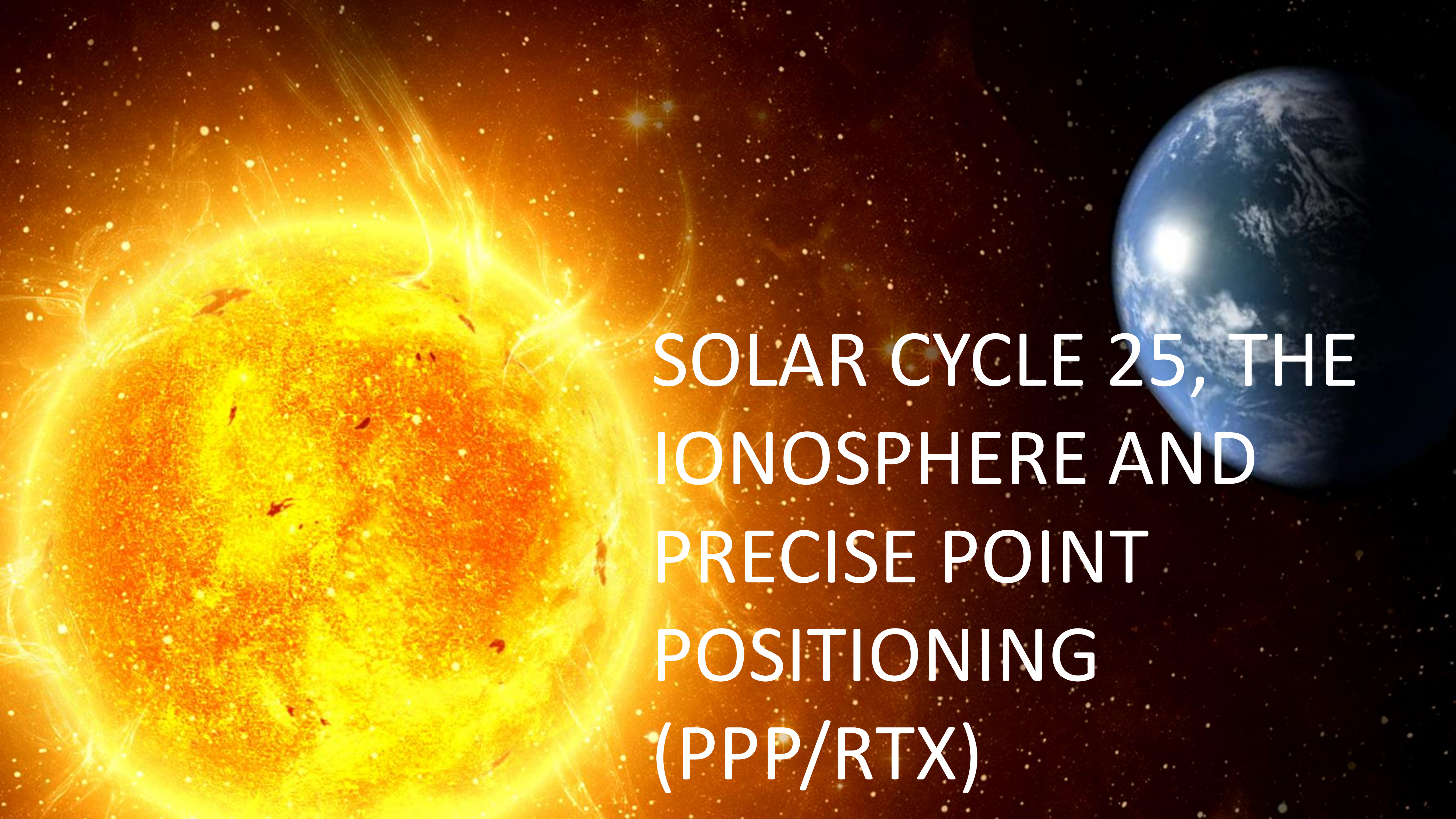
# SOLAR CYCLE 25, THE IONOSPHERE AND PRECISE POINT POSITIONING (PPP/RTX)

