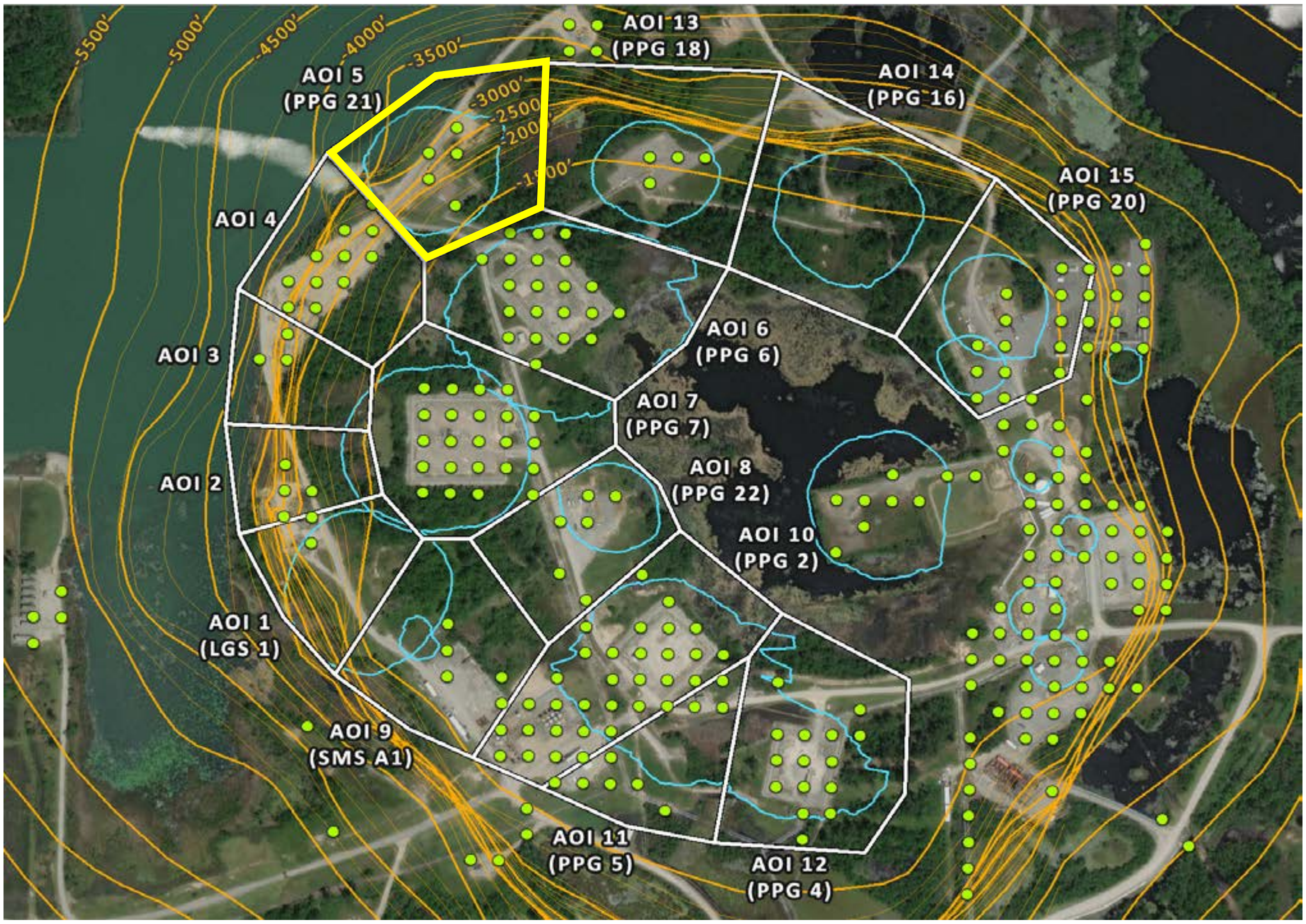
	Nonlinear Trend		Linear Trend	
Velocity:	-0.25	in/yr	-0.53	in/yr
Acceleration:	+0.35	in/yr^2	0.00	in/yr^2

■ 2D Displacement Measurement

- - - - Nonlinear Trend Line (Quadratic Regression)

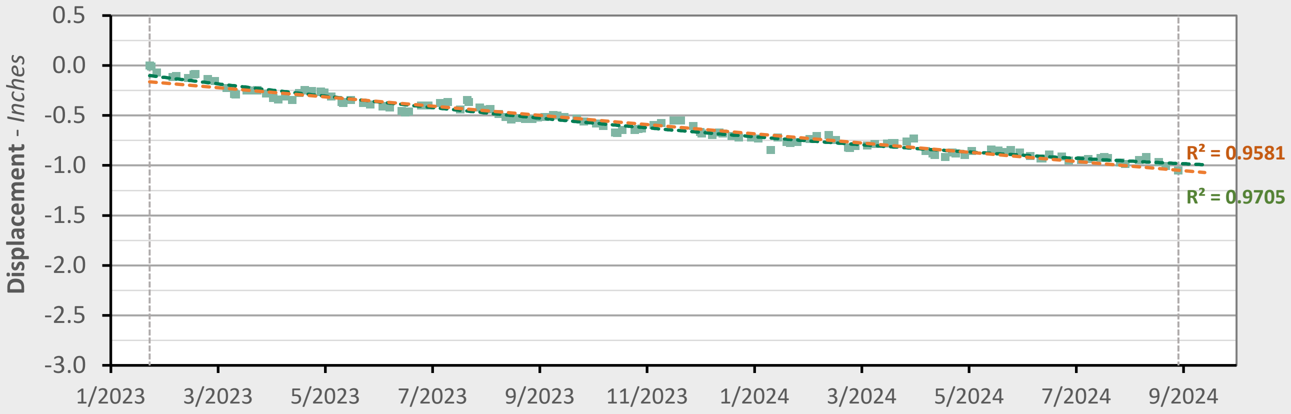
- - - - Linear Trend Line (Linear Regression)

AOI 5 *(PPG 21)* - Location Map



AOI 5 *(PPG 21)* - Vertical Time Series

Vertical (8/29/2024) Point Count: 5



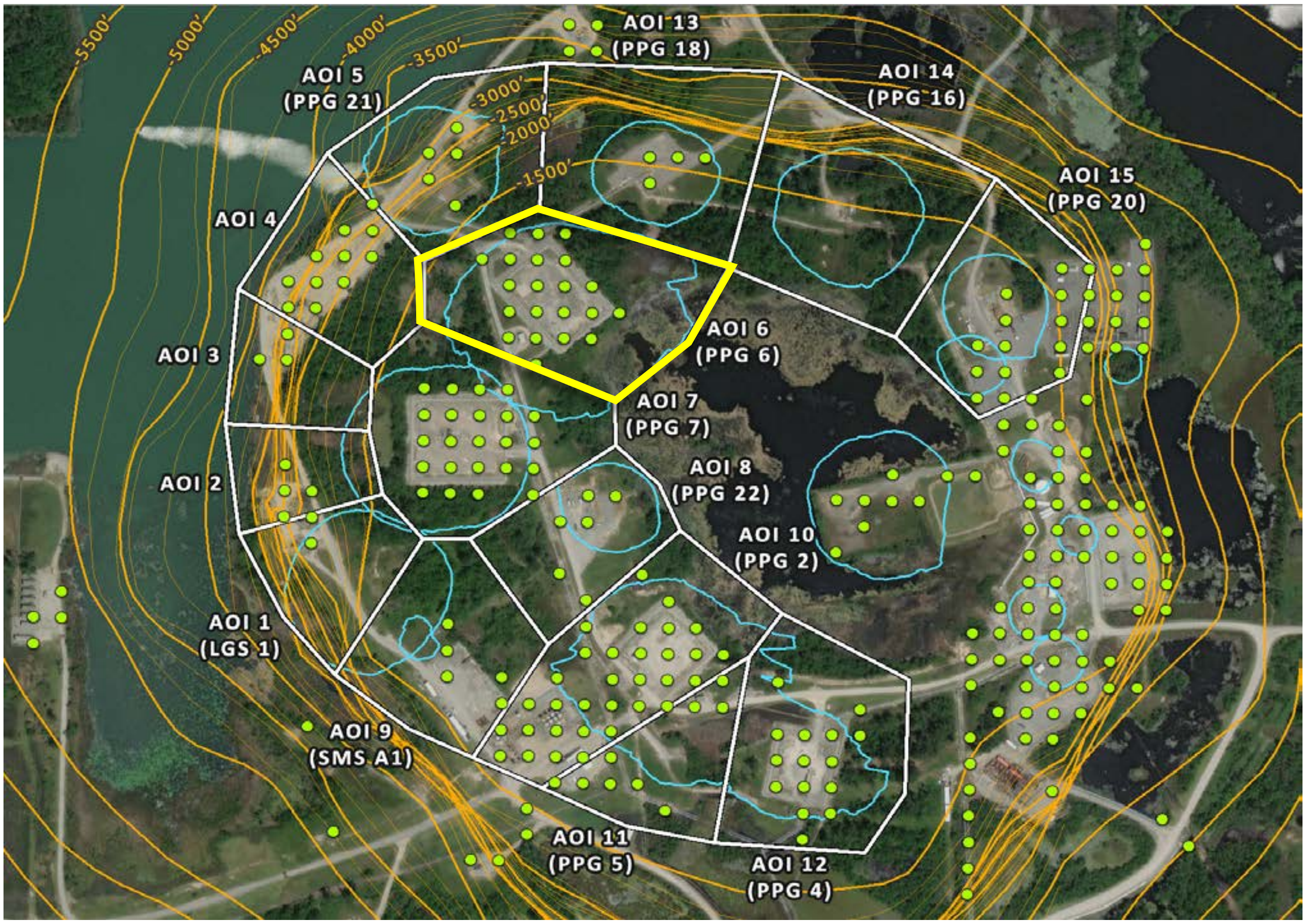
	Nonlinear Trend		Linear Trend	
Velocity:	-0.31	in/yr	-0.55	in/yr
Acceleration:	+0.31	in/yr^2	0.00	in/yr^2

■ 2D Displacement Measurement

---- Nonlinear Trend Line (Quadratic Regression)

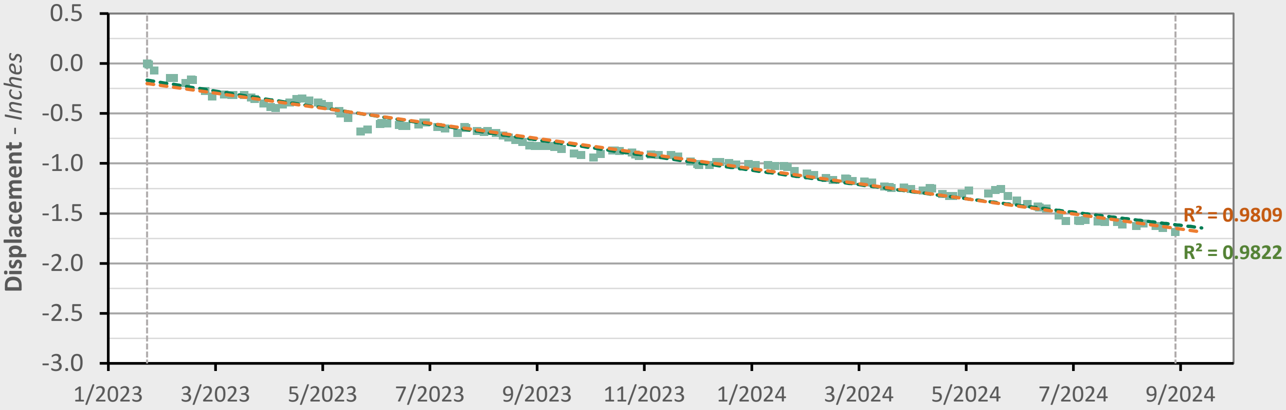
---- Linear Trend Line (Linear Regression)

AOI 6 *(PPG 6)* - Location Map



AOI 6 *(PPG 6)* - Vertical Time Series

Vertical (8/29/2024) Point Count: **21**



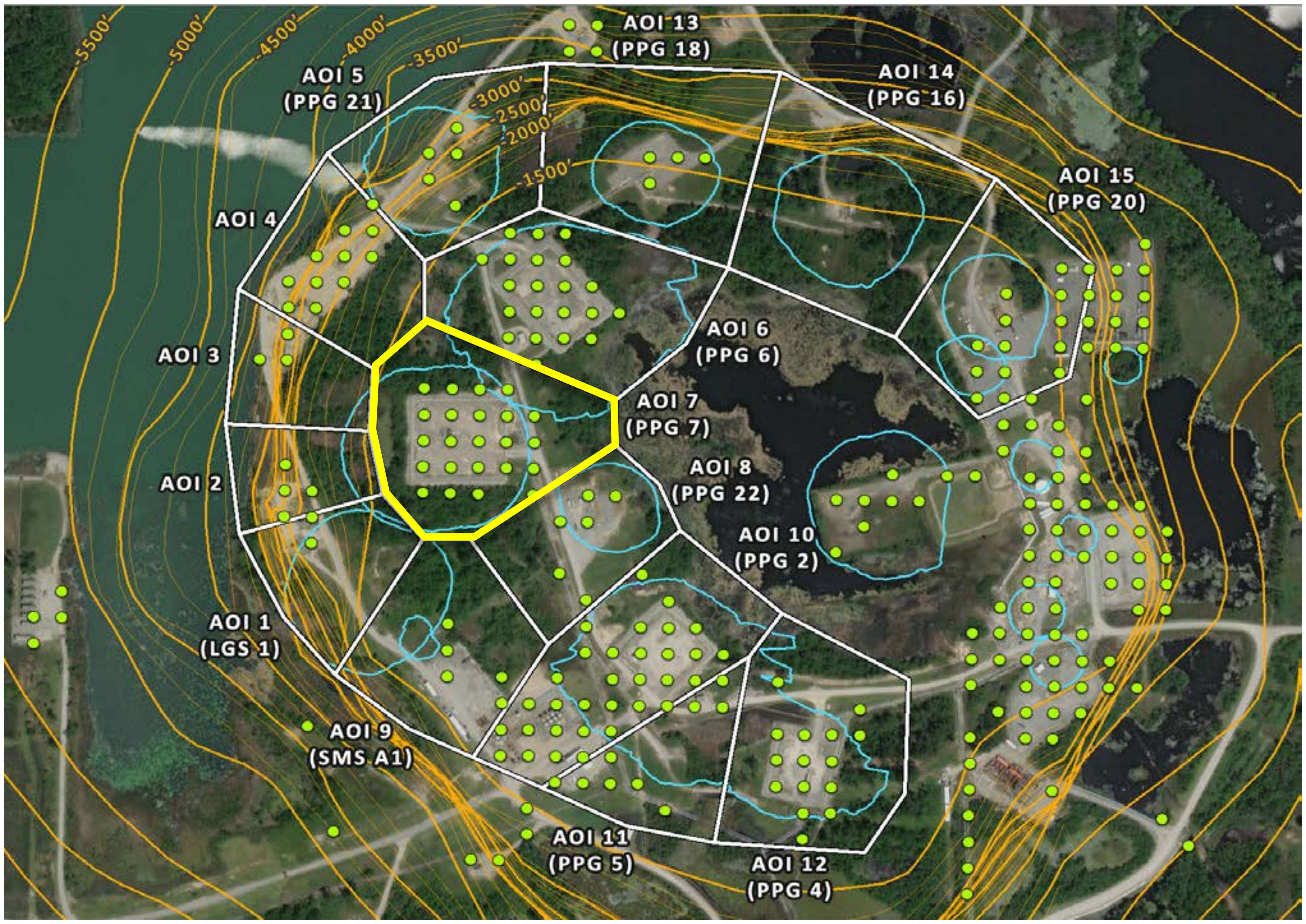
	Nonlinear Trend		Linear Trend	
Velocity:	-0.77	in/yr	-0.91	in/yr
Acceleration:	+0.16	in/yr^2	0.00	in/yr^2

🟩 2D Displacement Measurement

---- Nonlinear Trend Line (Quadratic Regression)

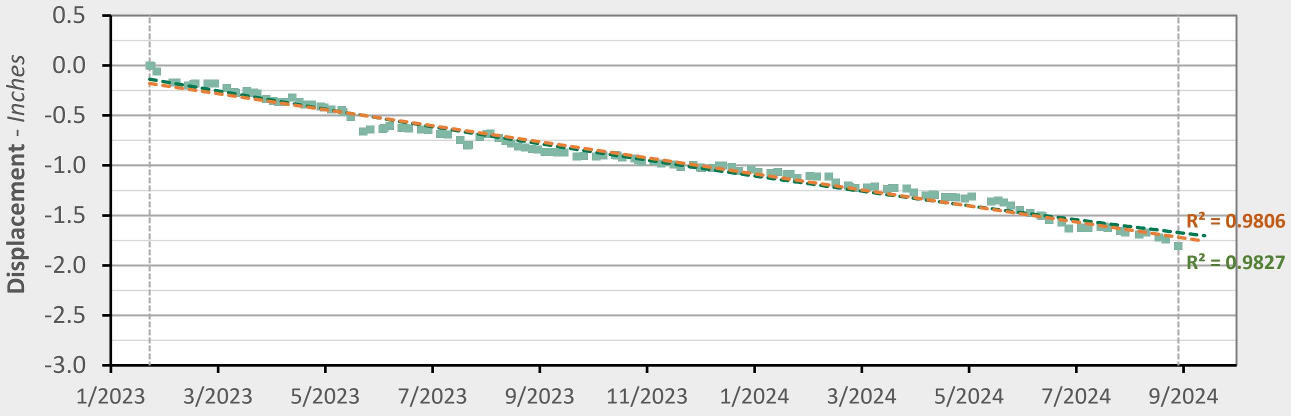
---- Linear Trend Line (Linear Regression)

AOI 7 *(PPG 7)* - Location Map



AOI 7 *(PPG 7)* - Vertical Time Series

Vertical (8/29/2024) Point Count: **23**



	Nonlinear Trend	Linear Trend
Velocity:	-0.79 in/yr	-0.96 in/yr
Acceleration:	+0.21 in/yr^2	0.00 in/yr^2

🟩 2D Displacement Measurement

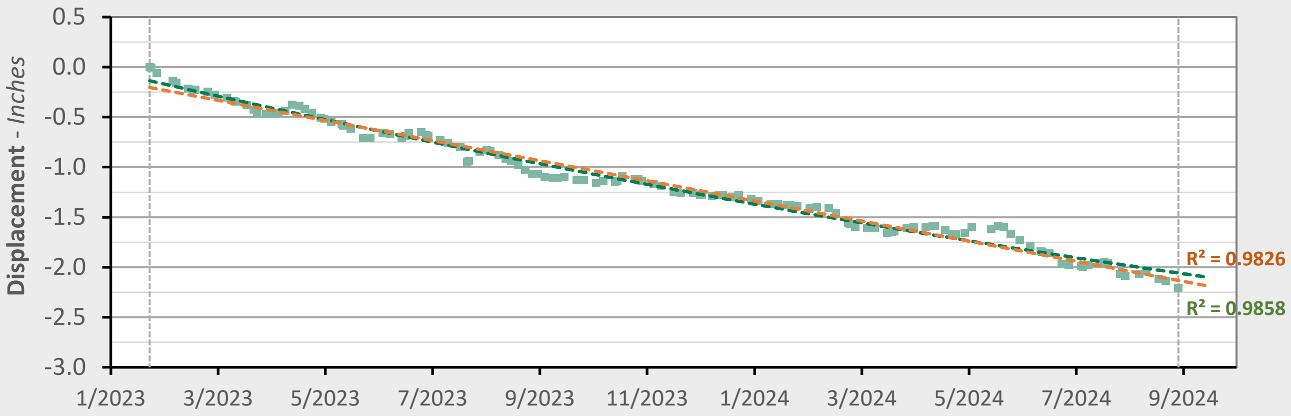
\- - - - Nonlinear Trend Line (Quadratic Regression)