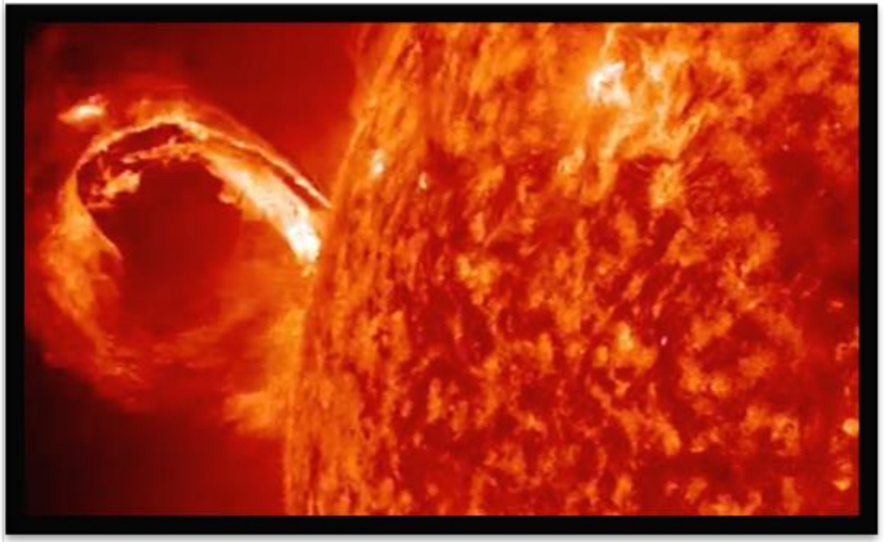


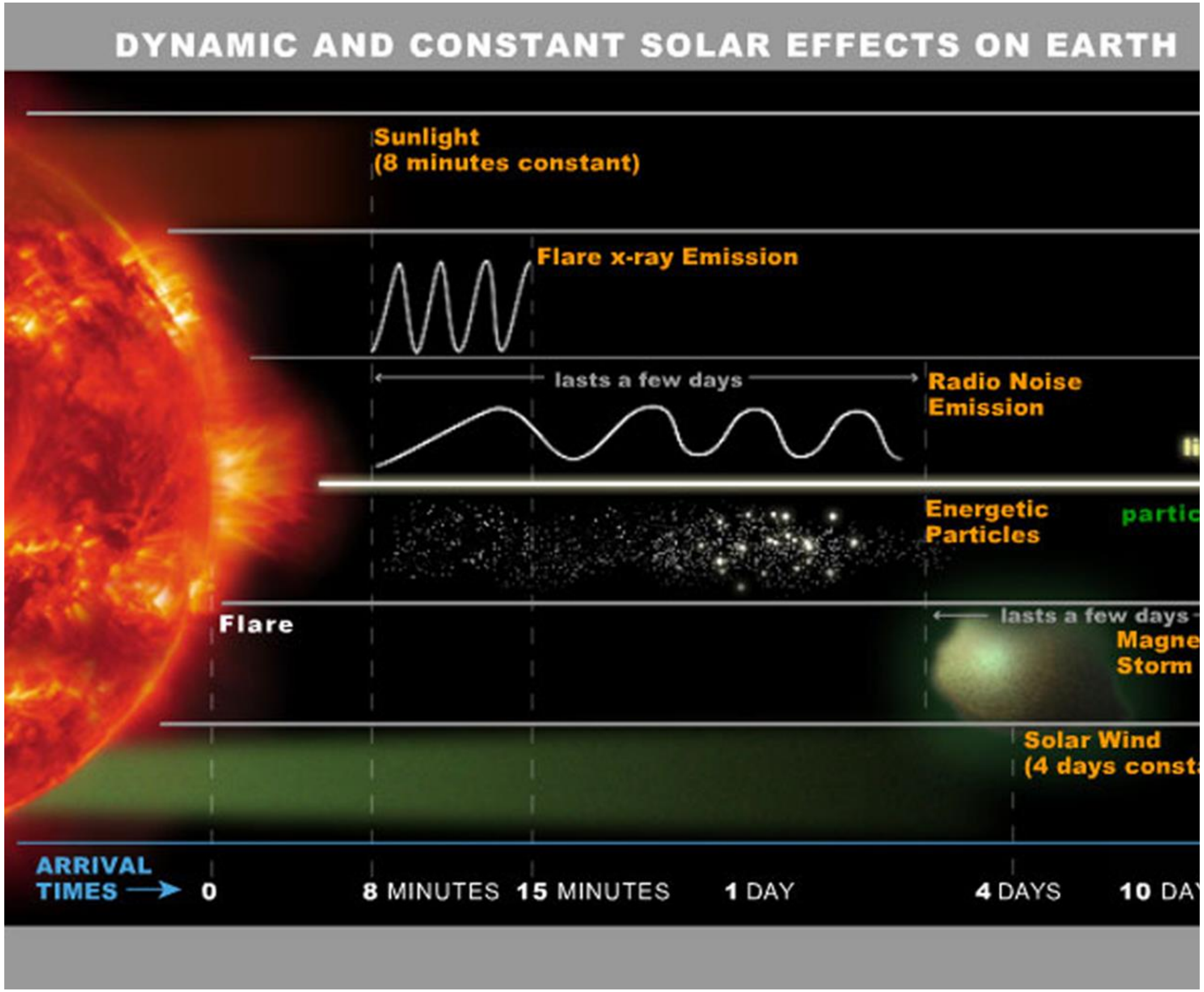
FRONTIER PRECISION

# Bob Green, PLS

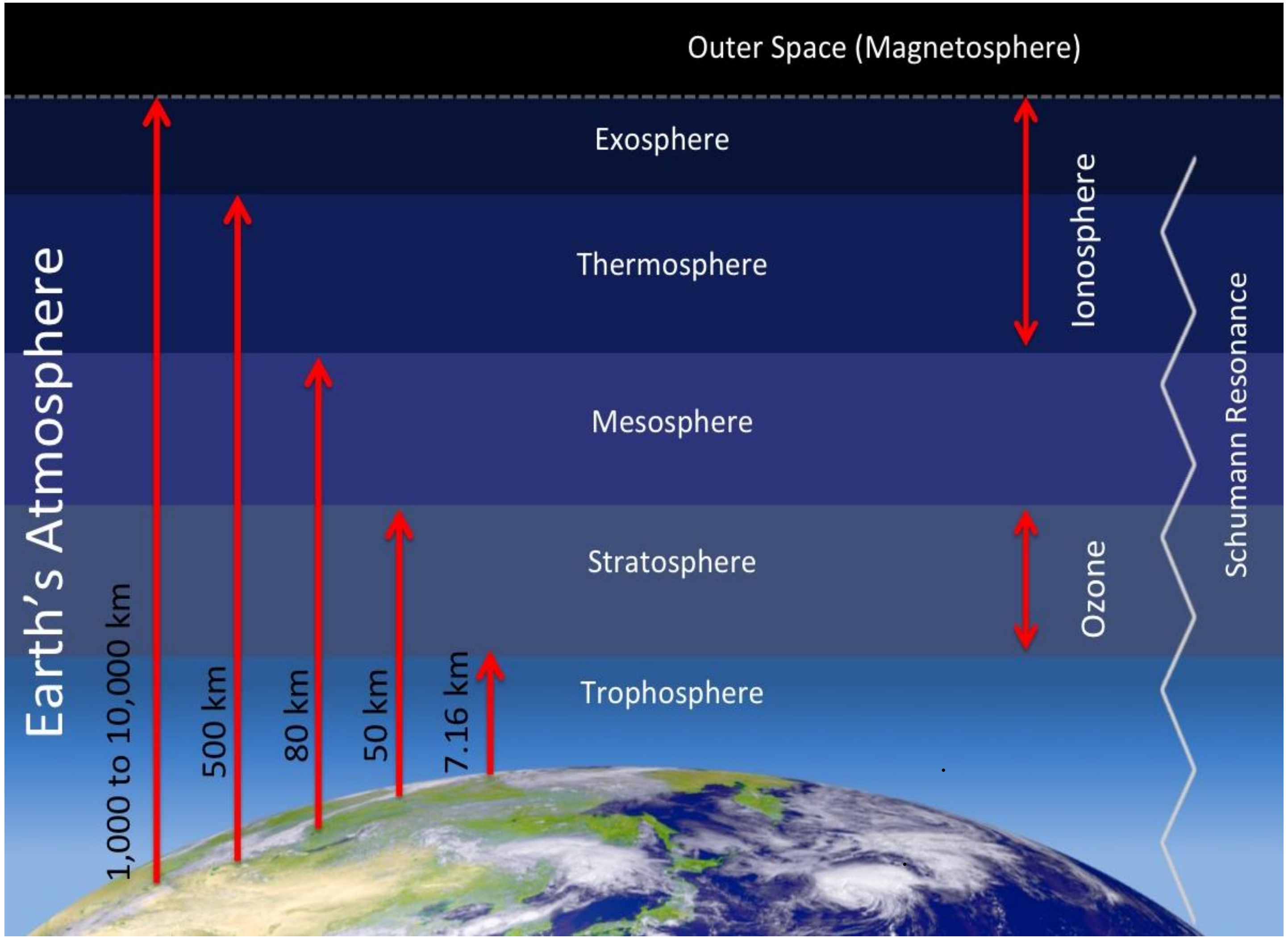
- Geospatial Analyst – Frontier Precision / 5 + Years
- Professional Land Surveyor – 32 years
    - 46 years Total Land Surveying Experience
- Past 2 Term Member of The Monitor Panel to the (NKA) Colorado State Board of Licensure for Architects, Professional Engineers and Professional Land Surveyors
- Past 2 Term Member of the Survey Engineering Industrial Advisory Committee – New Mexico State University
- Published Author, Public Speaker and Measurement Technology Advocate
- Government and Private Sector Trainer and Consultant
- Terrestrial Scanning Pioneer and Innovator

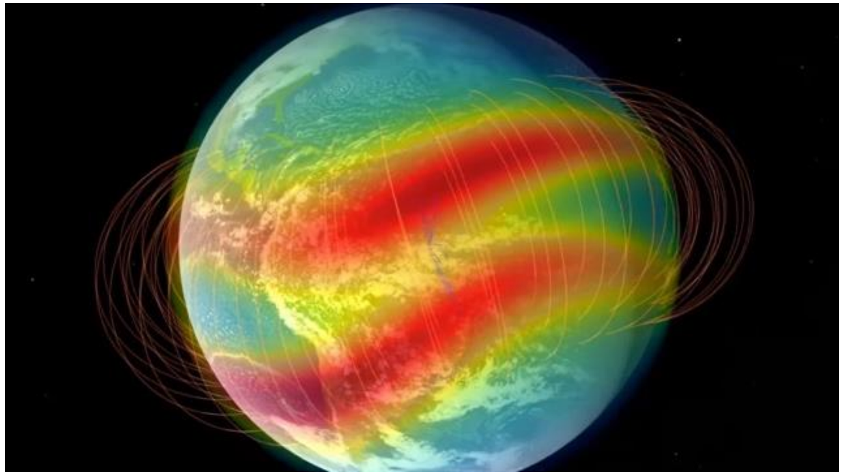

# Solar Effects and CME's Impact the Ionosphere





# EARTHS ATMOSPHERE



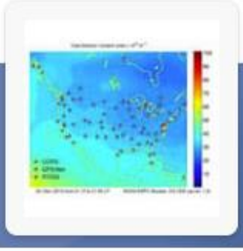



# What are *ionospheric disturbances* and how do they affect GNSS?

# TOTAL ELECTRON CONTENT and SCINTILLATION

**Total electron content**

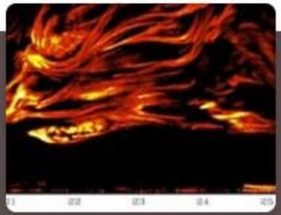
Descriptive quantity



Total electron content is an important descriptive quantity for the ionosphere of the Earth. TEC is the total number of electrons integrated between two points, along a tube of one meter squared cross...

The change in the path and velocity of radio waves in the ionosphere has a big impact on the accuracy of satellite navigation systems such as **GPS**/GNSS. Neglecting changes in the ionosphere TEC can introduce tens of meters of error in the position calculations.