\- - - - Linear Trend Line (Linear Regression)

AOI 8 *(PPG 22)* - Location Map

AOI 8 *(PPG 22)* - Vertical Time Series

Vertical (8/29/2024) Point Count: 5



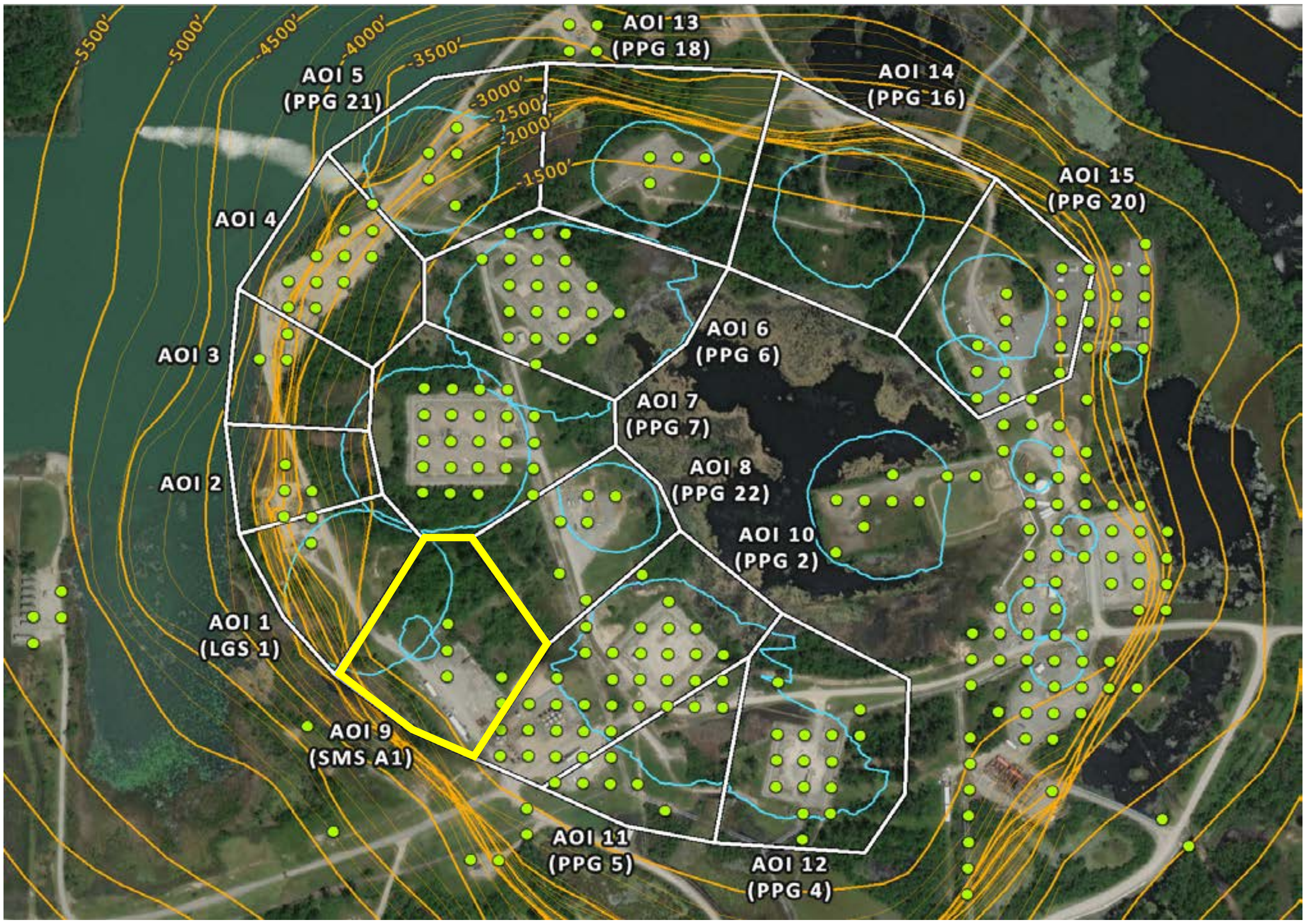
	Nonlinear Trend		Linear Trend	
Velocity:	-0.94	in/yr	-1.21	in/yr
Acceleration:	+0.33	in/yr^2	0.00	in/yr^2

🟩 2D Displacement Measurement

---- Nonlinear Trend Line (Quadratic Regression)

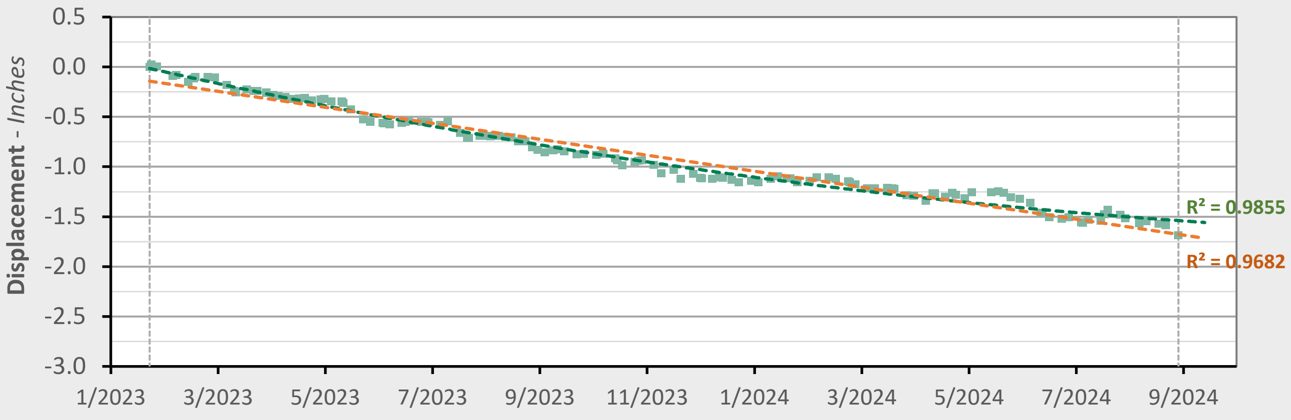
---- Linear Trend Line (Linear Regression)

AOI 9 *(PPG A1)* - Location Map



AOI 9 *(SMS A1)* - Vertical Time Series

Vertical (8/29/2024) Point Count: 5



	Nonlinear Trend		Linear Trend	
Velocity:	-0.45	in/yr	-0.96	in/yr
Acceleration:	+0.63	in/yr^2	0.00	in/yr^2

🟩 2D Displacement Measurement

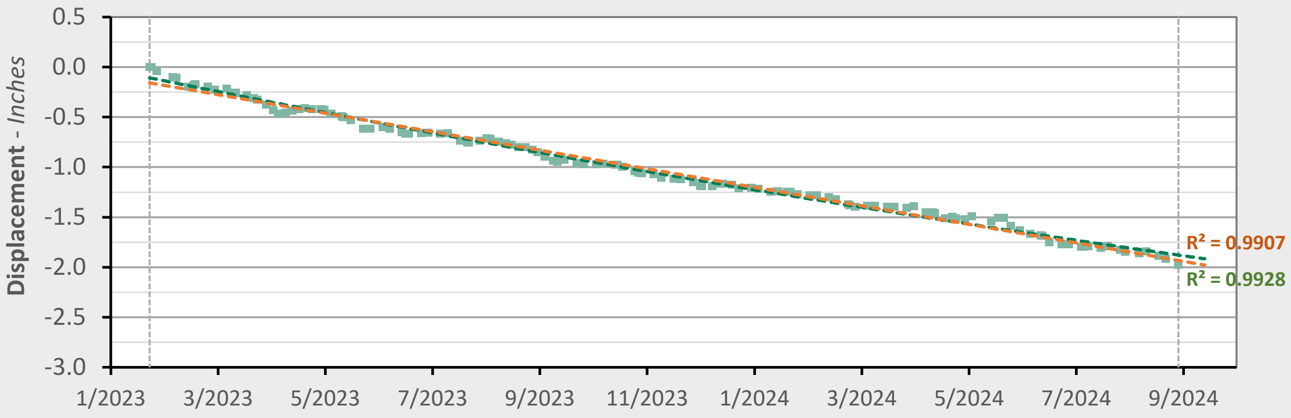
- - - - Nonlinear Trend Line (Quadratic Regression)

- - - - Linear Trend Line (Linear Regression)

AOI 10 *(PPG 2)* - Location Map

AOI 10 *(PPG 2)* - Vertical Time Series

Vertical (8/29/2024) Point Count: 32



	Nonlinear Trend		Linear Trend	
Velocity:	-0.91	in/yr	-1.11	in/yr
Acceleration:	+0.25	in/yr^2	0.00	in/yr^2

▪ 2D Displacement Measurement

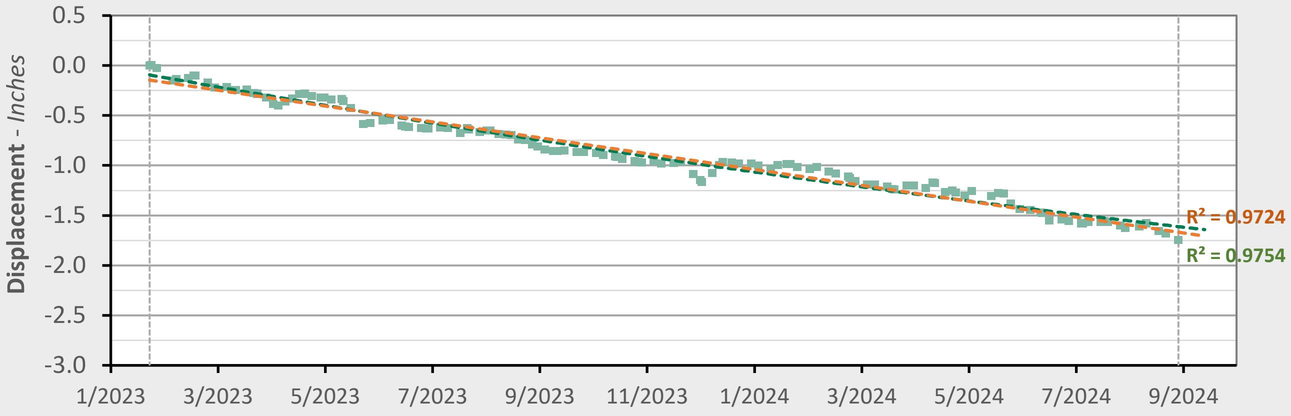
- - - - Nonlinear Trend Line (Quadratic Regression)

- - - - Linear Trend Line (Linear Regression)

AOI 11 *(PPG 5)* - Location Map

AOI 11 *(PPG 5)* - Vertical Time Series

Vertical (8/29/2024) Point Count: 9



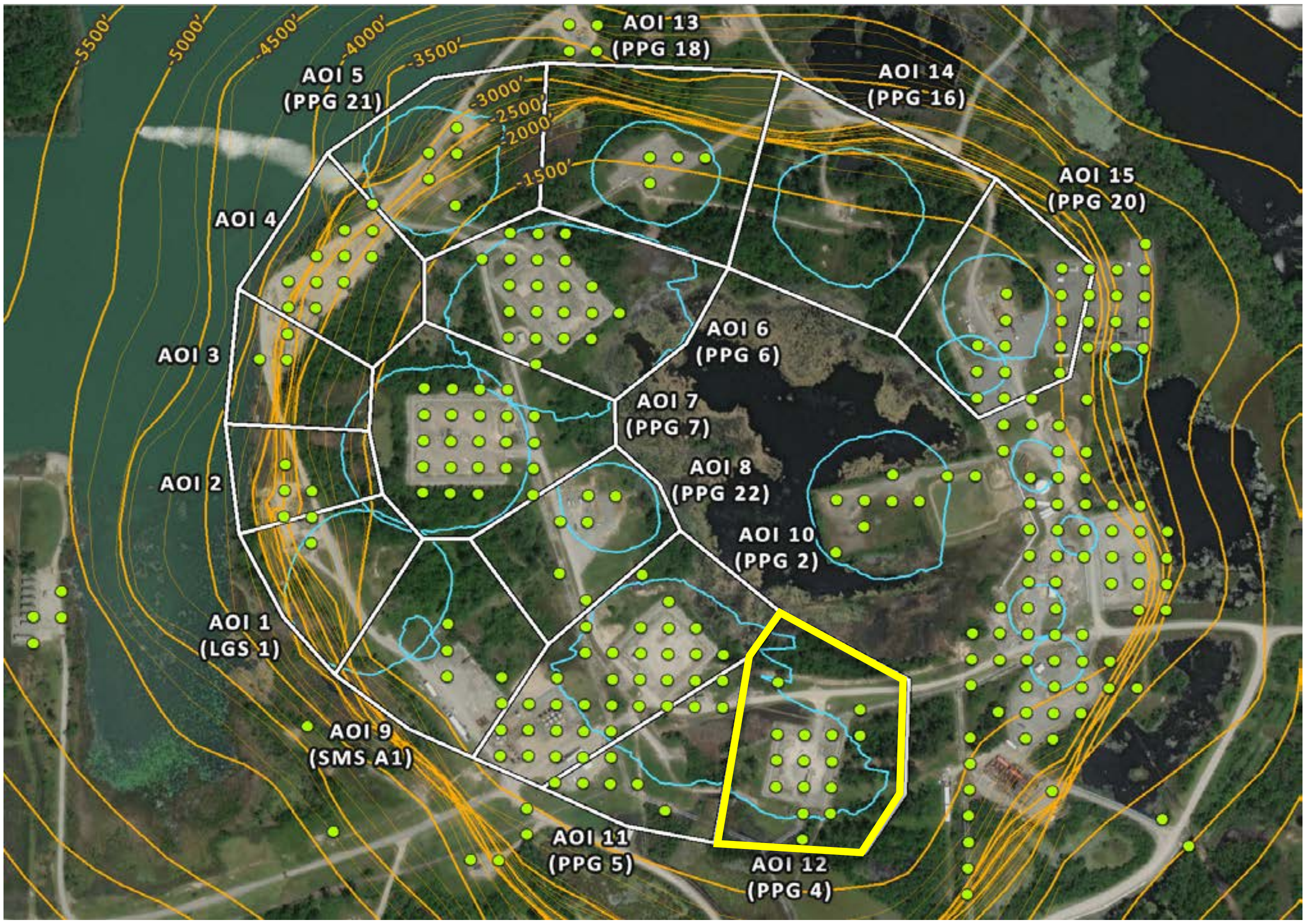
	Nonlinear Trend		Linear Trend	
Velocity:	-0.75	in/yr	-0.95	in/yr
Acceleration:	+0.26	in/yr^2	0.00	in/yr^2

🟩 2D Displacement Measurement

--- Nonlinear Trend Line (Quadratic Regression)

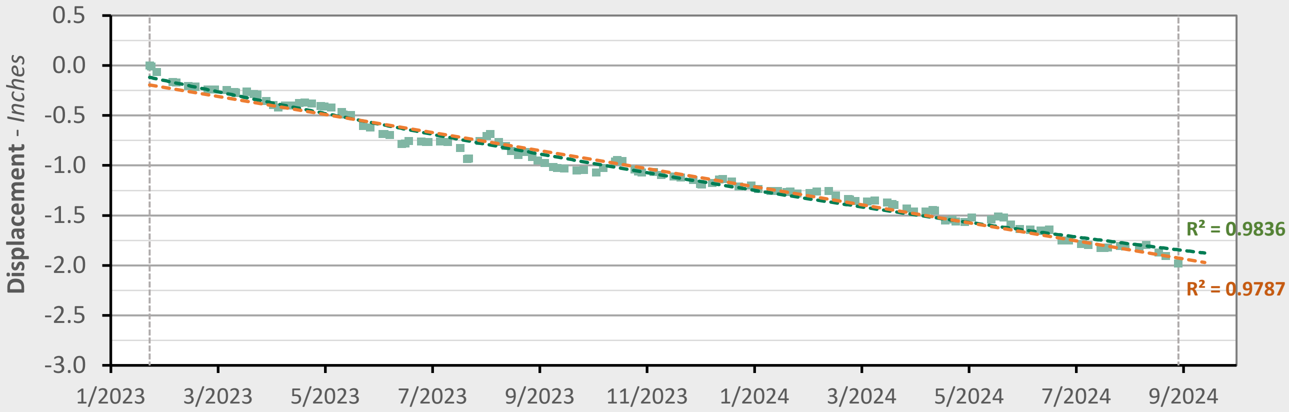
--- Linear Trend Line (Linear Regression)

AOI 12 *(PPG 4)* - Location Map



AOI 12 *(PPG 4)* - Vertical Time Series

Vertical (8/29/2024) Point Count: **15**



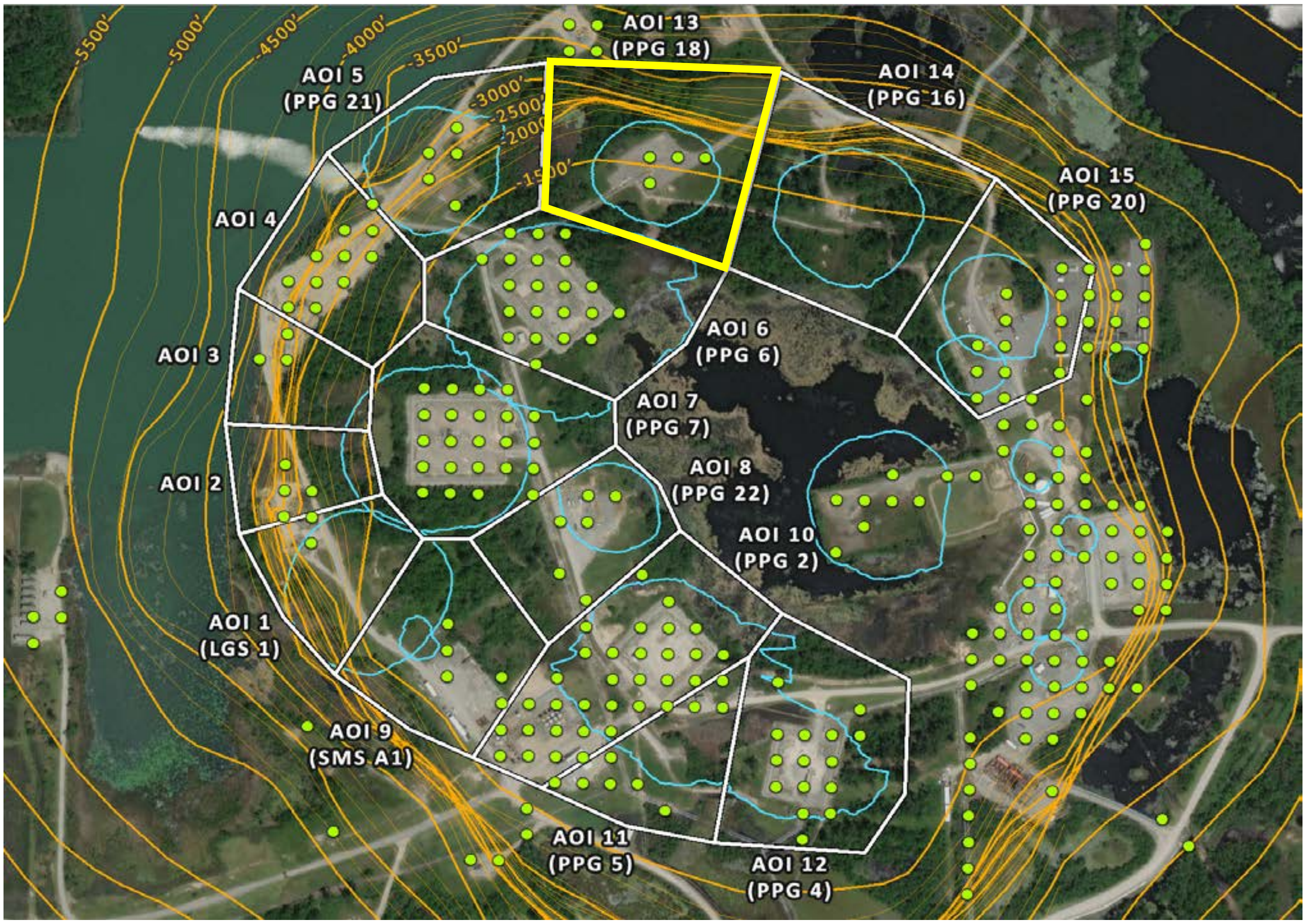
	Nonlinear Trend		Linear Trend	
Velocity:	-0.78	in/yr	-1.08	in/yr
Acceleration:	+0.37	in/yr^2	0.00	in/yr^2

■ 2D Displacement Measurement

- - - - Nonlinear Trend Line (Quadratic Regression)

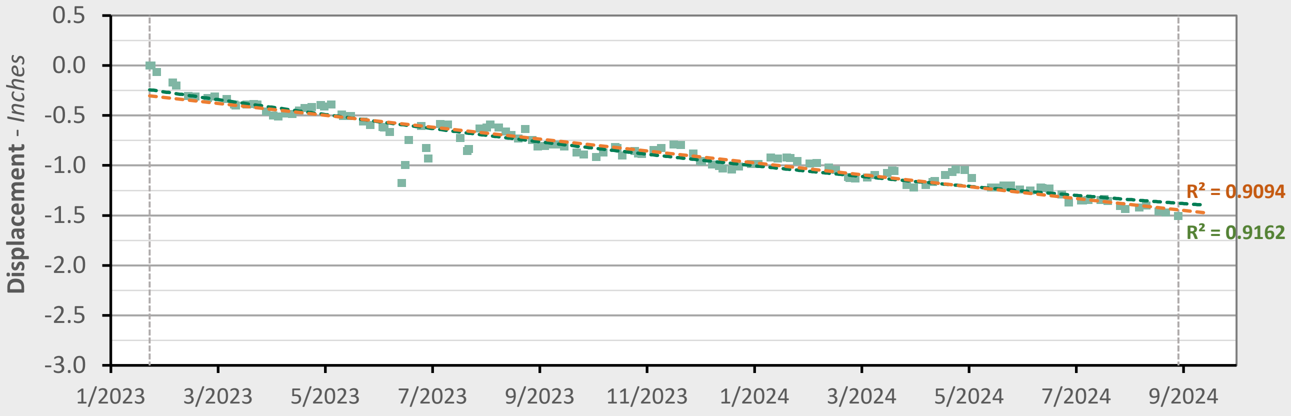
- - - - Linear Trend Line (Linear Regression)

AOI 13 *(PPG 18)* - Location Map



AOI 13 *(PPG 18)* - Vertical Time Series

Vertical (8/29/2024) Point Count: **4**



	Nonlinear Trend		Linear Trend	
Velocity:	-0.47	in/yr	-0.71	in/yr
Acceleration:	+0.30	in/yr^2	0.00	in/yr^2

■ 2D Displacement Measurement

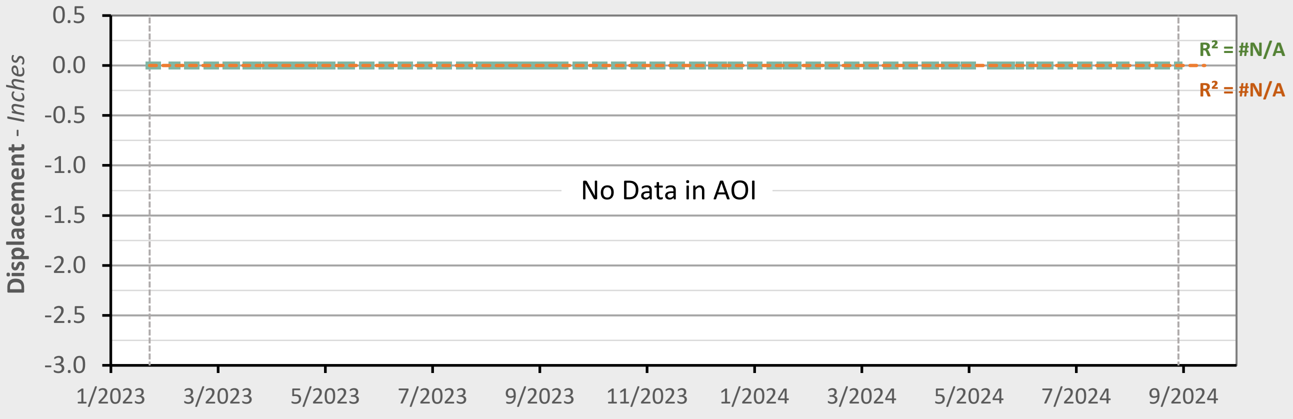
- - - - Nonlinear Trend Line (Quadratic Regression)

- - - - Linear Trend Line (Linear Regression)

AOI 14 *(PPG 16)* - Location Map

AOI 14 *(PPG 16)* - Vertical Time Series

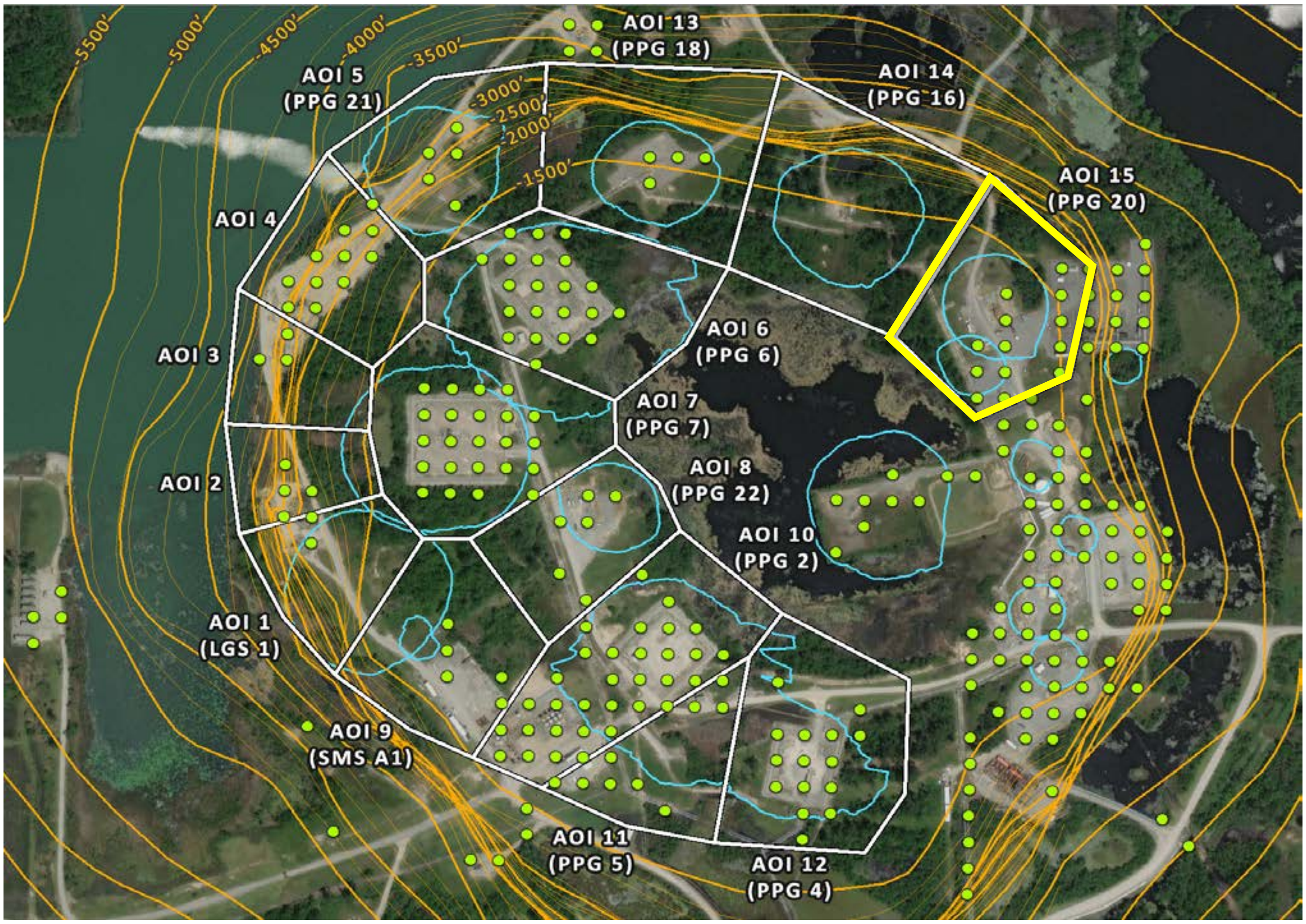
Vertical (8/29/2024) Point Count: 0



	Nonlinear Trend		Linear Trend	
Velocity:	N/A	in/yr	N/A	in/yr
Acceleration:	N/A	in/yr^2	N/A	in/yr^2

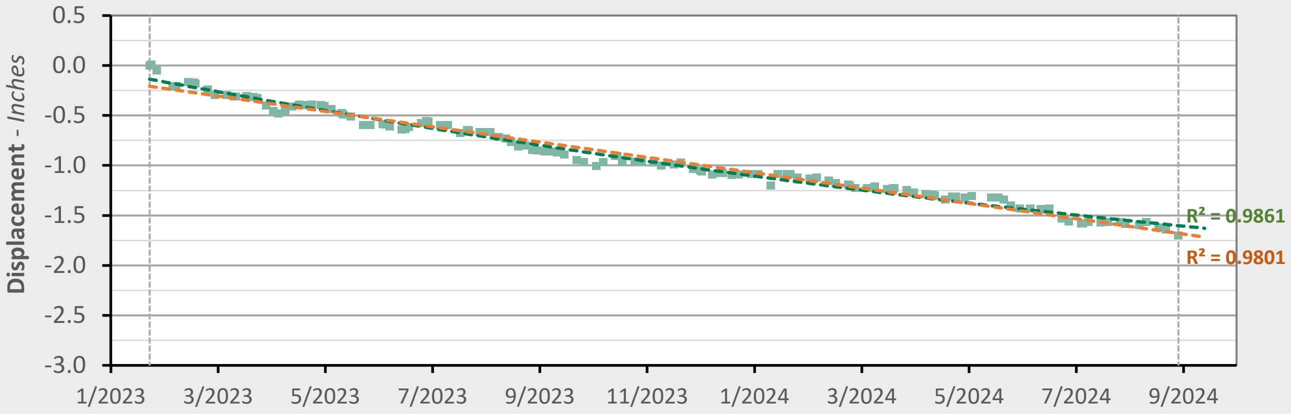
🟩 2D Displacement Measurement ---- Nonlinear Trend Line (Quadratic Regression) ---- Linear Trend Line (Linear Regression)

AOI 15 *(PPG 20)* - Location Map



AOI 15 *(PPG 20)* - Vertical Time Series

Vertical (8/29/2024) Point Count: **14**



	Nonlinear Trend		Linear Trend	
Velocity:	-0.64	in/yr	-0.92	in/yr
Acceleration:	+0.35	in/yr^2	0.00	in/yr^2

■ 2D Displacement Measurement

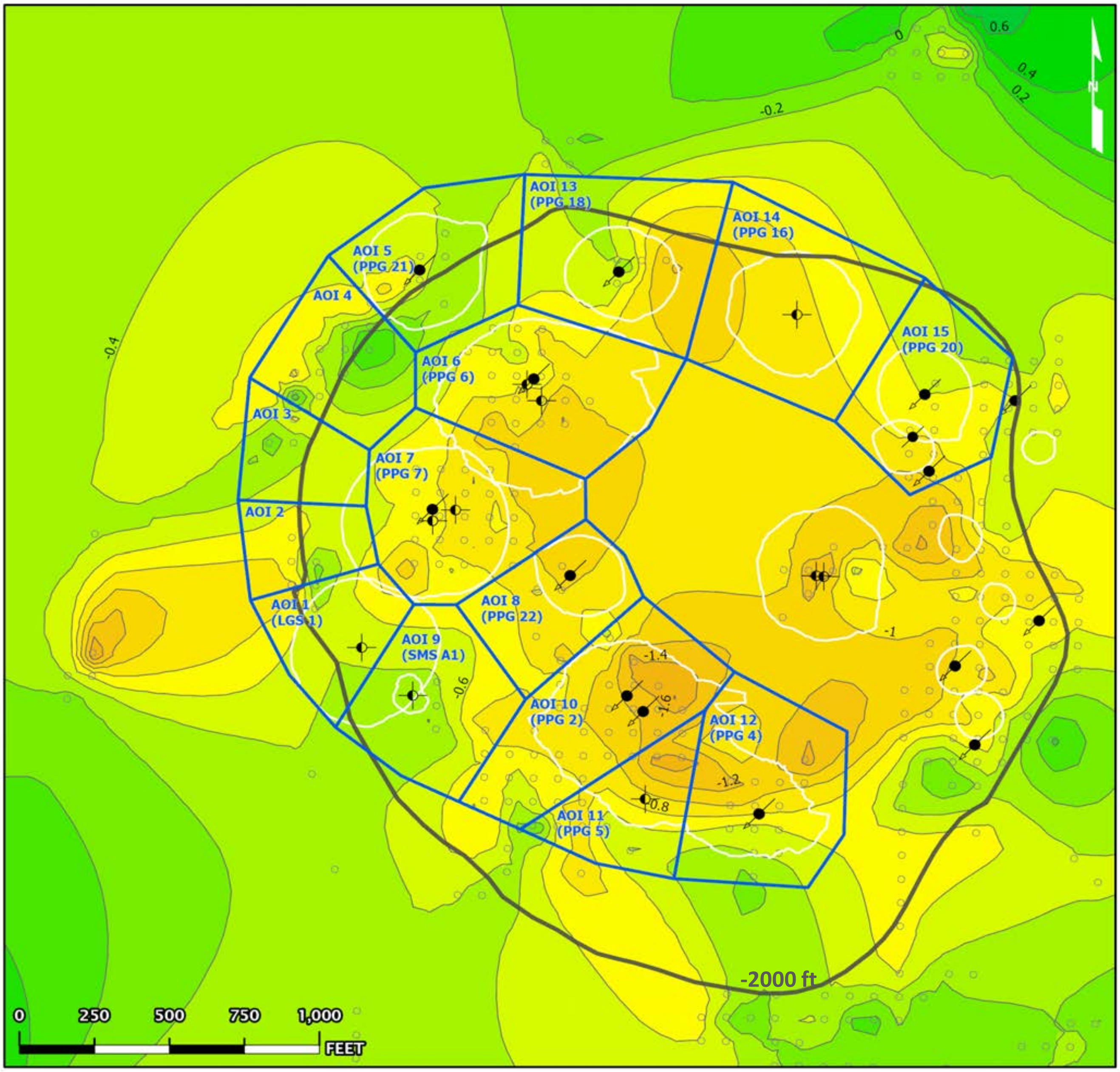
- - - - Nonlinear Trend Line (Quadratic Regression)

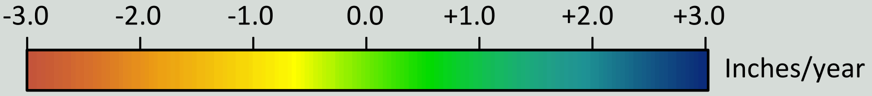
- - - - Linear Trend Line (Linear Regression)

Vertical Data (01/24/2023 - 08/29/2024)

Nonlinear Velocity Contours

As of date: 08/29/2024





▭ AOI Boundary ○ InSAR LOS Measurement Point — Contour (0.2)

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

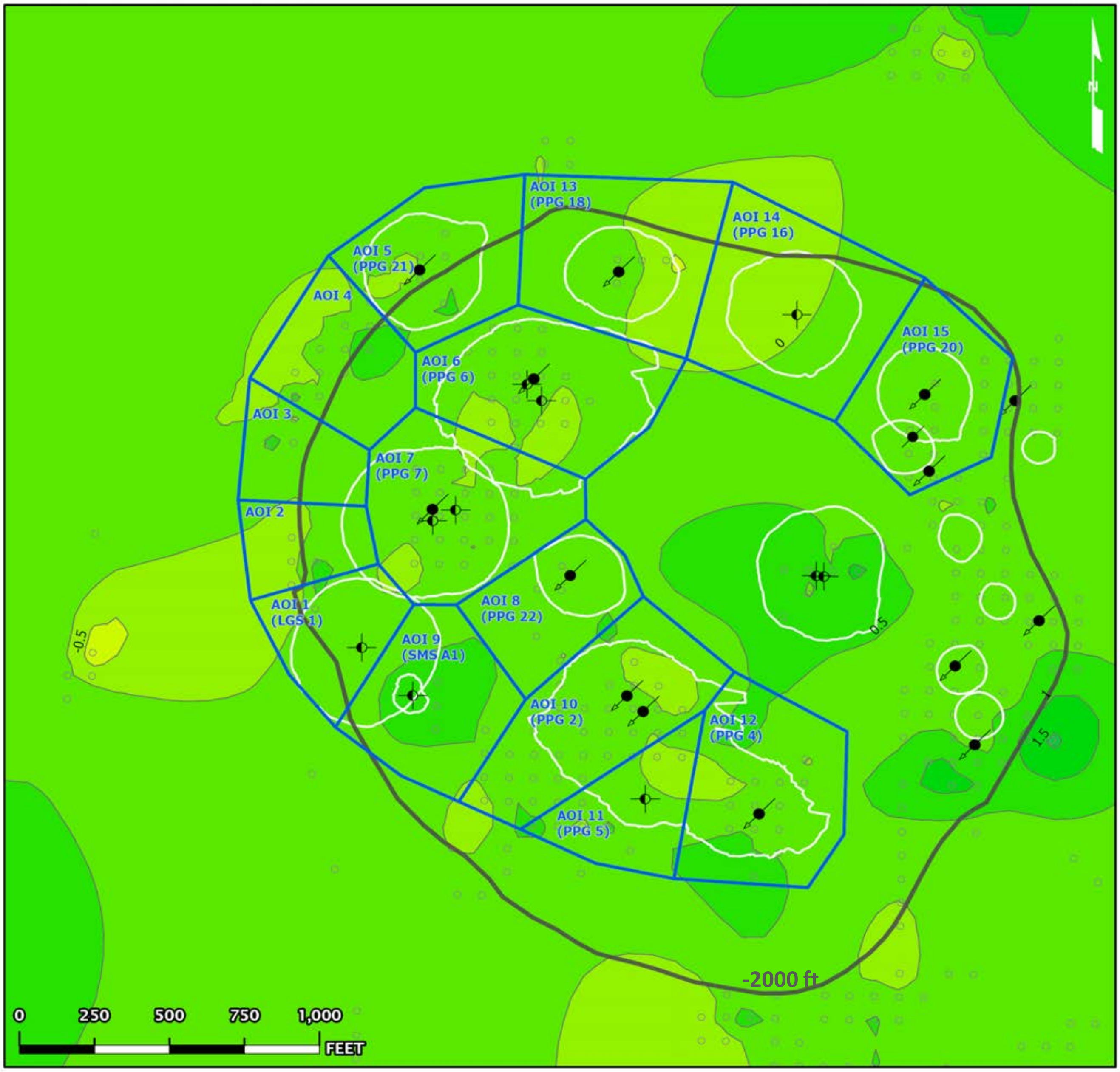
Cavern Well Surface Locations

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

Vertical Data (01/24/2023 - 08/29/2024)