Ionospheric Scintillation - Space Weather Prediction Center

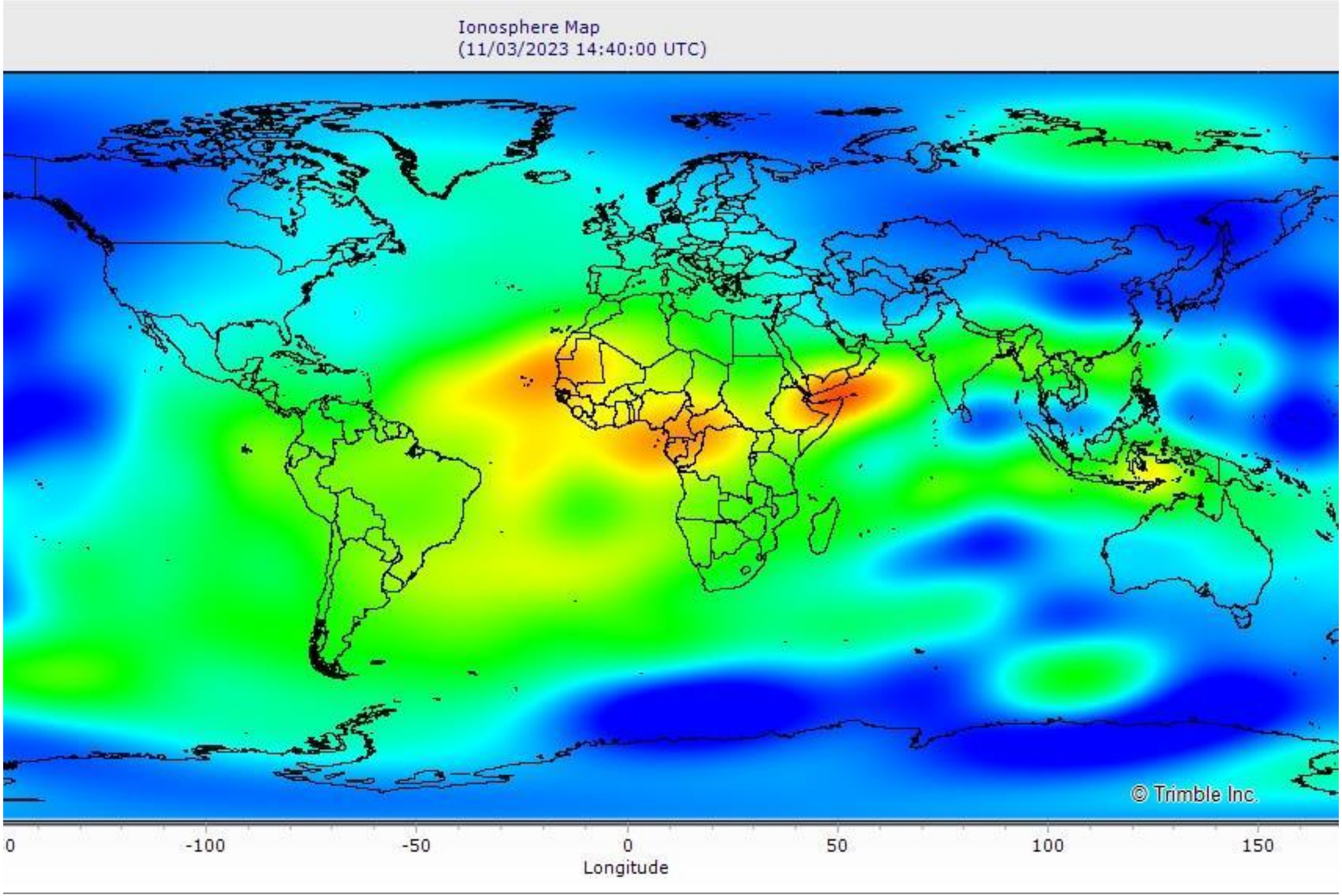


From swpc.noaa.gov

1 **What is ionospheric scintillation?**

Ionospheric scintillation is the rapid modification of radio waves caused by small scale structures in the ionosphere.

Severe scintillation conditions can prevent a GPS receiver from locking on to the signal and can make it impossible to calculate a position. Less severe scintillation conditions can reduce the accuracy and the confidence of positioning results.


Ionosphere Map
(11/03/2023 14:40:00 UTC)
© Trimble Inc.
0
-100
-50
0
50
100
150
Longitude

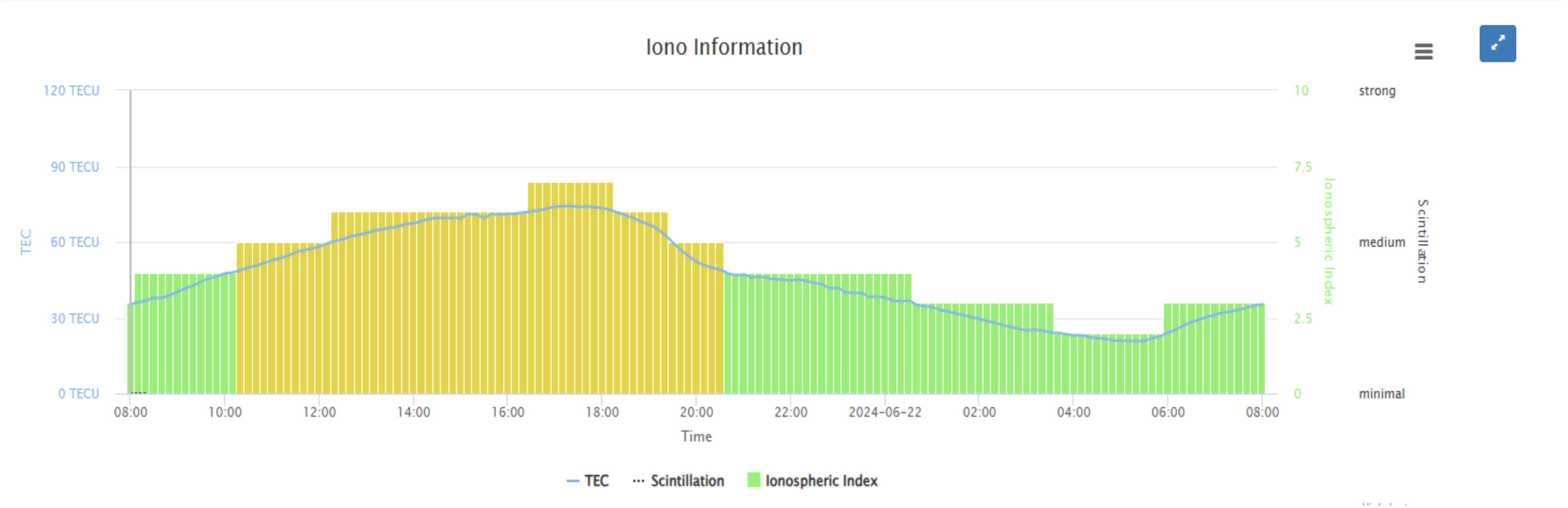
# Honolulu, Hawaii Ionosphere Information June 21, 2024