Nonlinear Acceleration Contours

Date range: 01/24/2023 - 08/29/2024



-6.0 -4.0 -2.0 0.0 +2.0 +4.0 +6.0

Inches/year^2

▭ AOI Boundary ○ InSAR LOS Measurement Point — Contour (0.5)

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

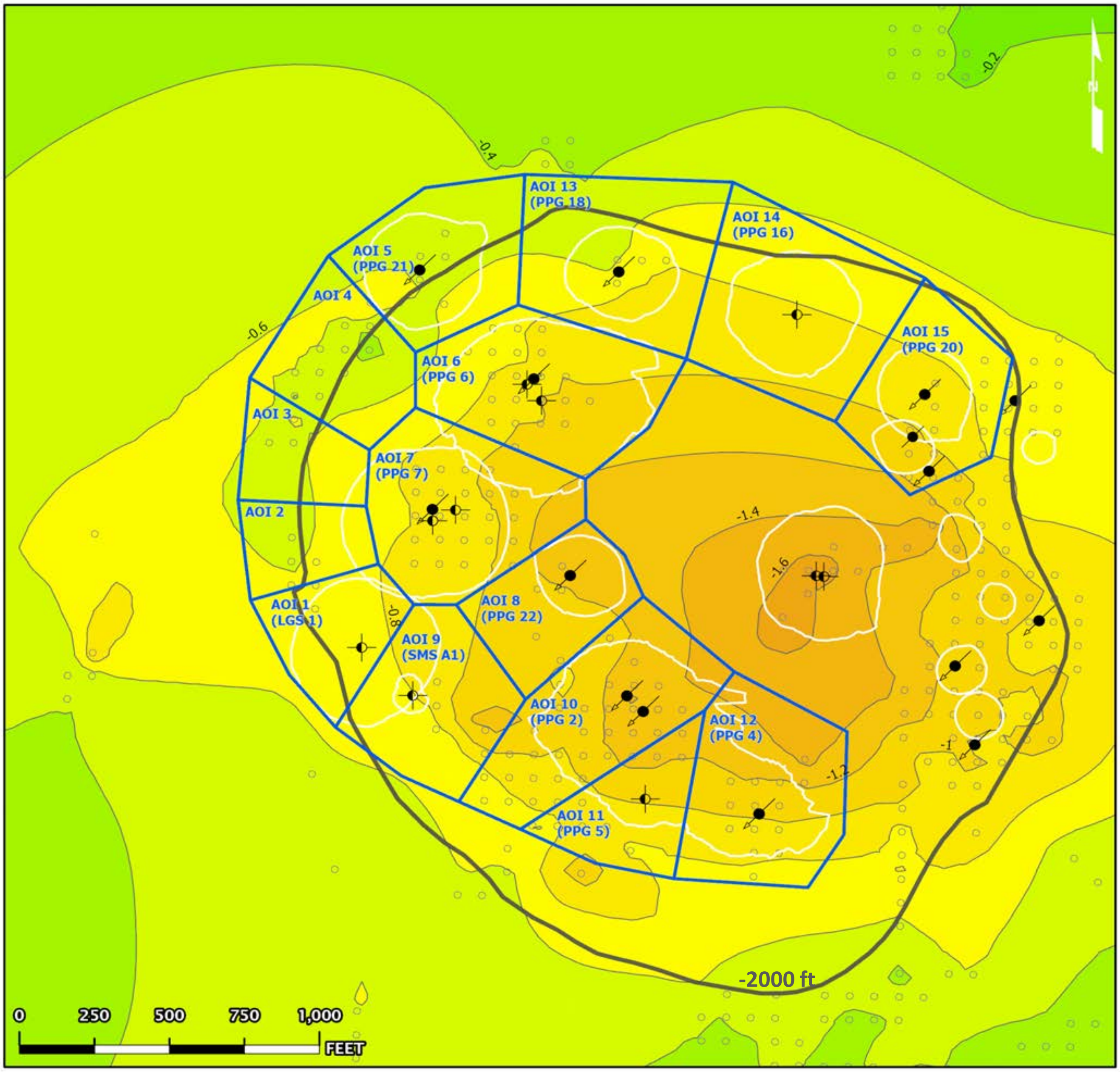
<u>Cavern Well Surface Locations</u>

09 - Active - Injection 29 - Dry and Plugged

Vertical Data (01/24/2023 - 08/29/2024)

Linear Velocity Contours

Date range: 01/24/2023 - 08/29/2024



-3.0 -2.0 -1.0 0.0 +1.0 +2.0 +3.0

Inches/year

▭ AOI Boundary ○ InSAR LOS Measurement Point — Contour (0.2)

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

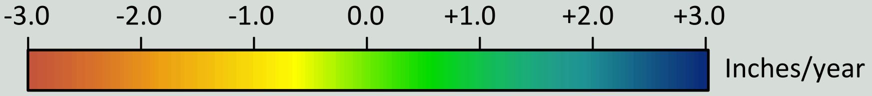
Cavern Well Surface Locations

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

Vertical Data (01/24/2023 - 08/29/2024)

Nonlinear Velocity Data Points

As of date: 08/29/2024



▭ AOI Boundary ○ InSAR LOS Measurement Point

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

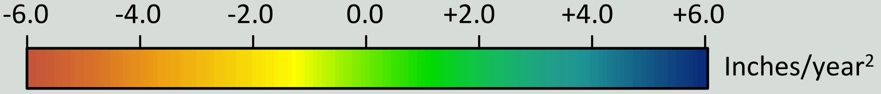
Cavern Well Surface Locations

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

Vertical Data (01/24/2023 - 08/29/2024)

Nonlinear Acceleration Data Points

Date range: 01/24/2023 - 08/29/2024



▭ 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

Vertical Data (01/24/2023 - 08/29/2024)

Linear Velocity Data Points

Date range: 01/24/2023 - 08/29/2024

-3.0 -2.0 -1.0 0.0 +1.0 +2.0 +3.0

Inches/year

AOI Boundary

○ InSAR LOS Measurement Point

Historical Cavern Extent

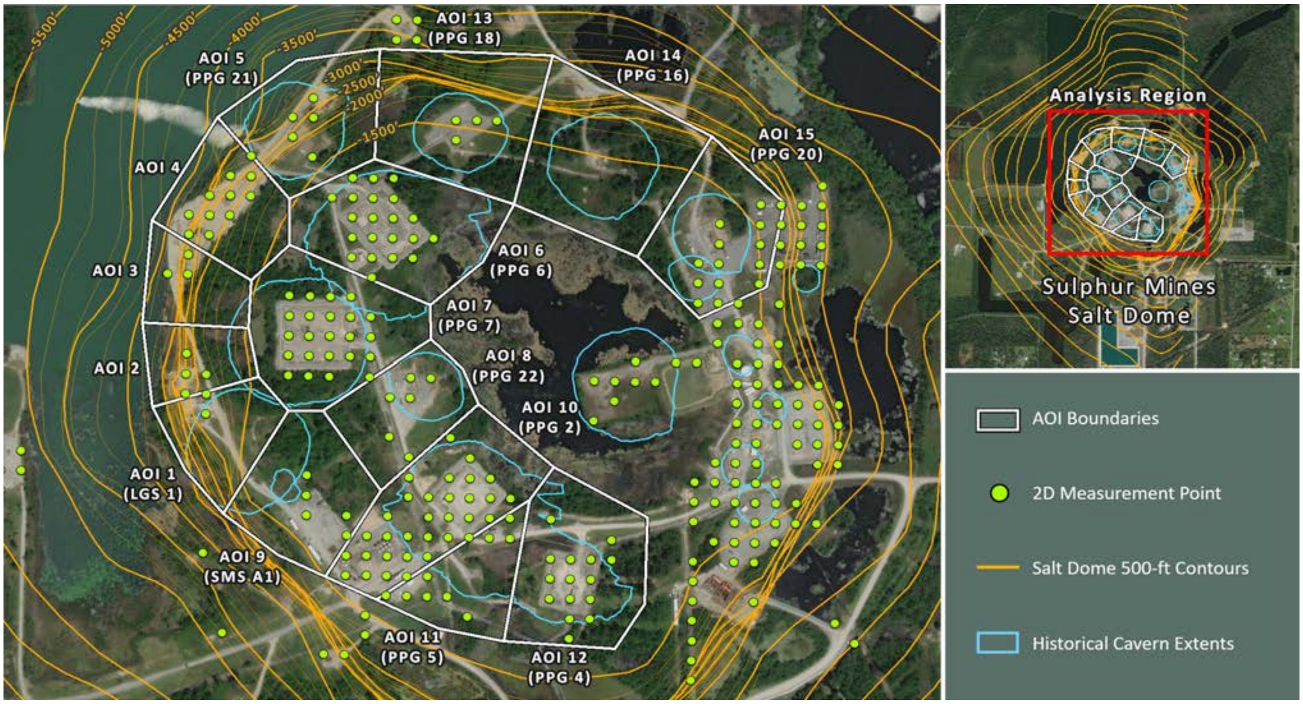
Top of Dome (-2000 ft Contour)

Cavern Well Surface Locations

09 - Active - Injection

29 - Dry and Plugged

AOI Boundaries & 2D InSAR Measurement Points

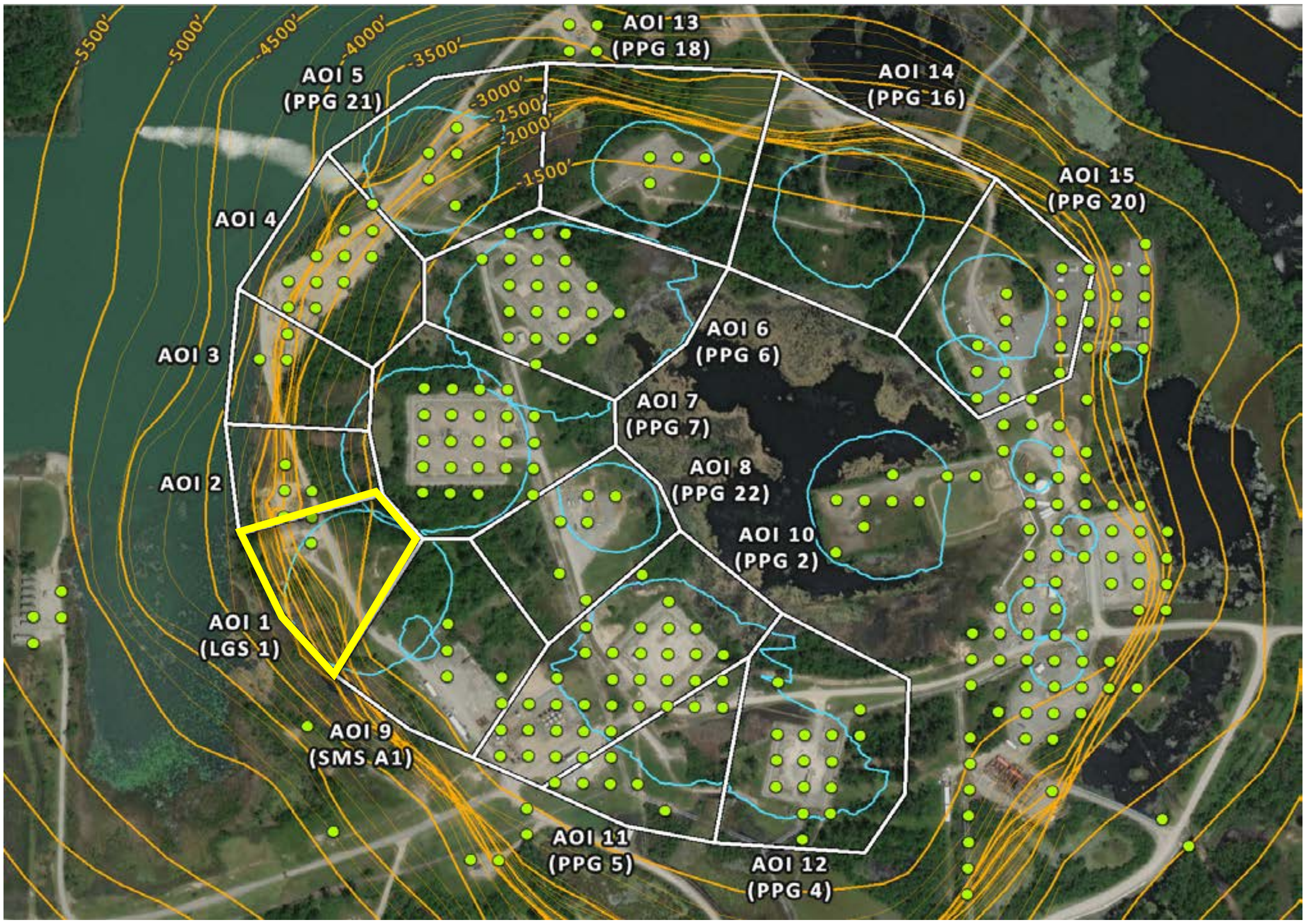


Subsidence Monitoring Areas of Interest (AOIs)

To visually convey and evaluate trend consistency for the East-West displacement time series of each ground target, measurment 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.

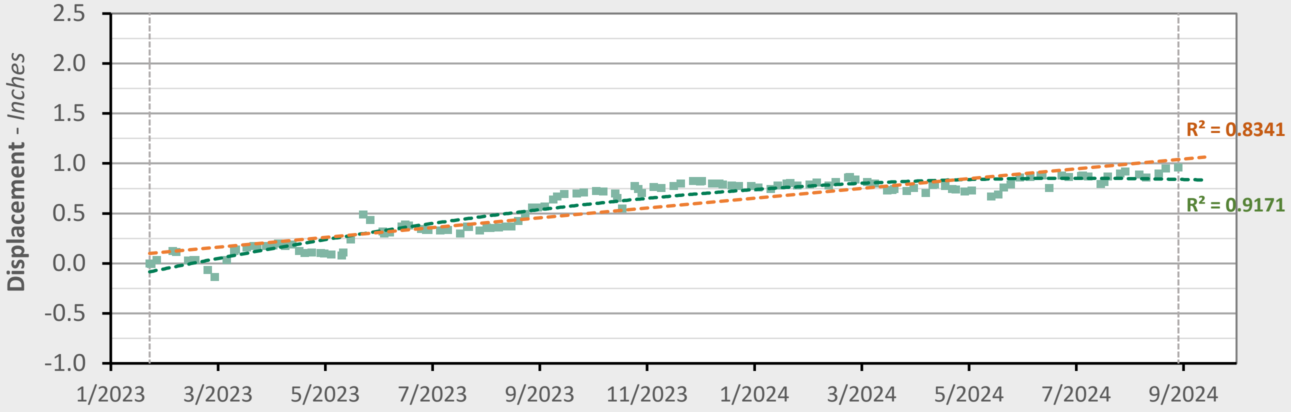
AOI Name	East-West (8/29/2024)	East-West Velocity (in/yr)		East-West Acceleration (in/yr^2)	
	Point Count	Nonlinear	Linear	Nonlinear	Linear
AOI 1 *(LGS 1)*	2	-0.14	+0.59	-0.90	0.00
AOI 2	4	+0.19	+0.66	-0.58	0.00
AOI 3	3	-0.09	+0.54	-0.77	0.00
AOI 4	11	+0.10	+0.47	-0.46	0.00
AOI 5 *(PPG 21)*	5	+0.14	+0.22	-0.09	0.00
AOI 6 *(PPG 6)*	21	+0.14	+0.34	-0.25	0.00
AOI 7 *(PPG 7)*	23	+0.23	+0.58	-0.43	0.00
AOI 8 *(PPG 22)*	5	+0.19	+0.53	-0.42	0.00
AOI 9 *(SMS A1)*	5	+0.09	+0.43	-0.42	0.00
AOI 10 *(PPG 2)*	32	+0.15	+0.34	-0.24	0.00
AOI 11 *(PPG 5)*	9	+0.13	+0.35	-0.26	0.00
AOI 12 *(PPG 4)*	15	-0.58	-0.21	-0.46	0.00
AOI 13 *(PPG 18)*	4	-0.64	-0.04	-0.73	0.00
AOI 14 *(PPG 16)*	0	N/A	N/A	N/A	N/A
AOI 15 *(PPG 20)*	14	-0.71	-0.56	-0.18	0.00

AOI 1 *(LGS 1)* - Location Map



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

E-W (8/29/2024) Point Count: **2**



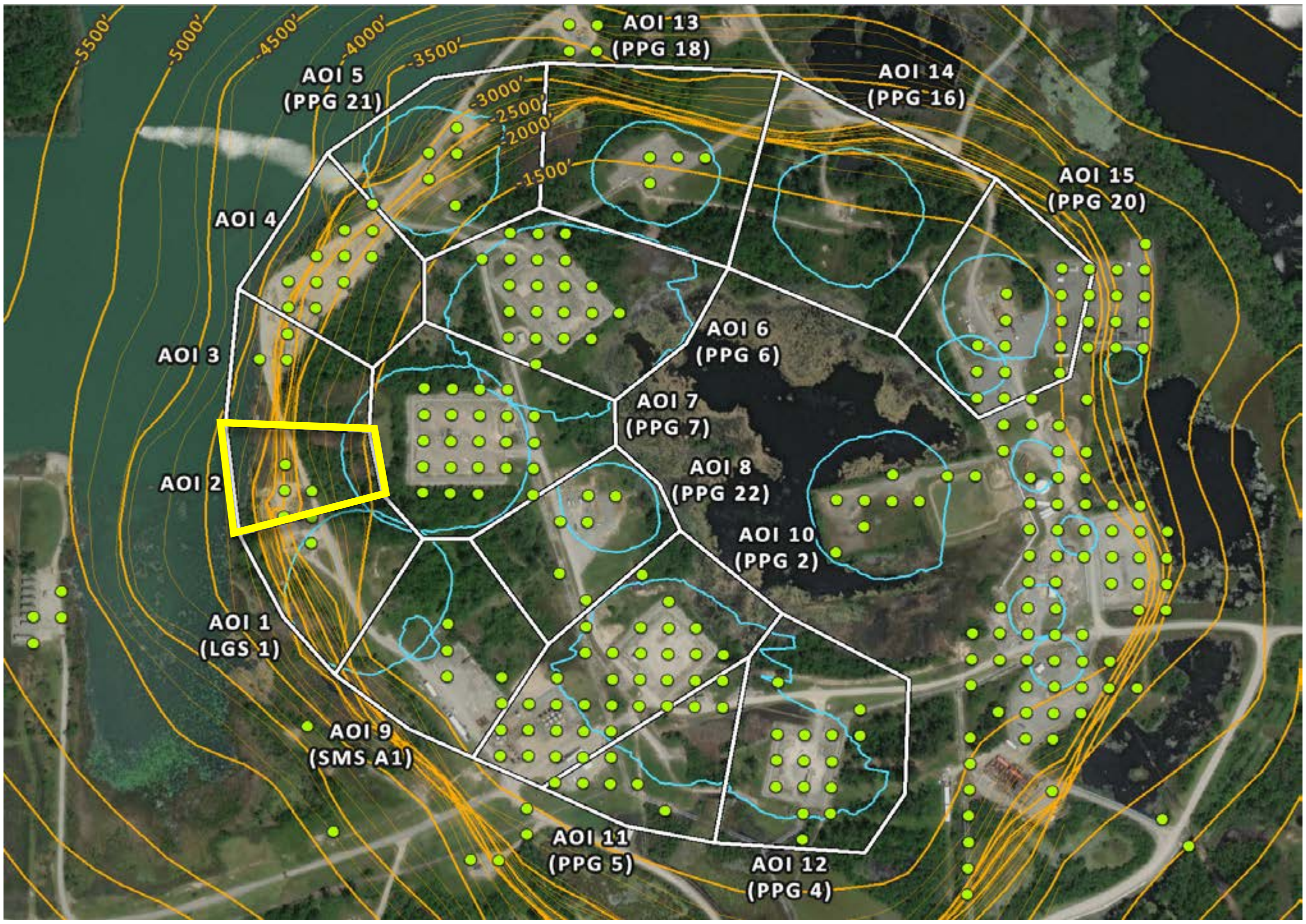
	Nonlinear Trend		Linear Trend	
Velocity:	-0.14	in/yr	+0.59	in/yr
Acceleration:	-0.90	in/yr^2	0.00	in/yr^2