**My Settings**

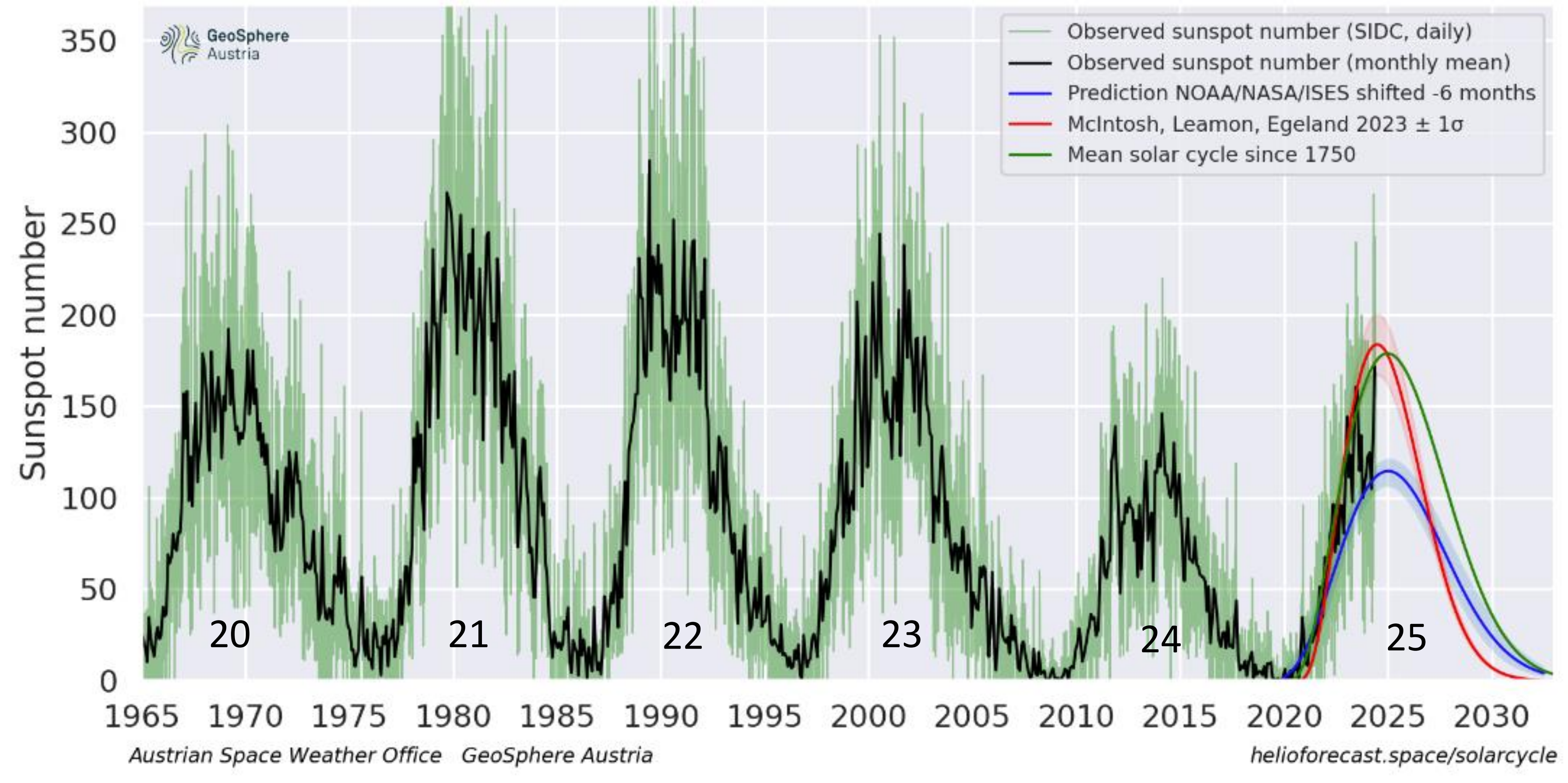
Change settings

| | |
|---|---|
| **Time of almanac:** | 2024-06-21 |
| **Time zone:** | UTC 10:00 |
| **Visible period:** | |
| 2024-06-21 08:00 - 2024-06-22 08:00 | |
| **Latitude:** | N 21° 21' 39.6472" |
| **Longitude:** | W 157° 51' 45.1758" |
| **Height:** | 1,600 m |
| **Elevation cutoff:** | 10 ° |

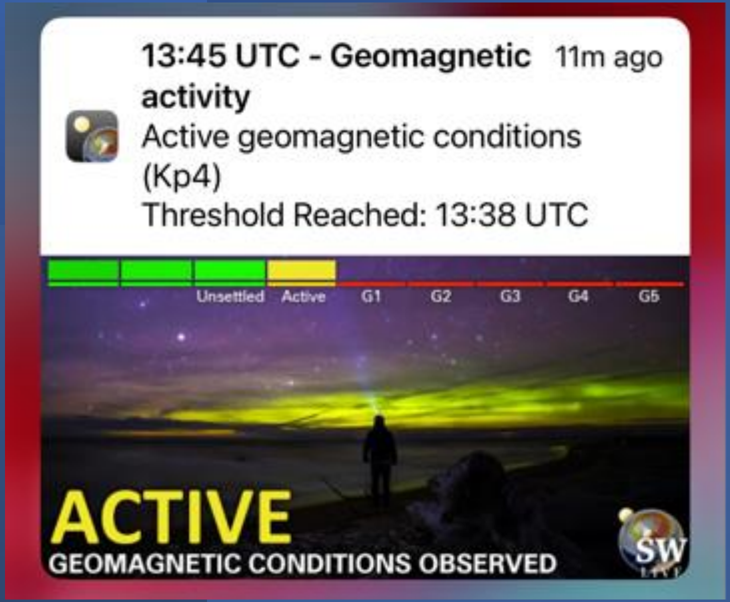
GNSS Planning Online, © 2017-2024, Trimble Inc.