■ 2D Displacement Measurement

- - - - Nonlinear Trend Line (Quadratic Regression)

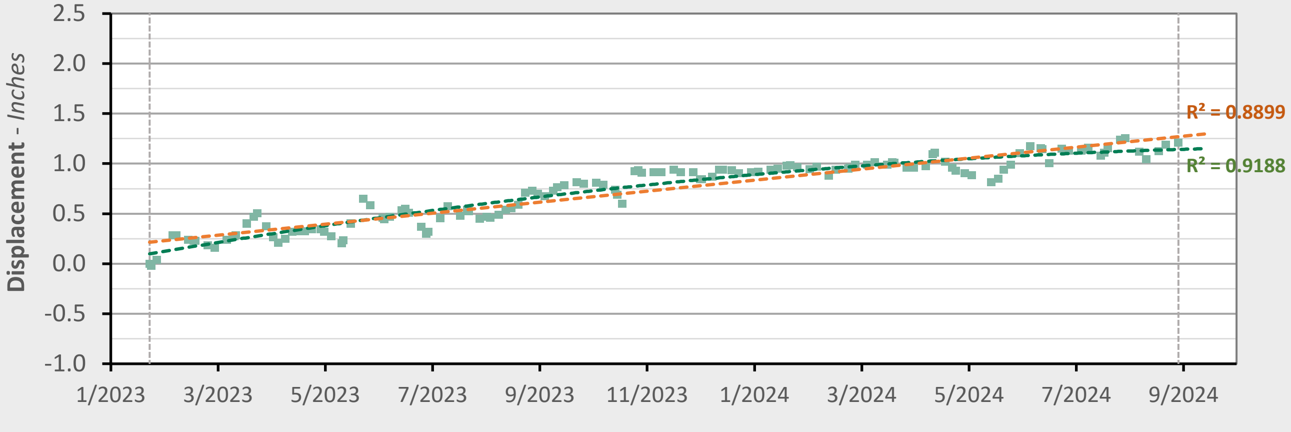
- - - - Linear Trend Line (Linear Regression)

AOI 2 - Location Map



AOI 2 - East-West Time Series

E-W (8/29/2024) Point Count: 4



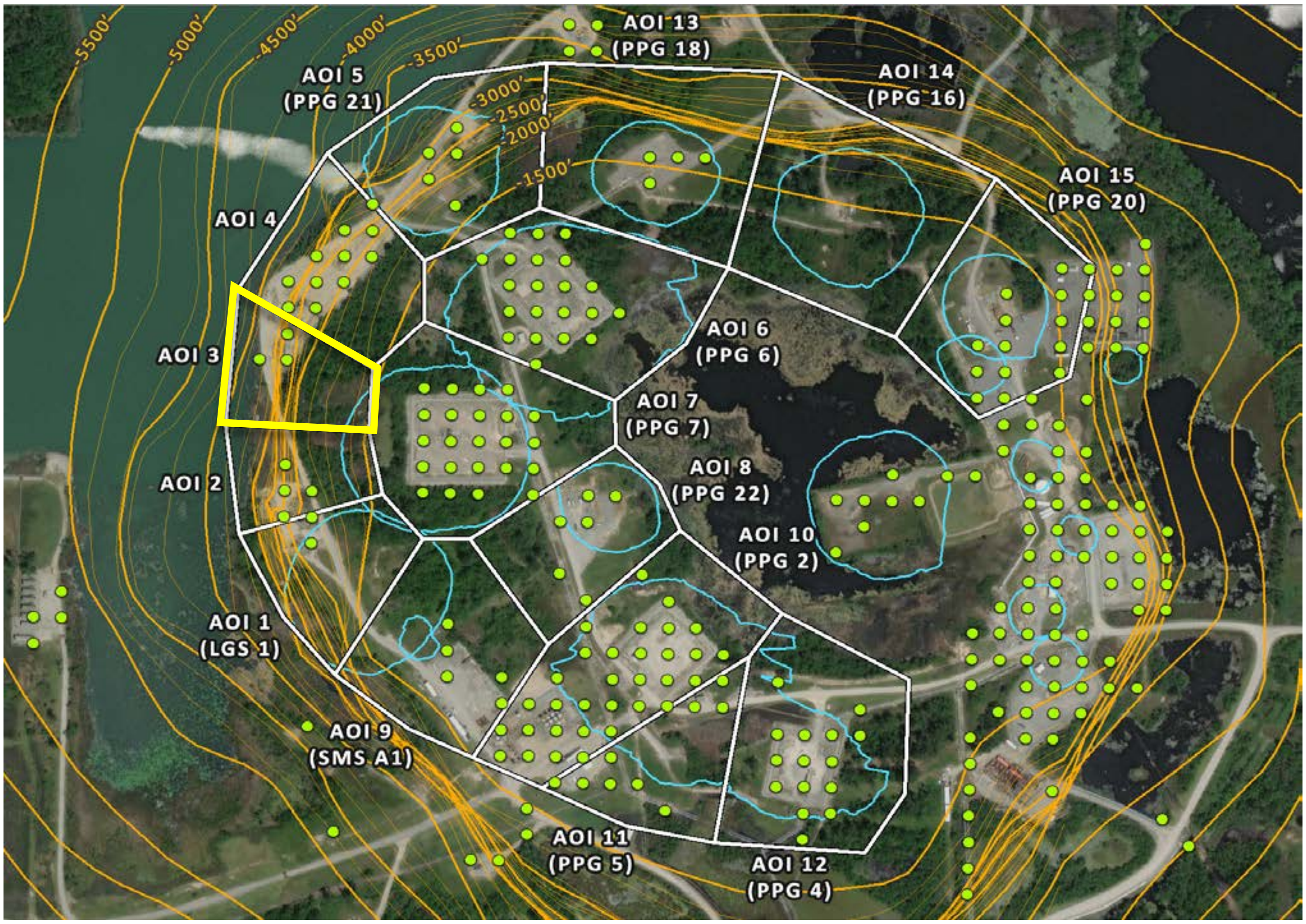
	Nonlinear Trend		Linear Trend	
Velocity:	+0.19	in/yr	+0.66	in/yr
Acceleration:	-0.58	in/yr^2	0.00	in/yr^2

■ 2D Displacement Measurement

- - - - Nonlinear Trend Line (Quadratic Regression)

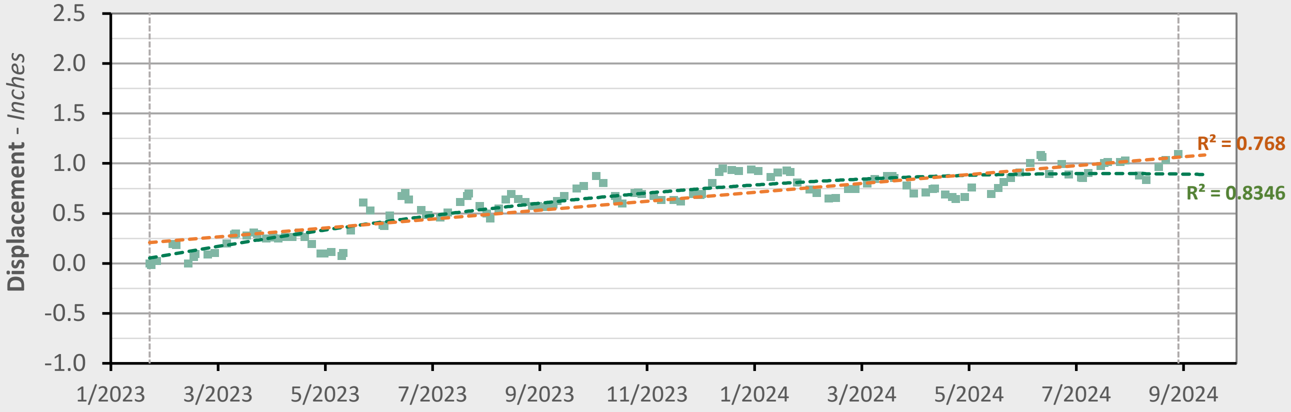
- - - - Linear Trend Line (Linear Regression)

AOI 3 - Location Map



AOI 3 - East-West Time Series

E-W (8/29/2024) Point Count: 3



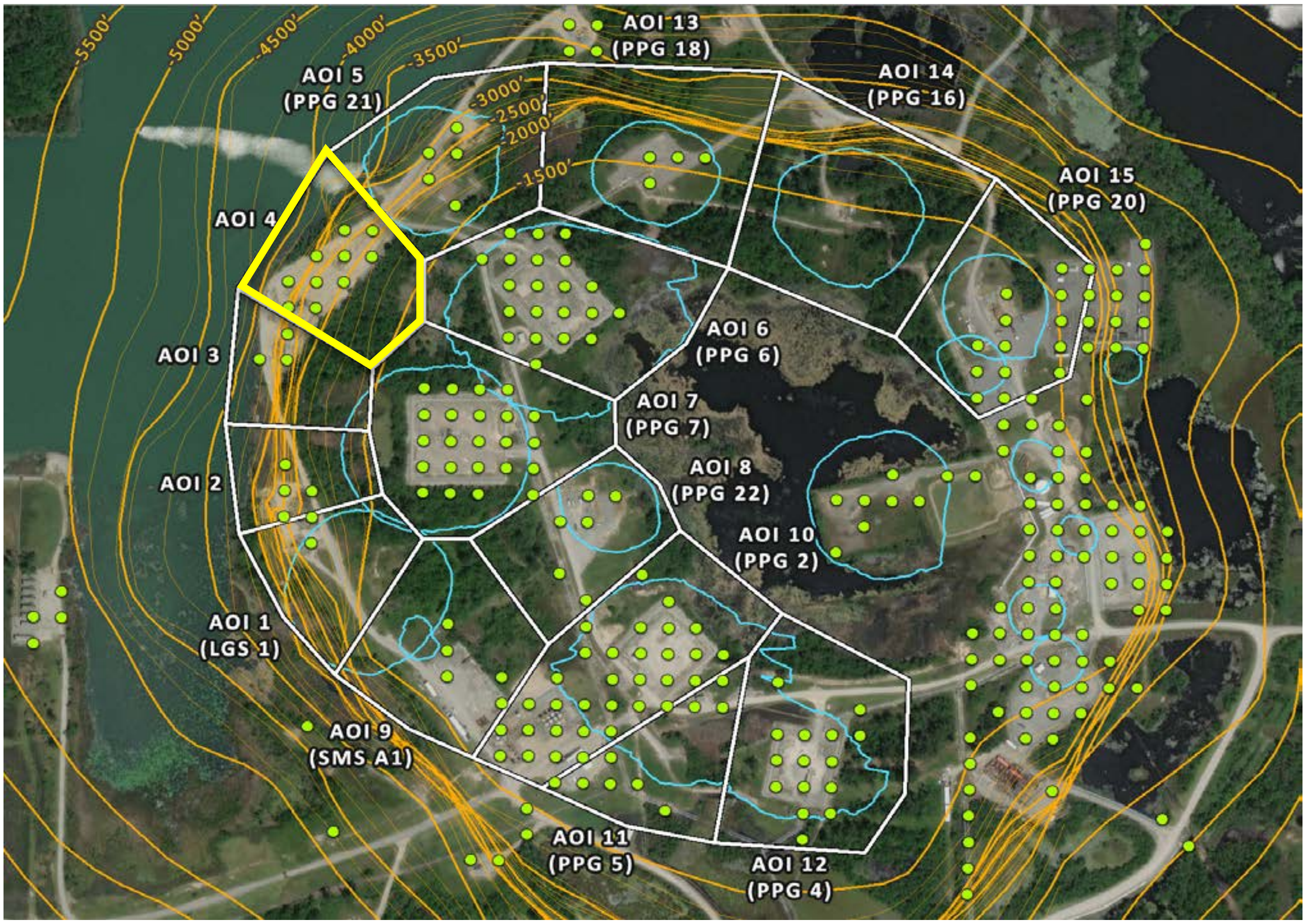
	Nonlinear Trend	Linear Trend
Velocity:	-0.09 in/yr	+0.54 in/yr
Acceleration:	-0.77 in/yr^2	0.00 in/yr^2

■ 2D Displacement Measurement

- - - - Nonlinear Trend Line (Quadratic Regression)

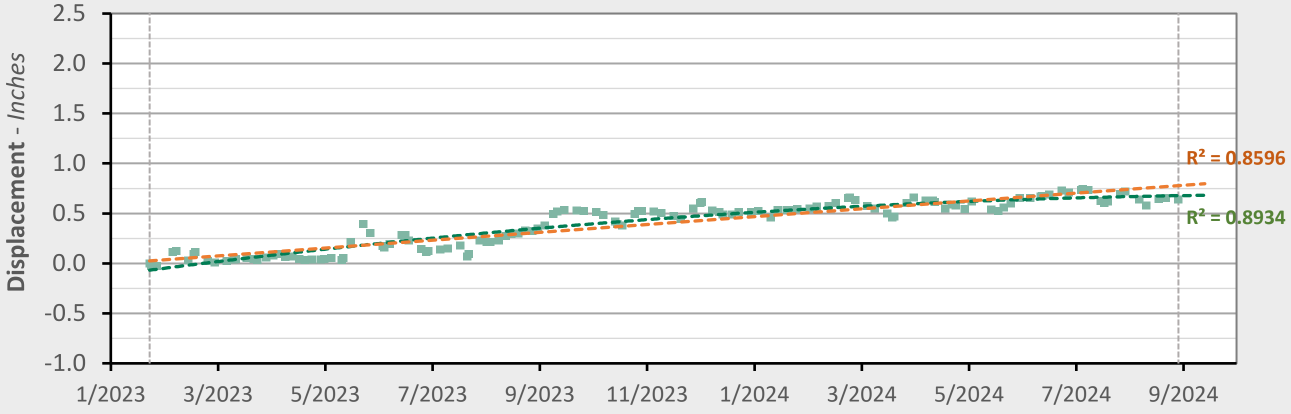
- - - - Linear Trend Line (Linear Regression)

AOI 4 - Location Map



AOI 4 - East-West Time Series

E-W (8/29/2024) Point Count: **11**



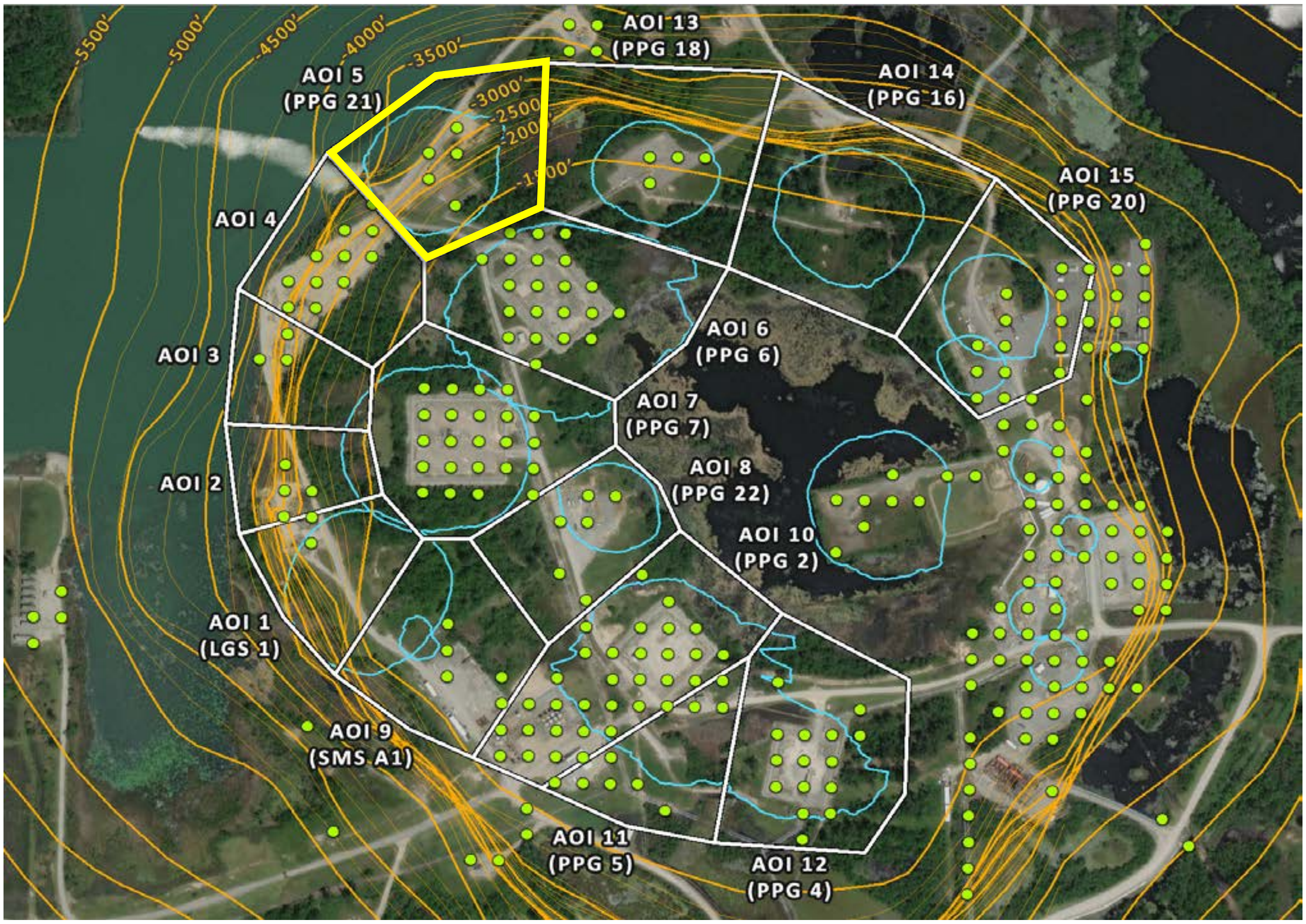
	Nonlinear Trend		Linear Trend	
Velocity:	+0.10	in/yr	+0.47	in/yr
Acceleration:	-0.46	in/yr^2	0.00	in/yr^2

▪ 2D Displacement Measurement

---- Nonlinear Trend Line (Quadratic Regression)

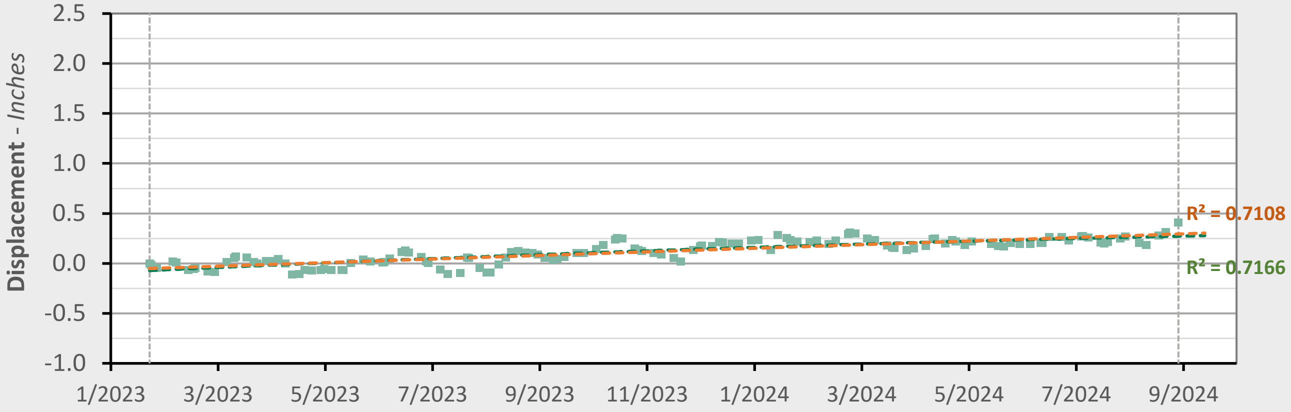
---- Linear Trend Line (Linear Regression)

AOI 5 *(PPG 21)* - Location Map



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

E-W (8/29/2024) Point Count: 5



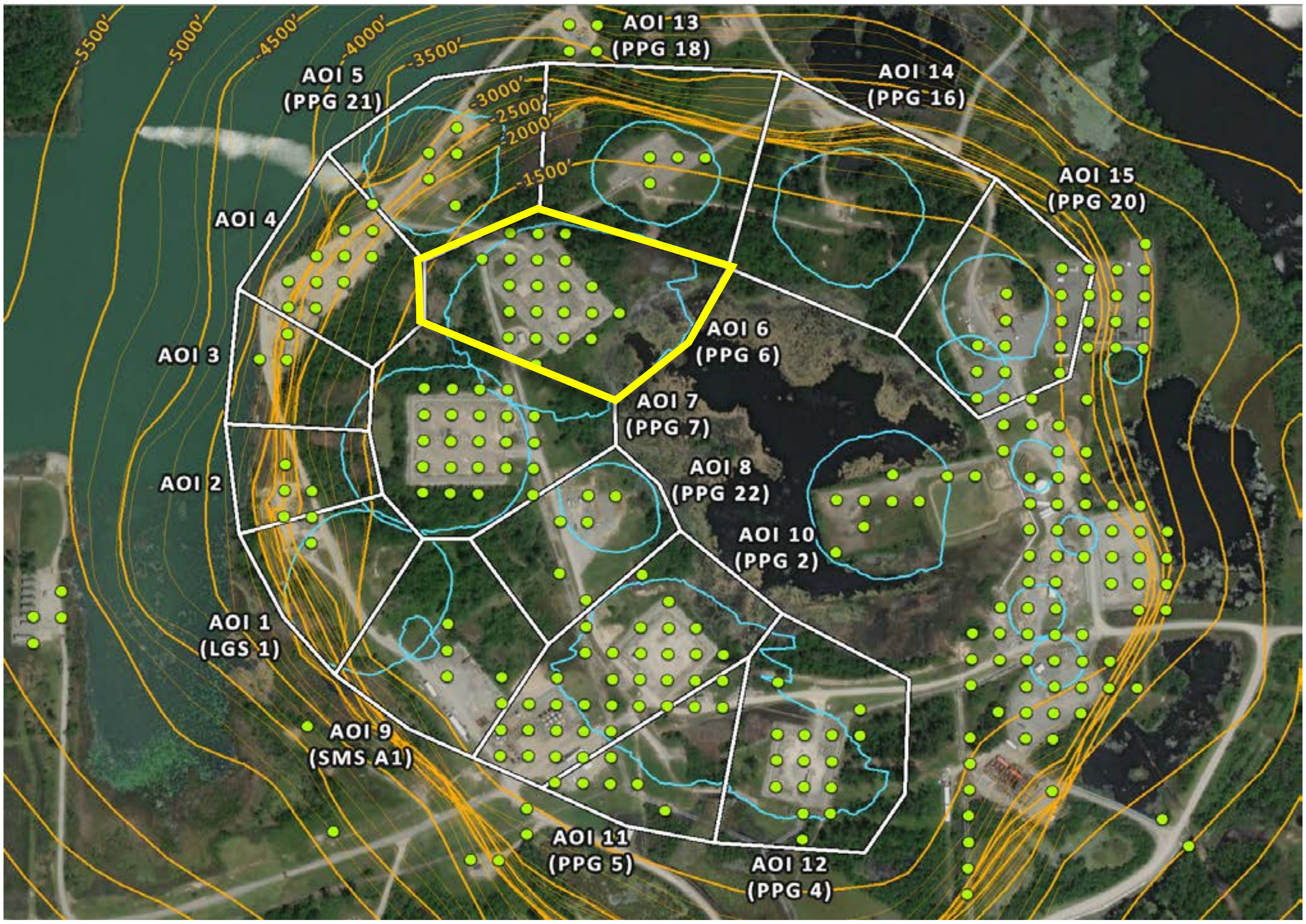
	Nonlinear Trend		Linear Trend	
Velocity:	+0.14	in/yr	+0.22	in/yr
Acceleration:	-0.09	in/yr^2	0.00	in/yr^2

🟩 2D Displacement Measurement

---- Nonlinear Trend Line (Quadratic Regression)

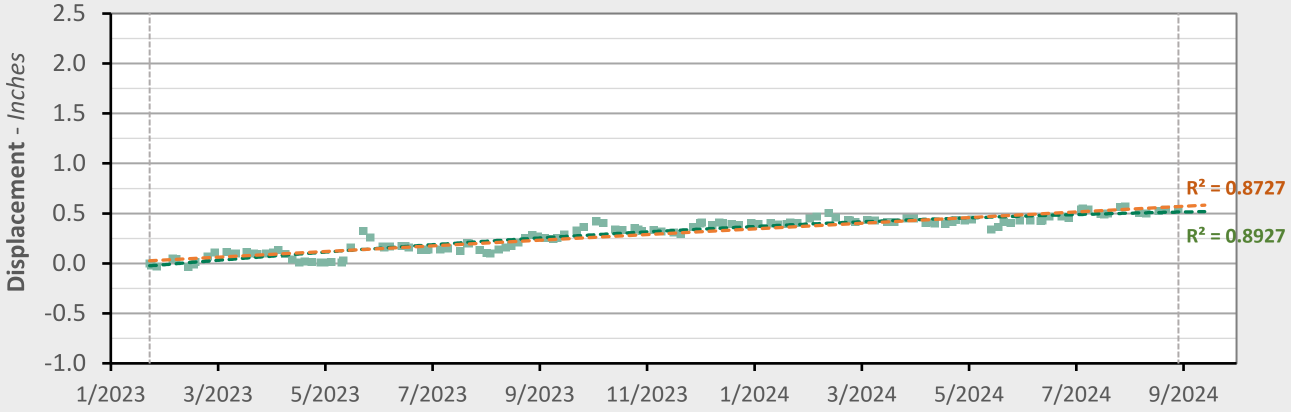
---- Linear Trend Line (Linear Regression)

AOI 6 *(PPG 6)* - Location Map



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

E-W (8/29/2024) Point Count: **21**



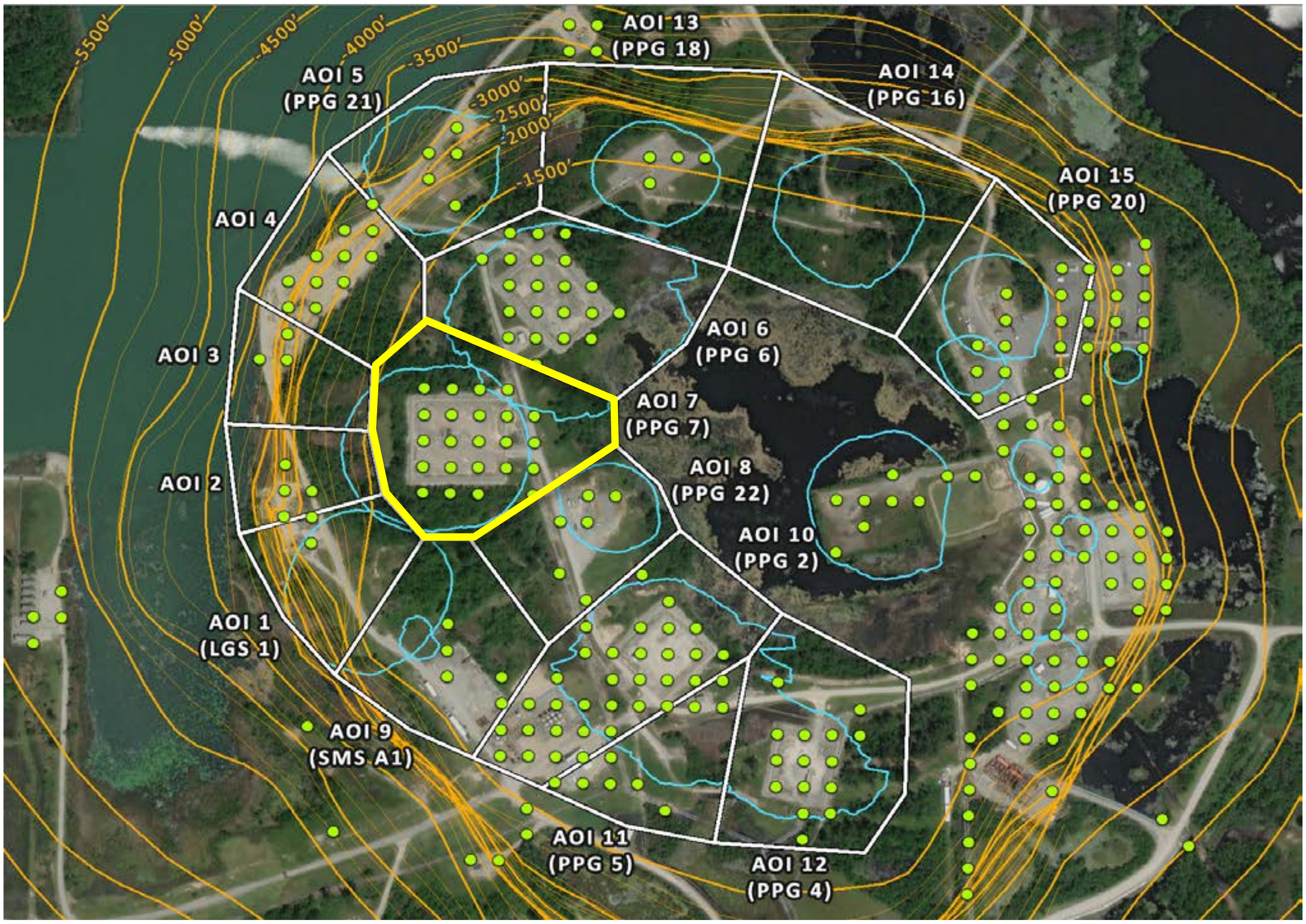
	Nonlinear Trend	Linear Trend
Velocity:	+0.14 in/yr	+0.34 in/yr
Acceleration:	-0.25 in/yr^2	0.00 in/yr^2

■ 2D Displacement Measurement

---- Nonlinear Trend Line (Quadratic Regression)

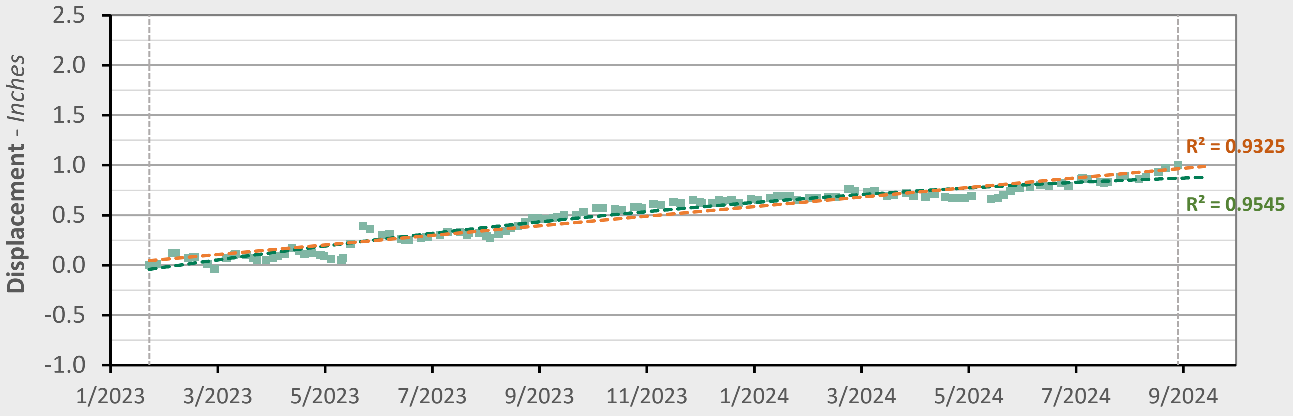
---- Linear Trend Line (Linear Regression)

AOI 7 *(PPG 7)* - Location Map



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

E-W (8/29/2024) Point Count: **23**



	Nonlinear Trend	Linear Trend
Velocity:	+0.23 in/yr	+0.58 in/yr
Acceleration:	-0.43 in/yr^2	0.00 in/yr^2

🟩 2D Displacement Measurement

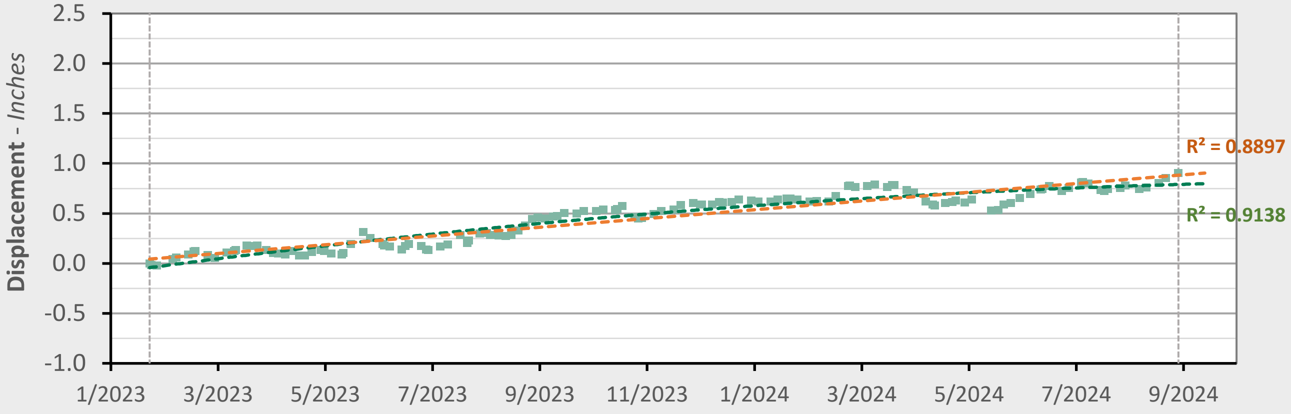
- - - - Nonlinear Trend Line (Quadratic Regression)

- - - - Linear Trend Line (Linear Regression)

AOI 8 *(PPG 22)* - Location Map

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

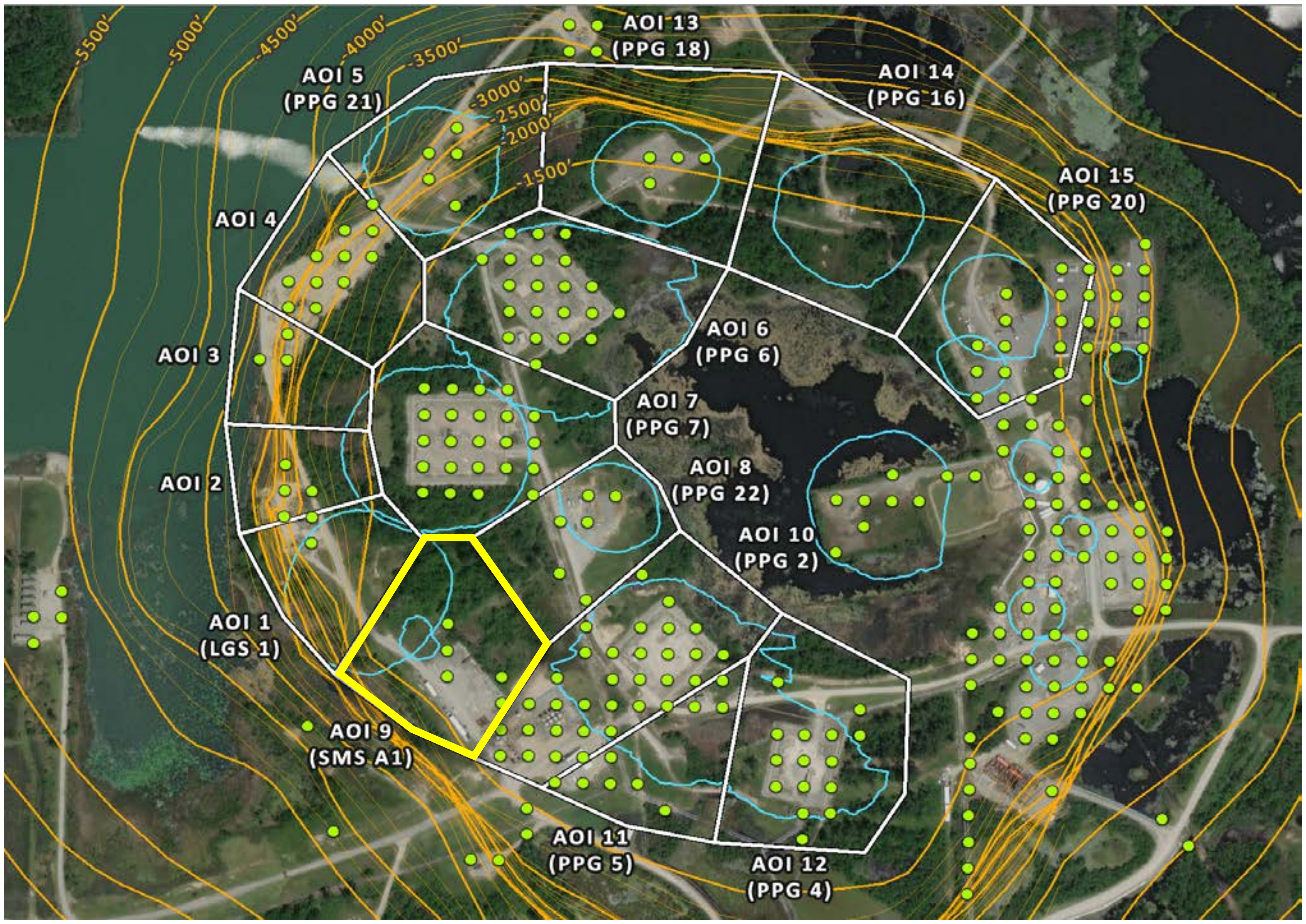
E-W (8/29/2024) Point Count: 5



	Nonlinear Trend		Linear Trend	
Velocity:	+0.19	in/yr	+0.53	in/yr
Acceleration:	-0.42	in/yr^2	0.00	in/yr^2