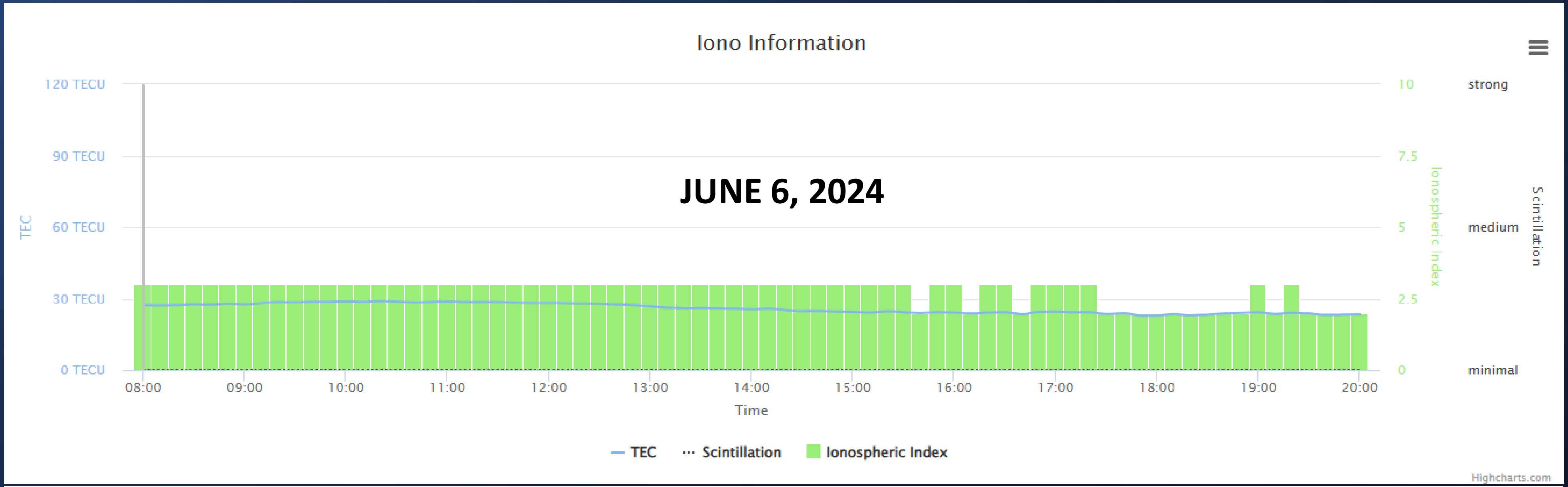
# HISTORIC SOLAR CYCLES

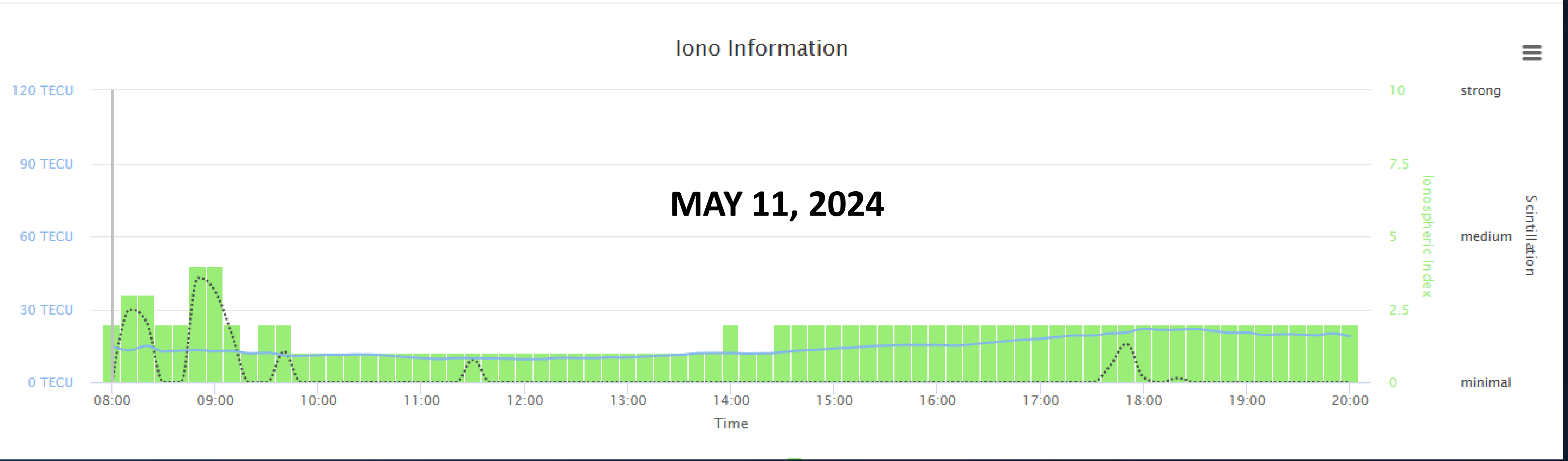


# SPACE WEATHER LIVE APP


# ANCHORAGE IONOSPHERIC TEC/INDEX/SCINTILLATION



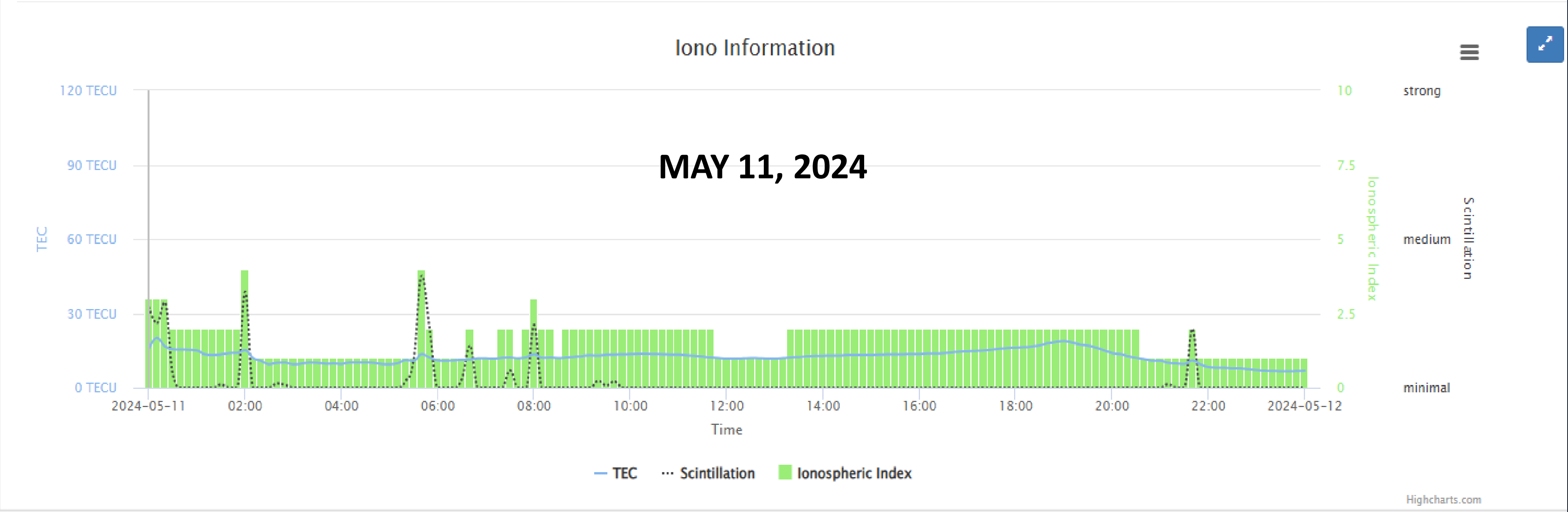
# SALEM, OR IONOSPHERIC TEC/INDEX/SCINTILLATION

**My Settings**

Change settings

| | |
|---|---|
| **Time of almanac:** | 2024-05-11 |
| **Time zone:** | UTC -7:00 |
| **Visible period:** | |
| 2024-05-11 00:00 - 2024-05-12 00:00 | |
| **Latitude:** | N 44° 56' 43.3012" |
| **Longitude:** | W 123° 1' 49.419" |
| **Height:** | 200 m |
| **Elevation cutoff:** | 10 ° |


Version: 1.8.0.0



# Receiver WebUI GPS Tracking

## Satellites - Tracking Information

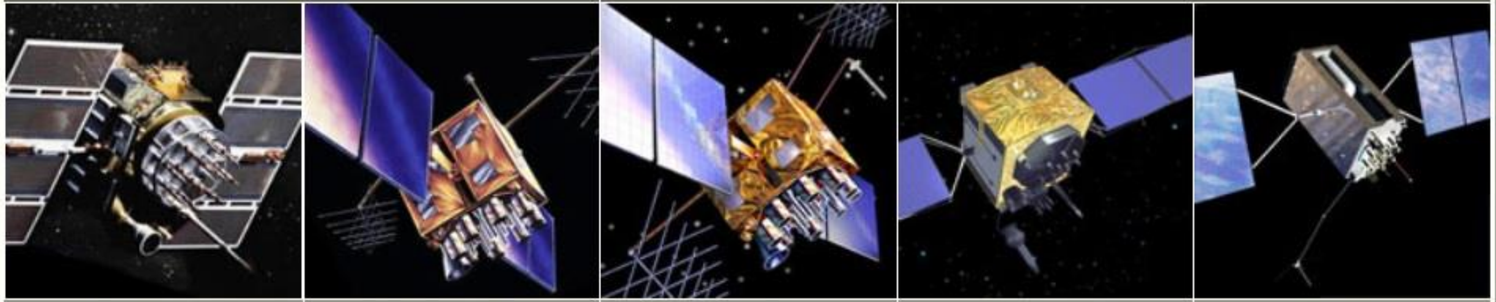
ALL | GPS | GLONASS | Galileo | BeiDou | QZSS | SBAS | MSS

| SV | Type | Elev. [°] | Azim. [°] | L1-C/No [dBHz] | L1 | L2-C/No [dBHz] | L2 | L5-C/No [dBHz] | L5 | Iono | IODE | URA [m] | Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | GPS | 13.68 | 179.48 | 38.9 | CA | 25.1/39.0 | E/CM+CL | - | - | | 3 | 2 | IIR-M |
| 6 | GPS | 47.47 | 39.95 | 48.1 | CA | 38.5/47.3 | E/CM+CL | 50.0 | I+Q | | 35 | 2 | IIF |
| 11 | GPS | 86.37 | 281.62 | 48.5/51.1 | CA/BOC | 44.5/53.8 | E/CM+CL | 55.7 | I+Q | | 122 | 2 | III |
| 12 | GPS | 58.06 | 314.93 | 48.7 | CA | 40.9/47.2 | E/CM+CL | - | - | | 14 | 2 | IIR-M |
| 17 | GPS | 10.49 | 82.45 | 39.9 | CA | 19.9/33.5 | E/CM+CL | - | - | | 108 | 2.8 | IIR-M |
| 19 | GPS | 31.08 | 69.48 | 42.8 | CA | 30.8 | E | - | - | | 21 | 2 | IIR |
| 20 | GPS | 38.67 | 162.51 | 46.4 | CA | 34.0 | E | - | - | | 50 | 2 | IIR |
| 22 | GPS | 15.69 | 135.55 | 37.9 | CA | 23.8 | E | - | - | | 51 | 2 | IIR |
| 24 | GPS | 24.25 | 230.16 | 43.2 | CA | 29.5/42.8 | E/CM+CL | 47.3 | I+Q | | 96 | 2.8 | IIF |
| 25 | GPS | 27.48 | 315.14 | 42.1 | CA | 26.9/40.3 | E/CM+CL | 44.5 | I+Q | | 20 | 2 | IIF |

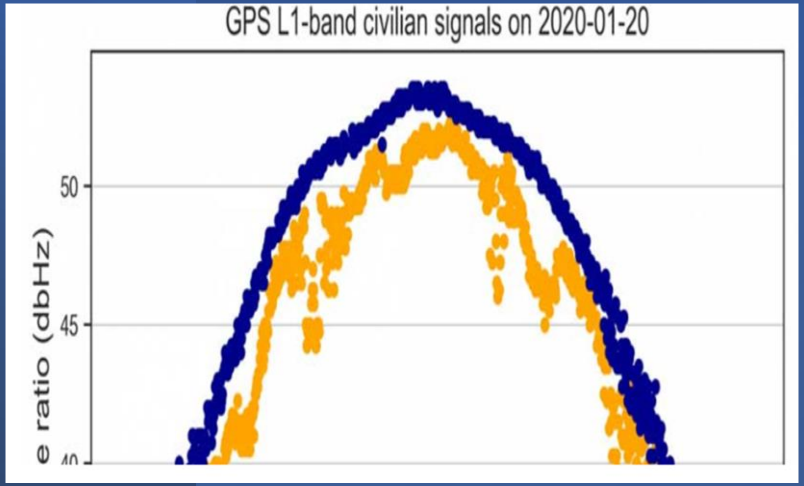
2024-06-07T16:19:14Z (UTC)