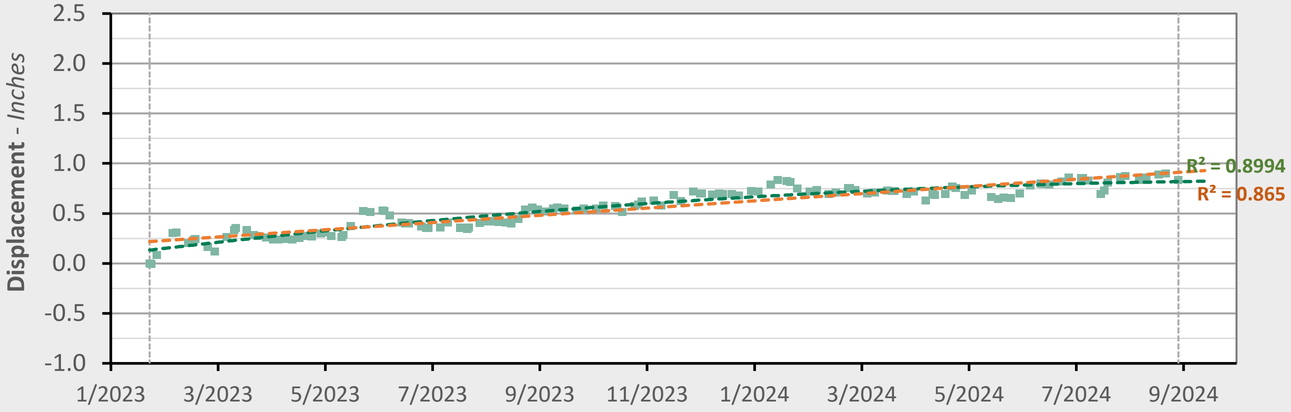
▪ 2D Displacement Measurement
---- Nonlinear Trend Line (Quadratic Regression)
---- Linear Trend Line (Linear Regression)

AOI 9 *(PPG A1)* - Location Map



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

E-W (8/29/2024) Point Count: 5



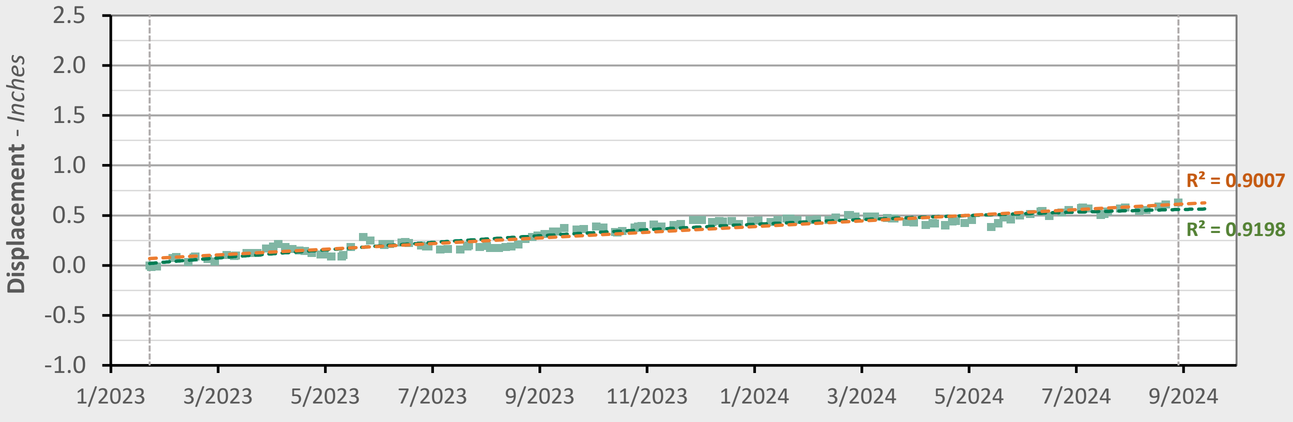
	Nonlinear Trend		Linear Trend	
Velocity:	+0.09	in/yr	+0.43	in/yr
Acceleration:	-0.42	in/yr^2	0.00	in/yr^2

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

AOI 10 *(PPG 2)* - Location Map

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

E-W (8/29/2024) Point Count: **32**



	Nonlinear Trend	Linear Trend
Velocity:	+0.15 in/yr	+0.34 in/yr
Acceleration:	-0.24 in/yr^2	0.00 in/yr^2

🟩 2D Displacement Measurement

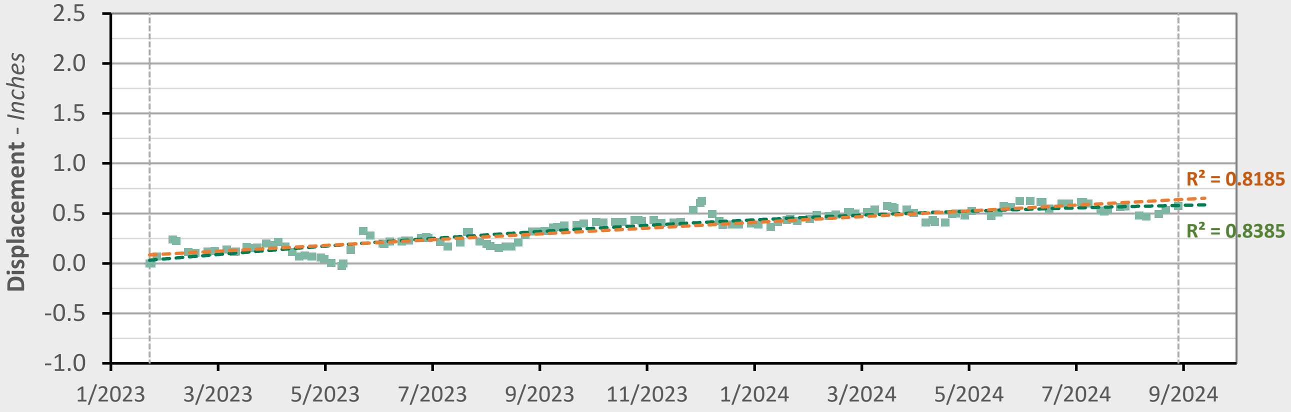
- - - - Nonlinear Trend Line (Quadratic Regression)

- - - - Linear Trend Line (Linear Regression)

AOI 11 *(PPG 5)* - Location Map

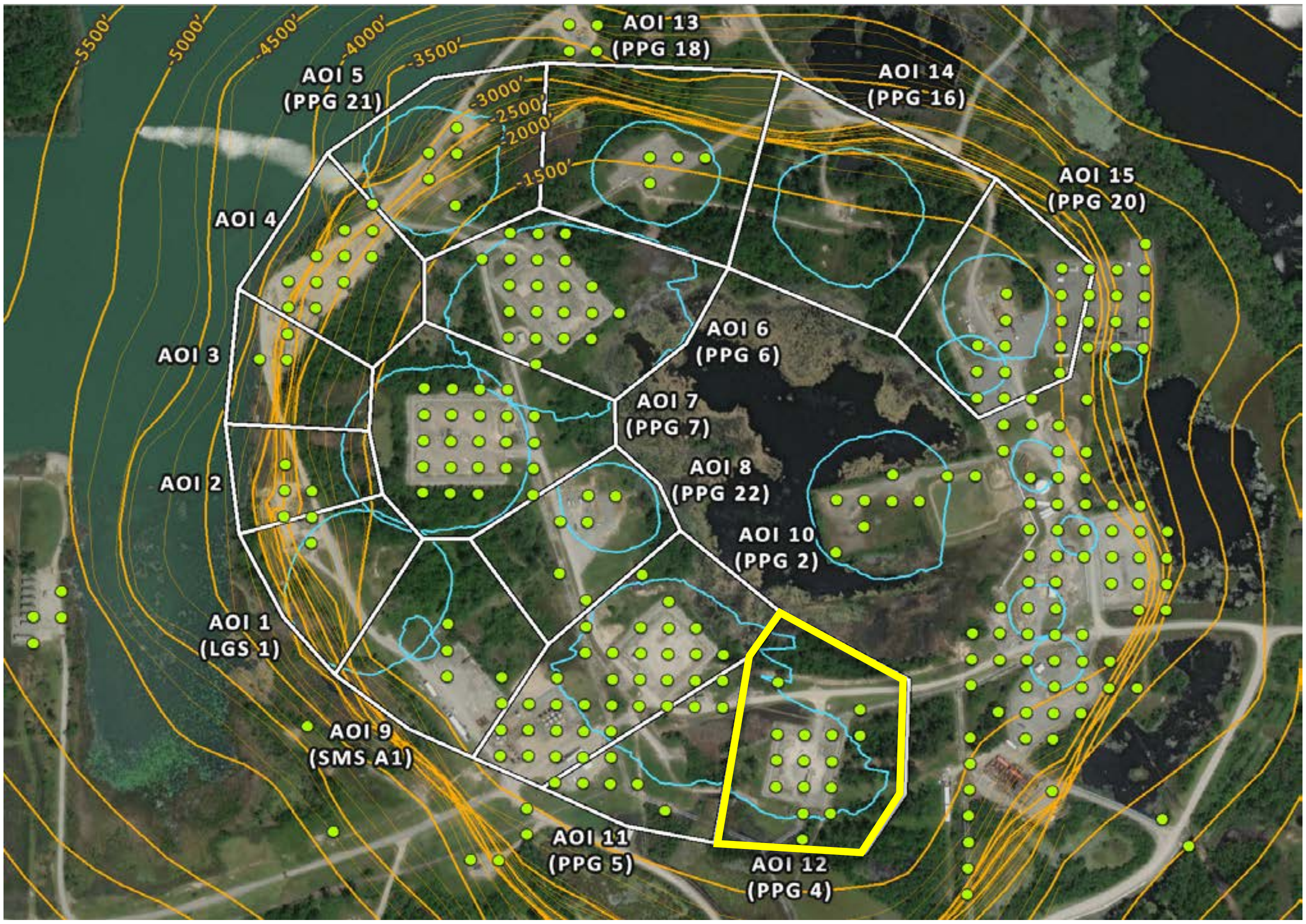
AOI 11 *(PPG 5)* - East-West Time Series

E-W (8/29/2024) Point Count: 9



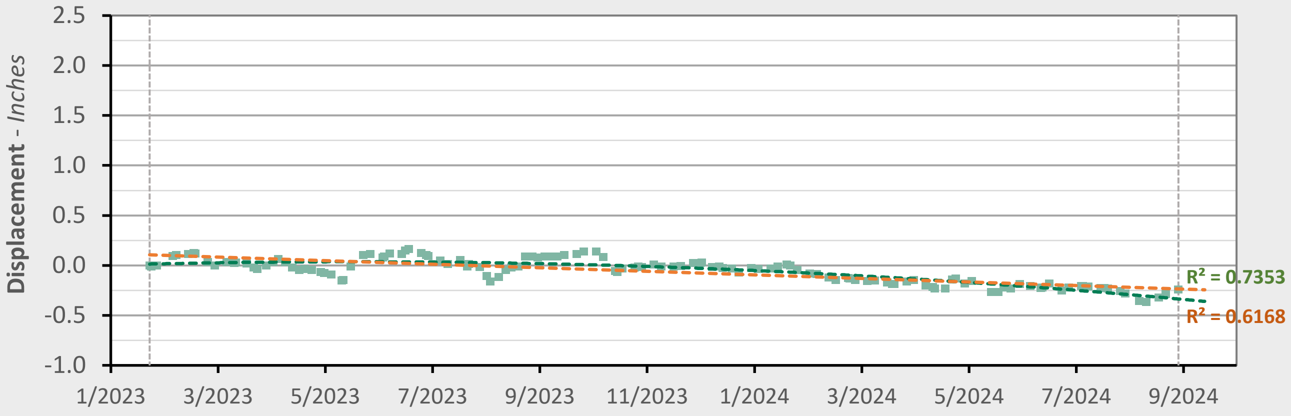
	Nonlinear Trend	Linear Trend
Velocity:	+0.13 in/yr	+0.35 in/yr
Acceleration:	-0.26 in/yr^2	0.00 in/yr^2

AOI 12 *(PPG 4)* - Location Map



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

E-W (8/29/2024) Point Count: 15



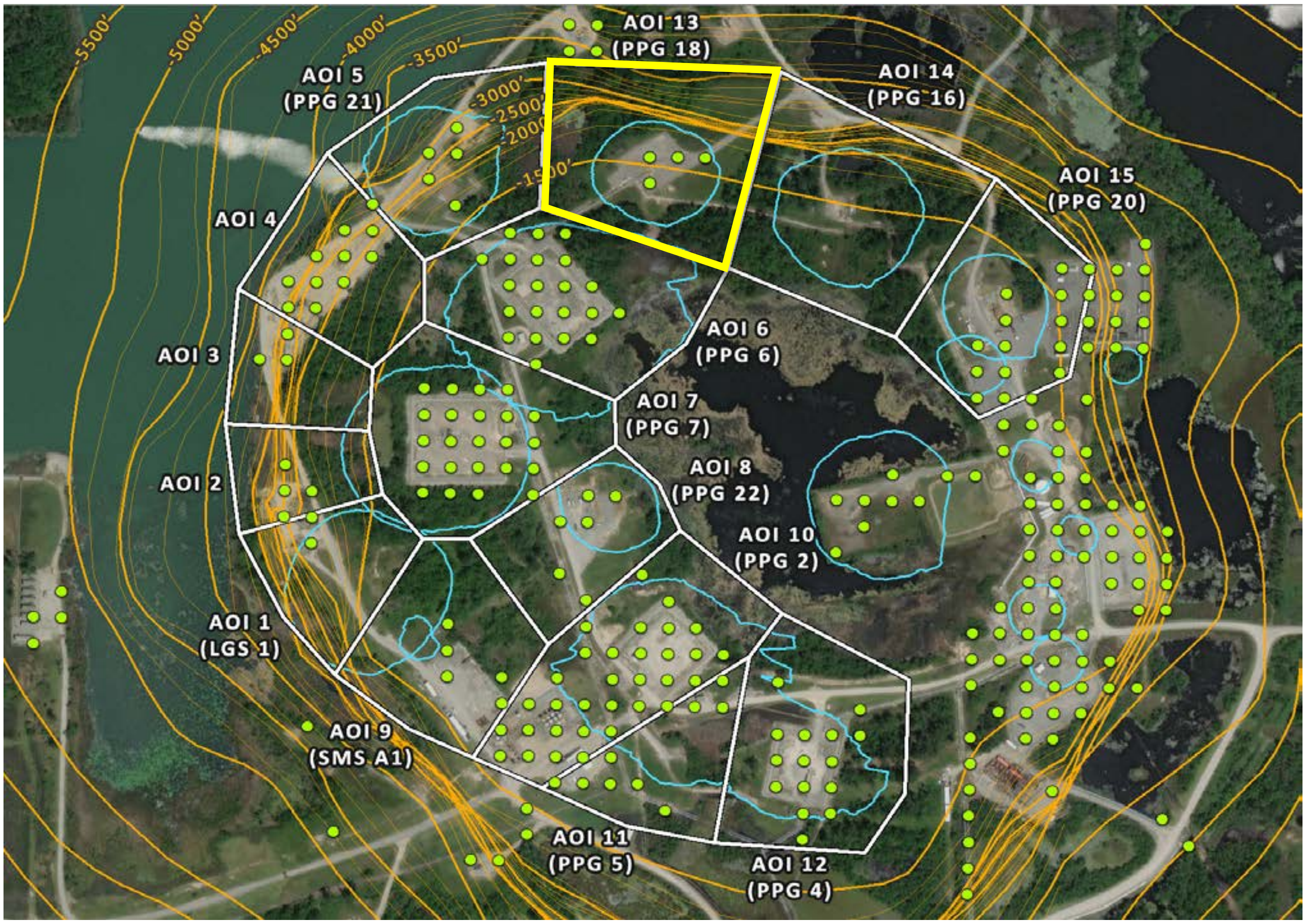
	Nonlinear Trend	Linear Trend
Velocity:	-0.58 in/yr	-0.21 in/yr
Acceleration:	-0.46 in/yr^2	0.00 in/yr^2

■ 2D Displacement Measurement

- - - - Nonlinear Trend Line (Quadratic Regression)

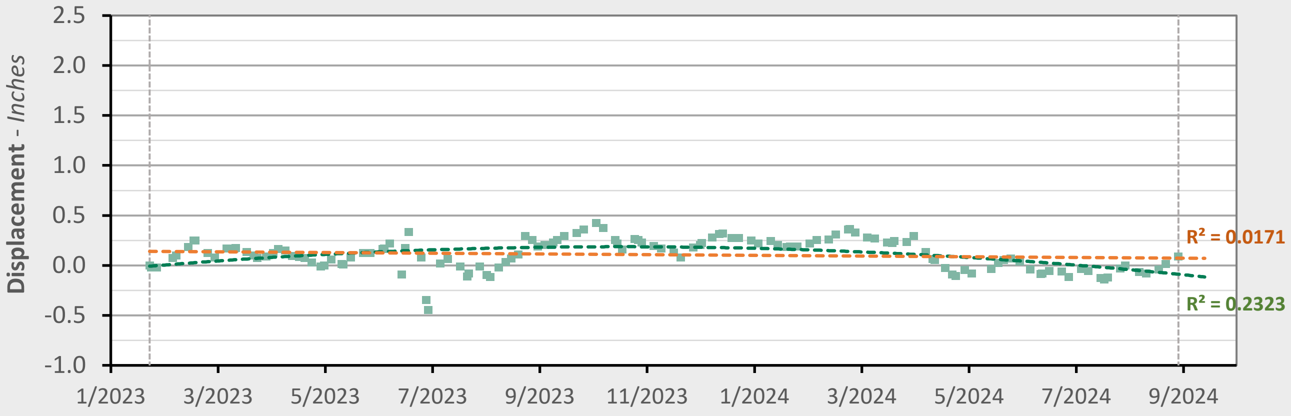
- - - - Linear Trend Line (Linear Regression)

AOI 13 *(PPG 18)* - Location Map



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

E-W (8/29/2024) Point Count: 4



	Nonlinear Trend	Linear Trend
Velocity:	-0.64 in/yr	-0.04 in/yr
Acceleration:	-0.73 in/yr^2	0.00 in/yr^2

🟩 2D Displacement Measurement

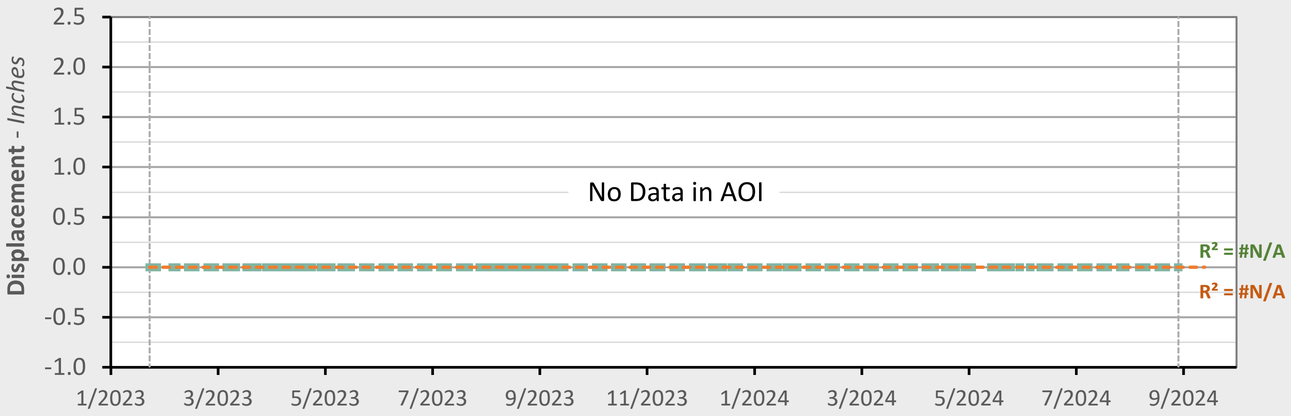
Nonlinear Trend Line (Quadratic Regression)

Linear Trend Line (Linear Regression)

AOI 14 *(PPG 16)* - Location Map

AOI 14 *(PPG 16)* - East-West Time Series

E-W (8/29/2024) Point Count: **0**



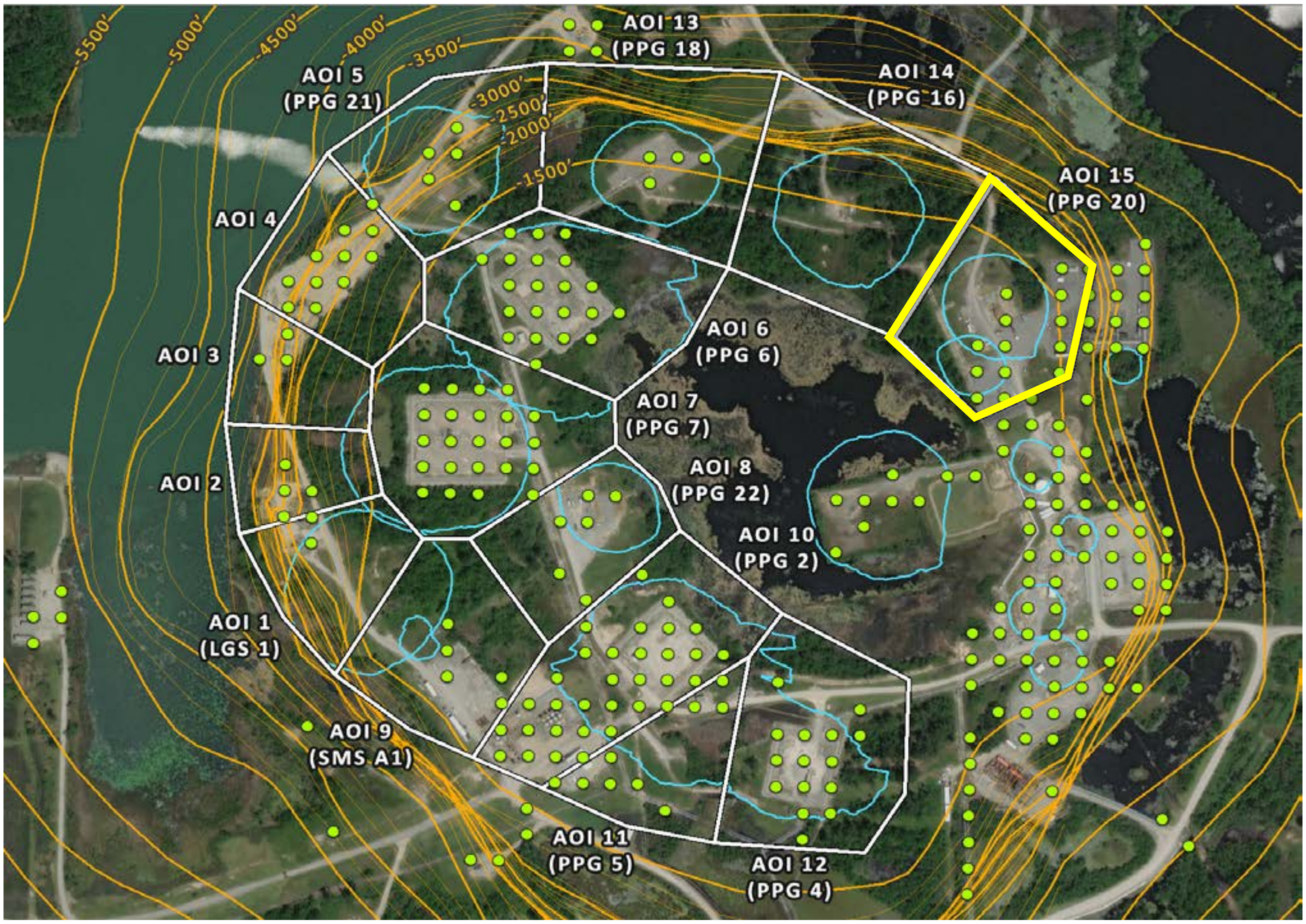
	Nonlinear Trend		Linear Trend	
Velocity:	N/A	in/yr	N/A	in/yr
Acceleration:	N/A	in/yr^2	N/A	in/yr^2

▪ 2D Displacement Measurement

---- Nonlinear Trend Line (Quadratic Regression)

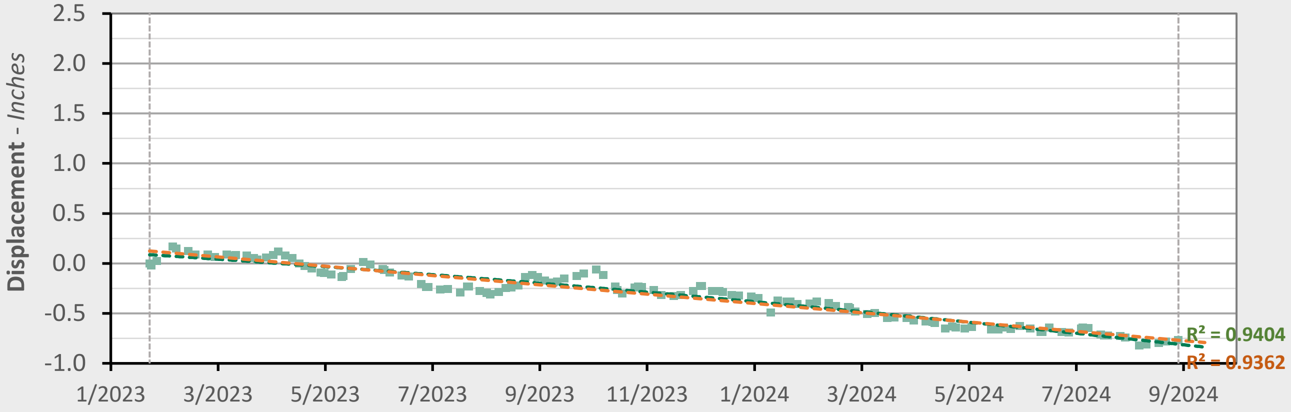
---- Linear Trend Line (Linear Regression)

AOI 15 *(PPG 20)* - Location Map



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

E-W (8/29/2024) Point Count: **14**



	Nonlinear Trend		Linear Trend	
Velocity:	-0.71	in/yr	-0.56	in/yr
Acceleration:	-0.18	in/yr^2	0.00	in/yr^2

■ 2D Displacement Measurement

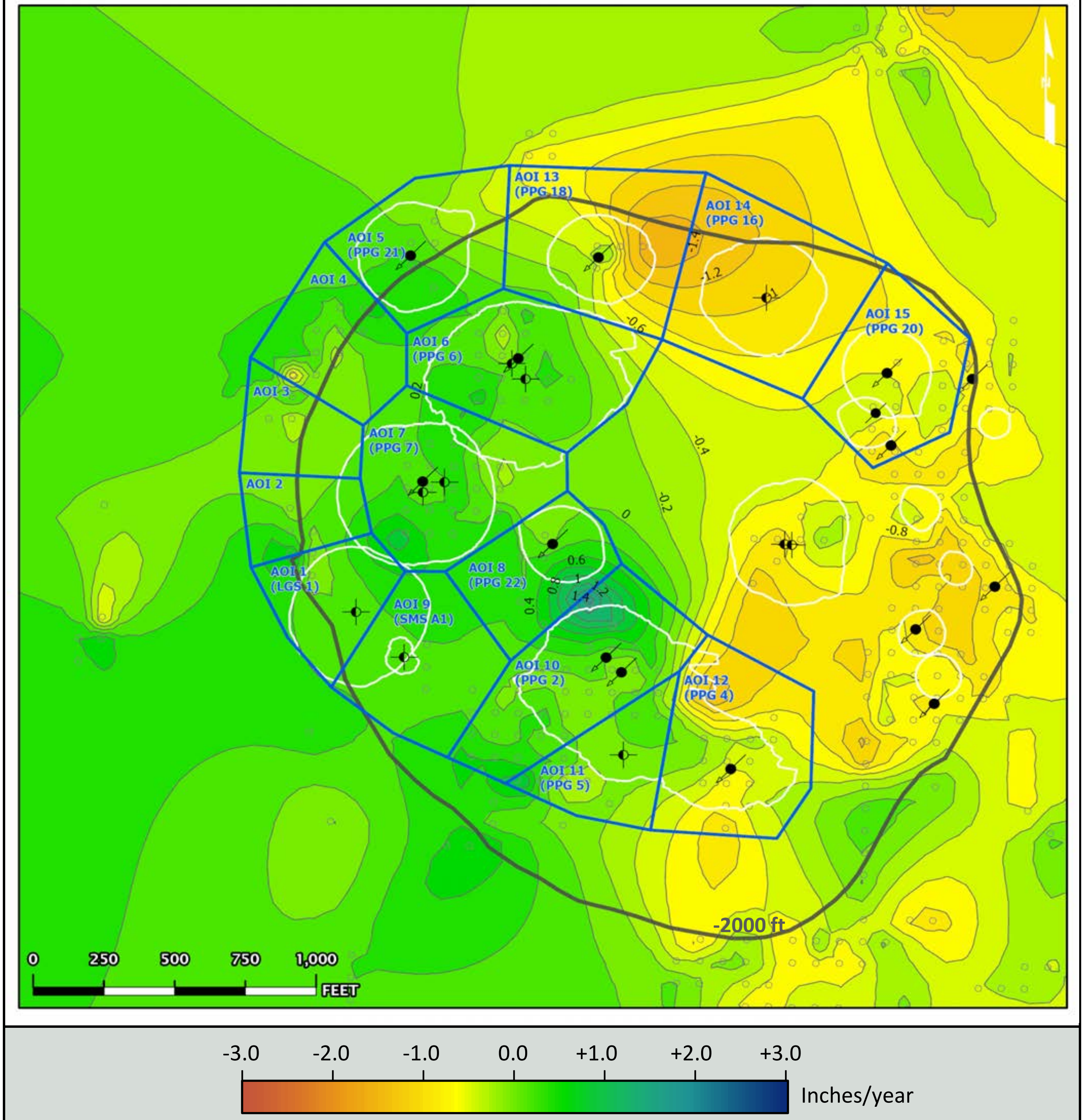
---- Nonlinear Trend Line (Quadratic Regression)

---- Linear Trend Line (Linear Regression)

East-West Data (01/24/2023 - 08/29/2024)

Nonlinear Velocity Contours

As of date: 08/29/2024



▭ AOI Boundary ○ InSAR LOS Measurement Point — Contour (0.2)

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

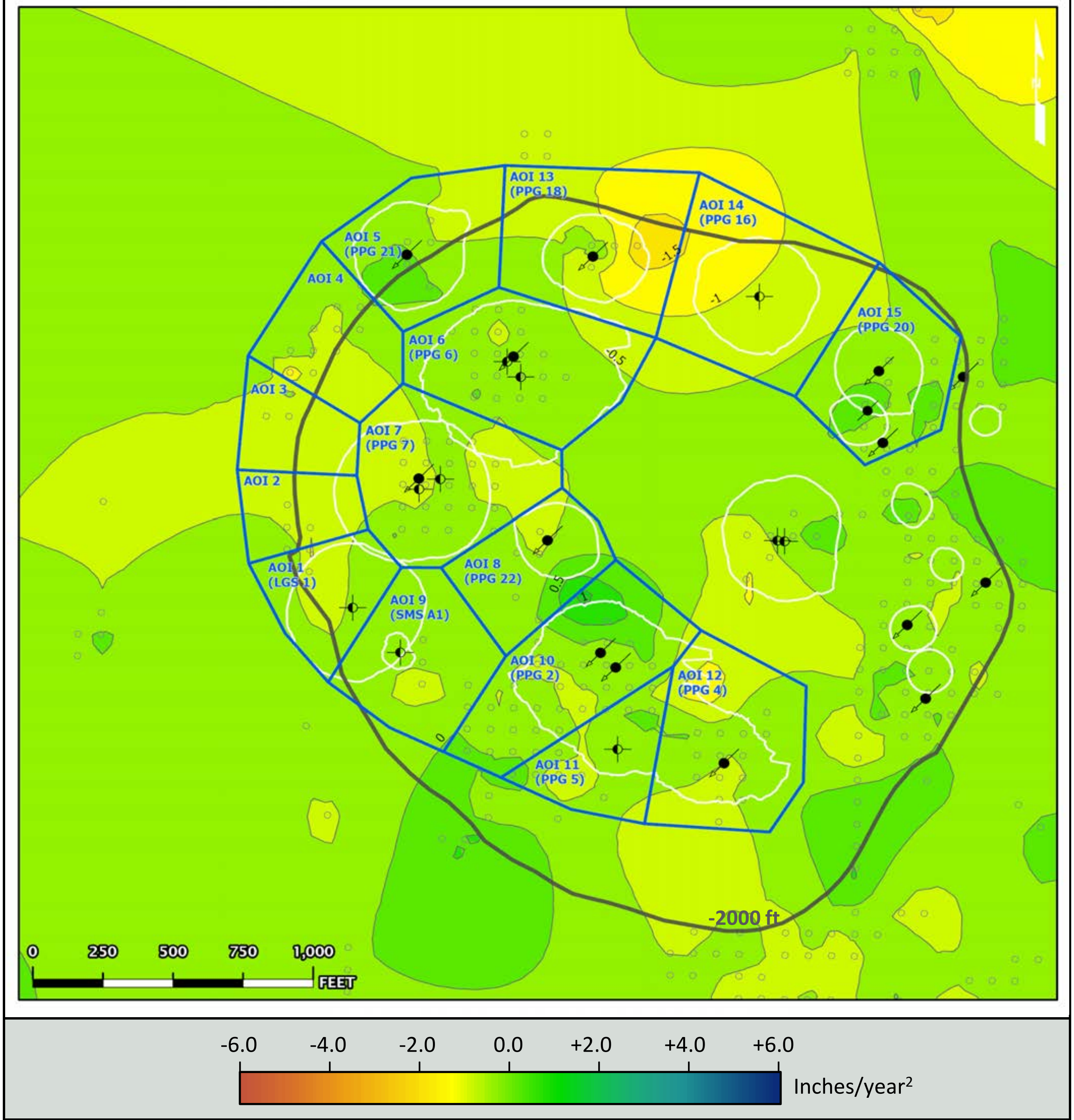
Cavern Well Surface Locations

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

East-West Data (01/24/2023 - 08/29/2024)

Nonlinear Acceleration Contours

Date range: 01/24/2023 - 08/29/2024



🟦 AOI Boundary ○ InSAR LOS Measurement Point — Contour (0.5)

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

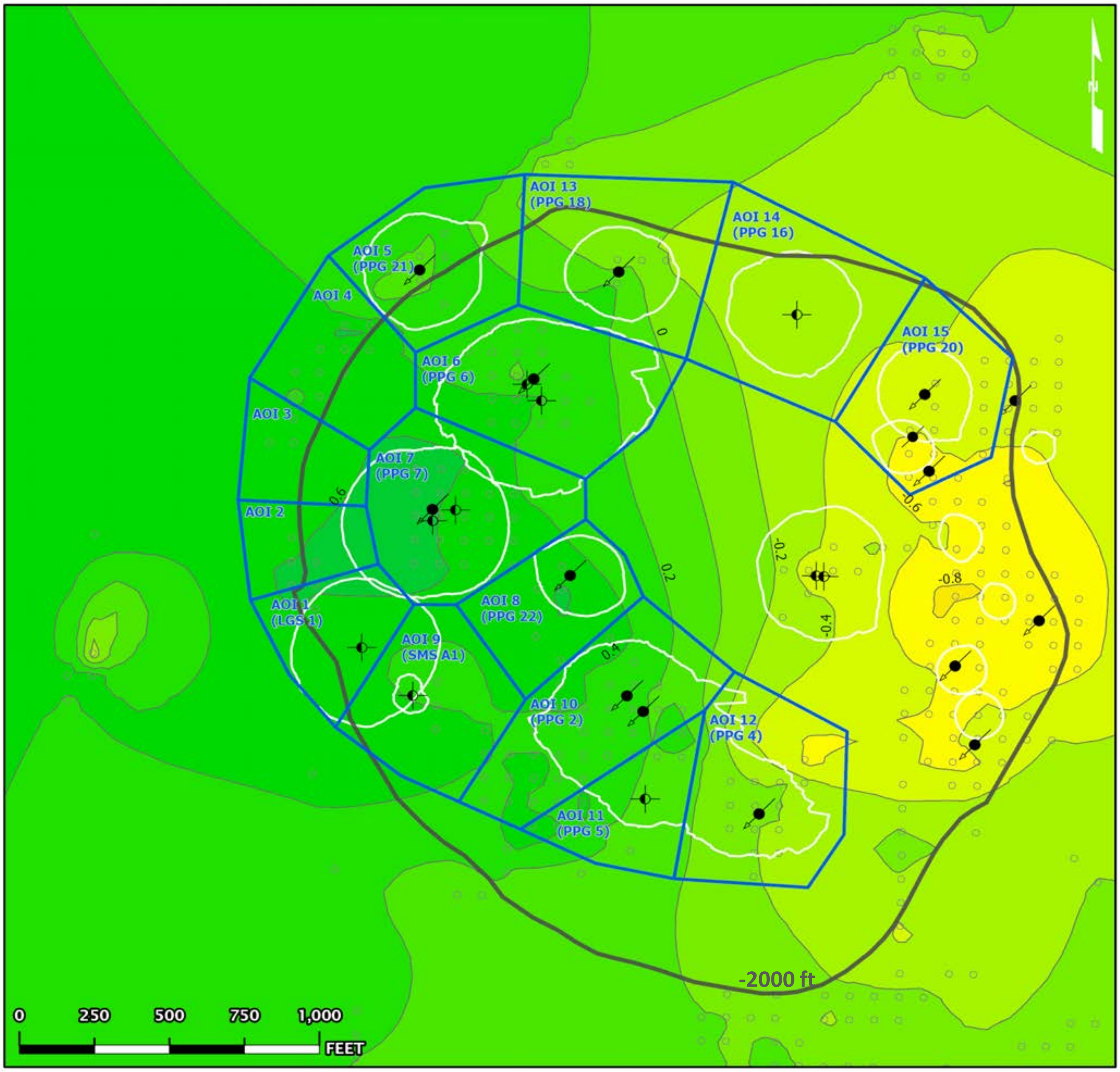
Cavern Well Surface Locations

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

East-West Data (01/24/2023 - 08/29/2024)

Linear Velocity Contours

Date range: 01/24/2023 - 08/29/2024



-3.0 -2.0 -1.0 0.0 +1.0 +2.0 +3.0

Inches/year

🟦 AOI Boundary ○ InSAR LOS Measurement Point — Contour (0.2)

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

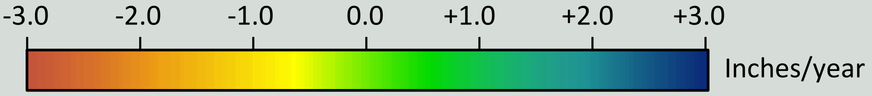
Cavern Well Surface Locations

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

East-West Data (01/24/2023 - 08/29/2024)

Nonlinear Velocity Data Points

As of date: 08/29/2024



▭ 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 - 08/29/2024)

Nonlinear Acceleration Data Points

Date range: 01/24/2023 - 08/29/2024

-6.0 -4.0 -2.0 0.0 +2.0 +4.0 +6.0 Inches/year^2

▭ 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 - 08/29/2024)

Linear Velocity Data Points

Date range: 01/24/2023 - 08/29/2024

-3.0 -2.0 -1.0 0.0 +1.0 +2.0 +3.0 Inches/year

▭ 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