FRONTIER PRECISION

# Current GPS Satellite Constellation



| LEGACY SATELLITES | | MODERNIZED SATELLITES | | |
|---|---|---|---|---|
| BLOCK IIA | BLOCK IIR | BLOCK IIR-M | BLOCK IIF | GPS III/IIIF |
| 0 operational | 6 operational | 7 operational | 12 operational | 6 operational |
| ▪ Coarse Acquisition (C/A) code on L1 frequency for civil users<br>▪ Precise P(Y) code on L1 & L2 frequencies for military users<br>▪ 7.5-year design lifespan<br>▪ Launched in 1990-1997<br>▪ Last one decommissioned in 2019 | ▪ C/A code on L1<br>▪ P(Y) code on L1 & L2<br>▪ On-board clock monitoring<br>▪ 7.5-year design lifespan<br>▪ Launched in 1997-2004 | ▪ All legacy signals<br>▪ 2nd civil signal on L2 (L2C) LEARN MORE<br>▪ New military M code signals for enhanced jam resistance<br>▪ Flexible power levels for military signals<br>▪ 7.5-year design lifespan<br>▪ Launched in 2005-2009 | ▪ All Block IIR-M signals<br>▪ 3rd civil signal on L5 frequency (L5) LEARN MORE<br>▪ Advanced atomic clocks<br>▪ Improved accuracy, signal strength, and quality<br>▪ 12-year design lifespan<br>▪ Launched in 2010-2016 | ▪ All Block IIF signals<br>▪ 4th civil signal on L1 (L1C) LEARN MORE<br>▪ Enhanced signal reliability, accuracy, and integrity<br>▪ No Selective Availability LEARN MORE<br>▪ 15-year design lifespan<br>▪ IIIF: laser reflectors; search & rescue payload |



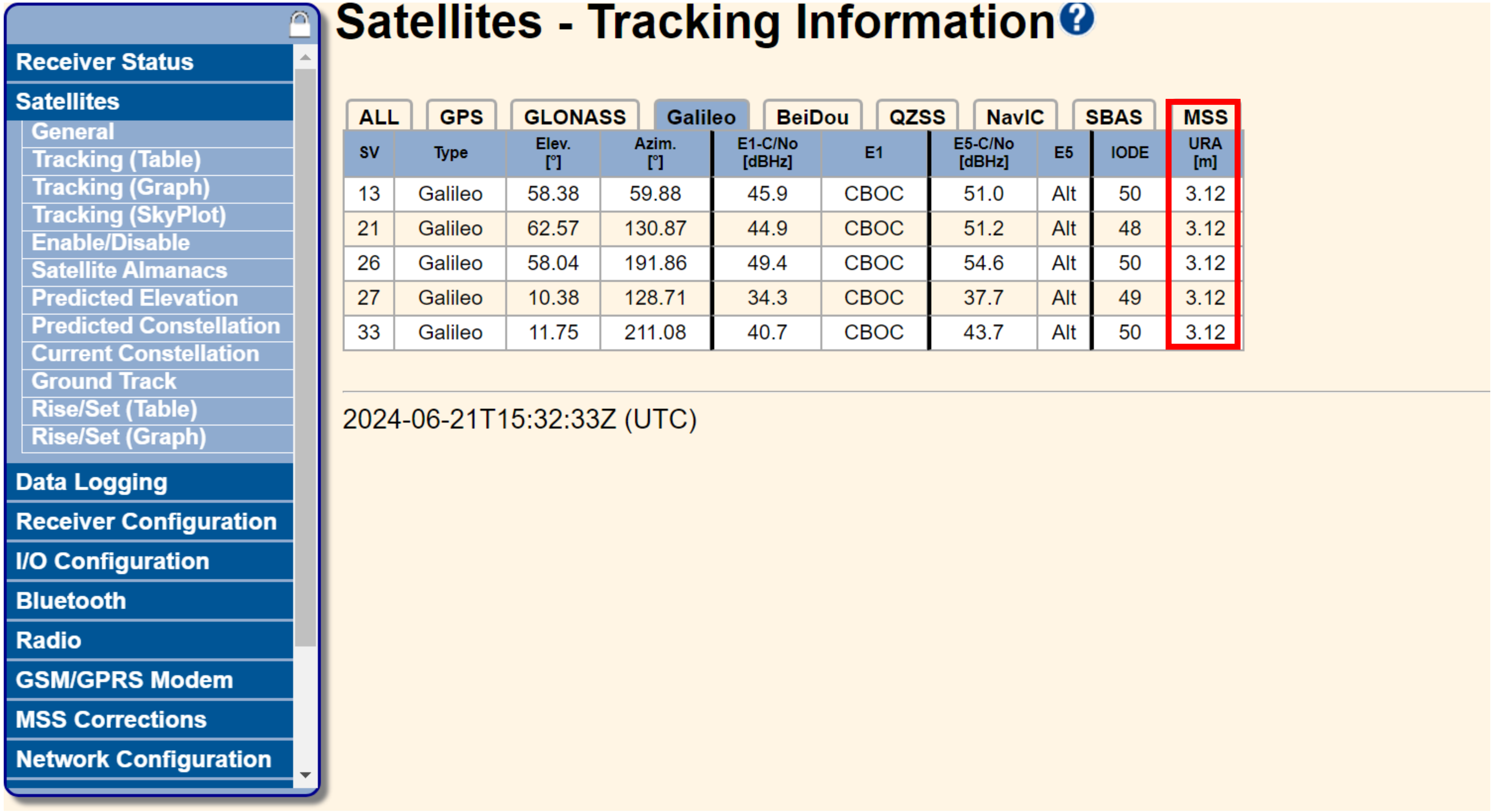

# Receiver WebUI GLONASS Tracking

ALL | GPS | **GLONASS** | Galileo | BeiDou | QZSS | SBAS | MSS

| SV | Type | Elev. [°] | Azim. [°] | L1-C/No [dBHz] | L1 | L2-C/No [dBHz] | L2 | Iono | IODE | URA [m] | Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | GLONASS | 13.30 | 81.24 | 42.8/41.3 | CA/P | 39.9/41.7 | P/CA | ● | 77 | 2 | M |
| 12 | GLONASS | 46.21 | 181.29 | 50.8/49.9 | CA/P | 46.8/48.6 | P/CA | ● | 77 | 2 | M |
| 13 | GLONASS | 67.40 | 278.20 | 39.2/38.4 | CA/P | 43.4/41.9 | P/CA | ● | 77 | 5 | M |
| 14 | GLONASS | 16.06 | 329.75 | 42.2/41.7 | CA/P | 37.1/39.1 | P/CA | ● | 77 | 2.5 | M |
| 22 | GLONASS | 32.60 | 34.49 | 47.0/46.4 | CA/P | 42.6/44.3 | P/CA | ● | 77 | 4 | M |
| 23 | GLONASS | 58.95 | 321.54 | 48.9/47.0 | CA/P | - | P/CA | ● | 77 | 4 | M |
| 24 | GLONASS | 22.28 | 257.73 | 46.4/45.1 | CA/P | 39.9/41.7 | P/CA | ● | 77 | 5 | M |

2024-06-07T16:29:17Z (UTC)

# Receiver WebUI GALILEO Tracking



Receiver Status
Satellites
General
Tracking (Table)
Tracking (Graph)
Tracking (SkyPlot)
Enable/Disable
Satellite Almanacs
Predicted Elevation
Predicted Constellation
Current Constellation
Ground Track
Rise/Set (Table)
Rise/Set (Graph)
Data Logging
Receiver Configuration
I/O Configuration
Bluetooth
Radio
GSM/GPRS Modem
MSS Corrections
Network Configuration

## Satellites - Tracking Information

ALL | GPS | GLONASS | Galileo | BeiDou | QZSS | NavIC | SBAS | MSS

| SV | Type | Elev. [°] | Azim. [°] | E1-C/No [dBHz] | E1 | E5-C/No [dBHz] | E5 | IODE | URA [m] |
|---|---|---|---|---|---|---|---|---|---|
| 13 | Galileo | 58.38 | 59.88 | 45.9 | CBOC | 51.0 | Alt | 50 | 3.12 |
| 21 | Galileo | 62.57 | 130.87 | 44.9 | CBOC | 51.2 | Alt | 48 | 3.12 |
| 26 | Galileo | 58.04 | 191.86 | 49.4 | CBOC | 54.6 | Alt | 50 | 3.12 |
| 27 | Galileo | 10.38 | 128.71 | 34.3 | CBOC | 37.7 | Alt | 49 | 3.12 |
| 33 | Galileo | 11.75 | 211.08 | 40.7 | CBOC | 43.7 | Alt | 50 | 3.12 |

2024-06-21T15:32:33Z (UTC)

# Galileo Satellite Constellation Update

GPS WORLD
GNSS POSITIONING NAVIGATION TIMING

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## SpaceX successfully launches Galileo GNSS satellites

April 30, 2024 - By Jesse Khalil

Photo: SpaceX

On April 27, 2024 the SpaceX Falcon 9 medium-lift launch vehicle launched into orbit Galileo satellites GM25 and FM27 from Kennedy Space Center in Florida. This was Falcon 9's 20th and final launch.

The EU Agency for the Space Programme (EUSPA) confirmed in a statement that it is now in the Launch and Early Orbit Phase (LEOP) stage of the two new L12 Galileo satellites. They will join the current Galileo operational fleet in the upcoming months. The latest batch of

E AGENCY

APPLICATIONS

## Galileo satellites

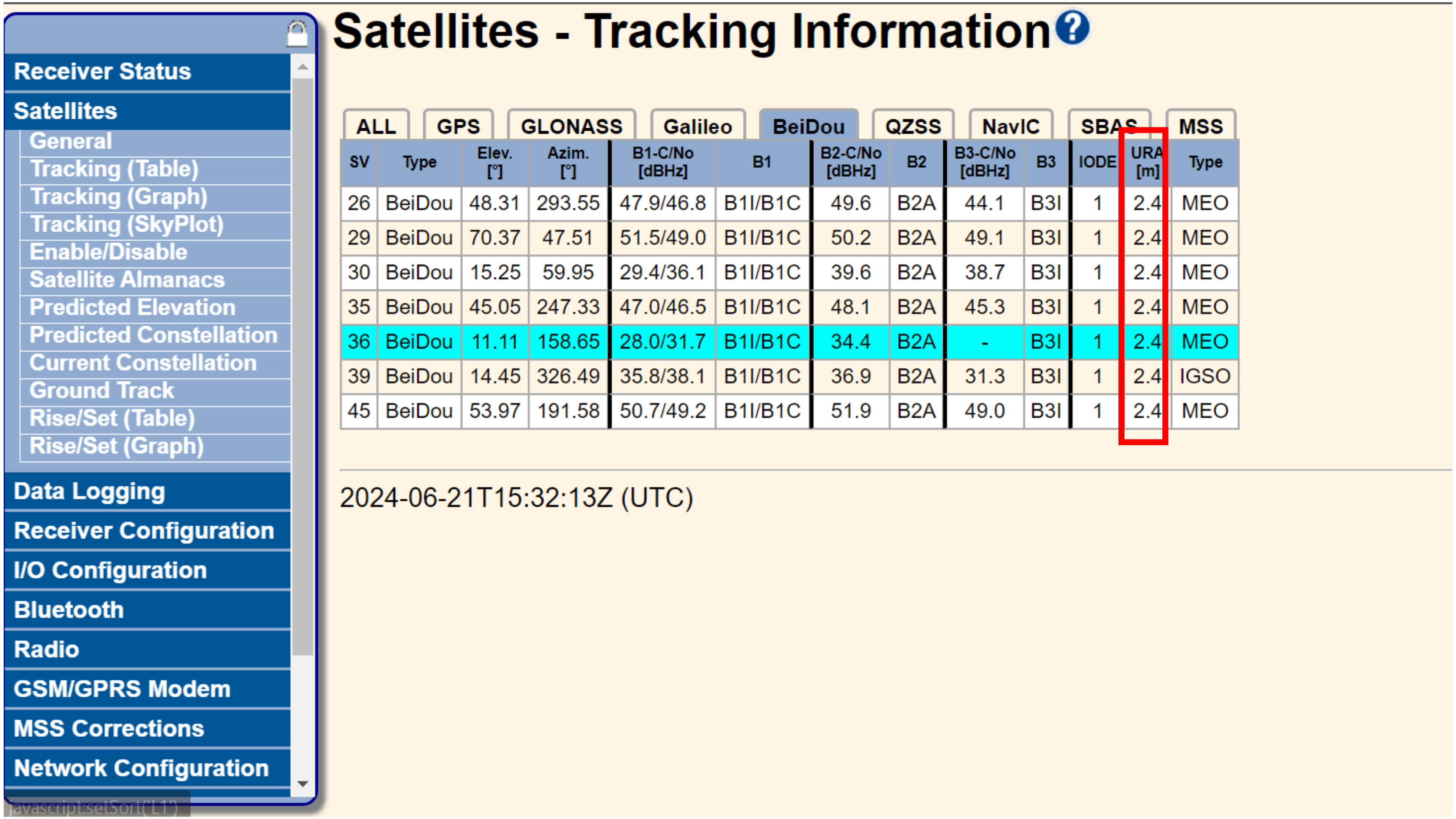
58393 VIEWS 92 LIKES

ESA / Applications / Satellite navigation / Galileo

The Galileo Space Segment will comprise a constellation of a total of 30 Medium Earth Orbit (MEO) satellites, of which 3 are spares, in a so-called Walker 27/3/1 constellation.

Currently, 23 satellites are operational, 2 are under commissioning, 4 are not usable and 1 was retired. The remaining 8 FOC satellites have completed manufacturing and testing. They are currently in storage awaiting launch by Falcon 9 and Ariane 6.

# Receiver WebUI BeiDOU Tracking




| SV | Type | Elev. [°] | Azim. [°] | B1-C/No [dBHz] | B1 | B2-C/No [dBHz] | B2 | B3-C/No [dBHz] | B3 | IODE | URA [m] | Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | BeiDou | 48.31 | 293.55 | 47.9/46.8 | B1I/B1C | 49.6 | B2A | 44.1 | B3I | 1 | 2.4 | MEO |
| 29 | BeiDou | 70.37 | 47.51 | 51.5/49.0 | B1I/B1C | 50.2 | B2A | 49.1 | B3I | 1 | 2.4 | MEO |
| 30 | BeiDou | 15.25 | 59.95 | 29.4/36.1 | B1I/B1C | 39.6 | B2A | 38.7 | B3I | 1 | 2.4 | MEO |
| 35 | BeiDou | 45.05 | 247.33 | 47.0/46.5 | B1I/B1C | 48.1 | B2A | 45.3 | B3I | 1 | 2.4 | MEO |
| 36 | BeiDou | 11.11 | 158.65 | 28.0/31.7 | B1I/B1C | 34.4 | B2A | - | B3I | 1 | 2.4 | MEO |
| 39 | BeiDou | 14.45 | 326.49 | 35.8/38.1 | B1I/B1C | 36.9 | B2A | 31.3 | B3I | 1 | 2.4 | IGSO |
| 45 | BeiDou | 53.97 | 191.58 | 50.7/49.2 | B1I/B1C | 51.9 | B2A | 49.0 | B3I | 1 | 2.4 | MEO |

2024-06-21T15:32:13Z (UTC)

# BeiDOU Satellite Constellation Update

GPS WORLD GNSS POSITIONING NAVIGATION TIMING

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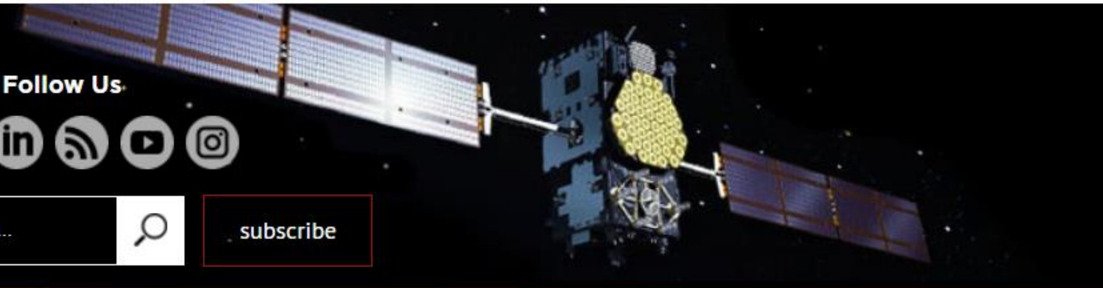

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## China's BeiDou challenges US GPS dominance

October 26, 2023 - By Jesse Khalil

Est.

Image: imaginima/iStock/Getty Images Plus/Getty Images

**Recent launch and surveillance fears**

On May 16, 2023, China launched its most recent BeiDou satellite to replenish the constellation, bringing its total to 56 satellites, nearly twice as many as the 31 GPS satellites.

The latest BeiDou satellites also feature two-way messaging, a feature that GPS does not have. It is mainly available in China and requires special chips that are not widely available in the consumer market. It enables users to send short messages in areas without ground network cell coverage and can be used for search and rescue operations.

The CNBC report noted the fear that, with its most recent enhancements, the BeiDou system could be used as a surveillance device — as the two-way messaging feature reveals a user's locations as well as other types of data.

Trimble

# Trimble IonoGuard

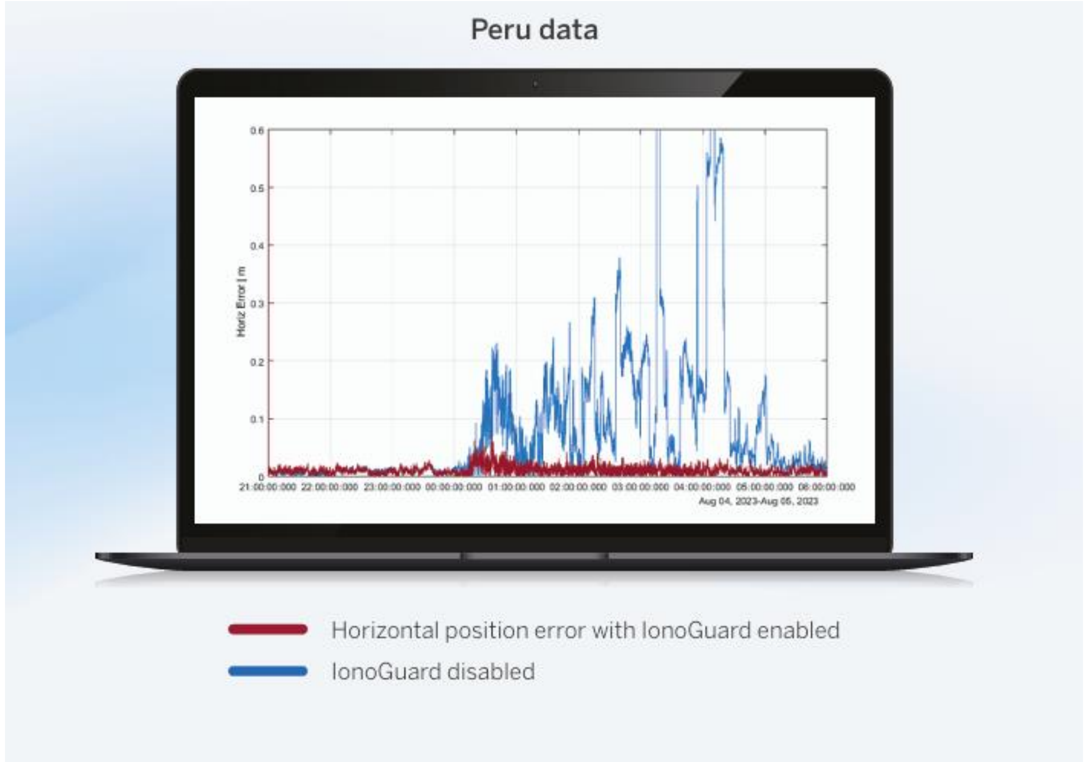
## Protecting RTK GNSS from Ionospheric disturbances

Minimum Receiver Firmware
Version 6.23/ProPoint

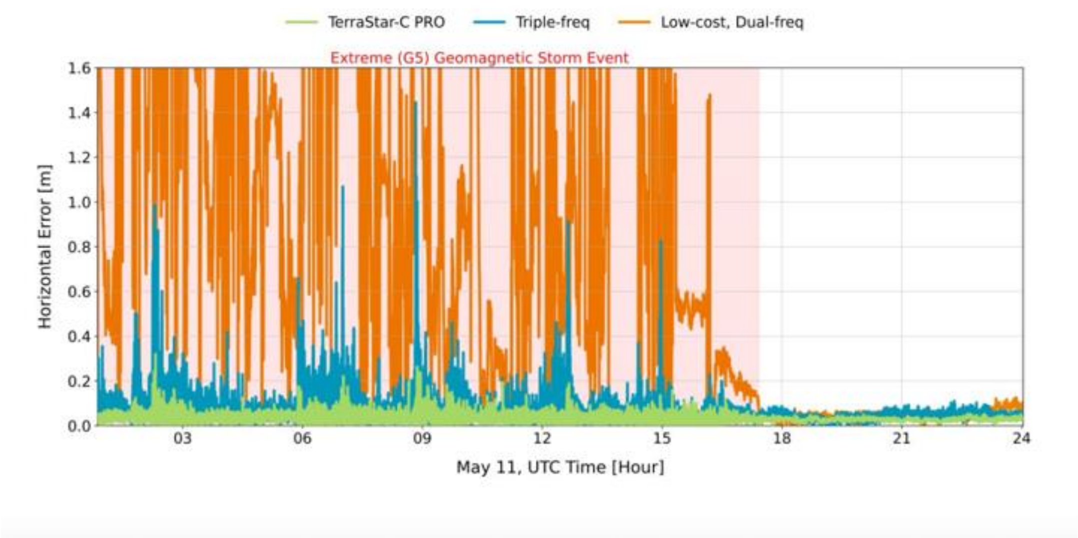
FRONTIER PRECISION
How You Measure Matters
— An Employee-Owned Company —
35

# IONOSPHERIC MITIGATION PLATFORMS

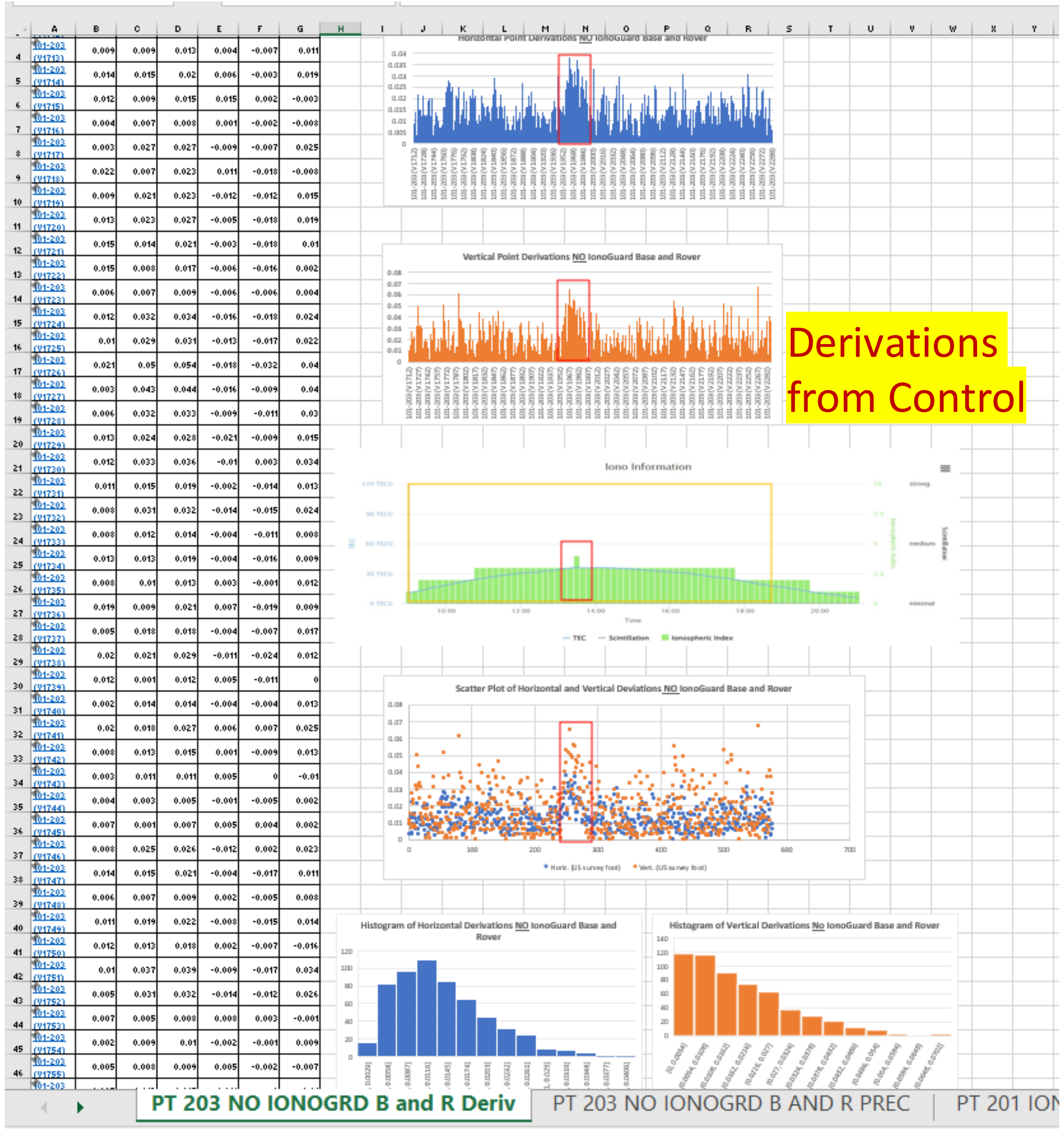
## TRIMBLE NAVIGATION

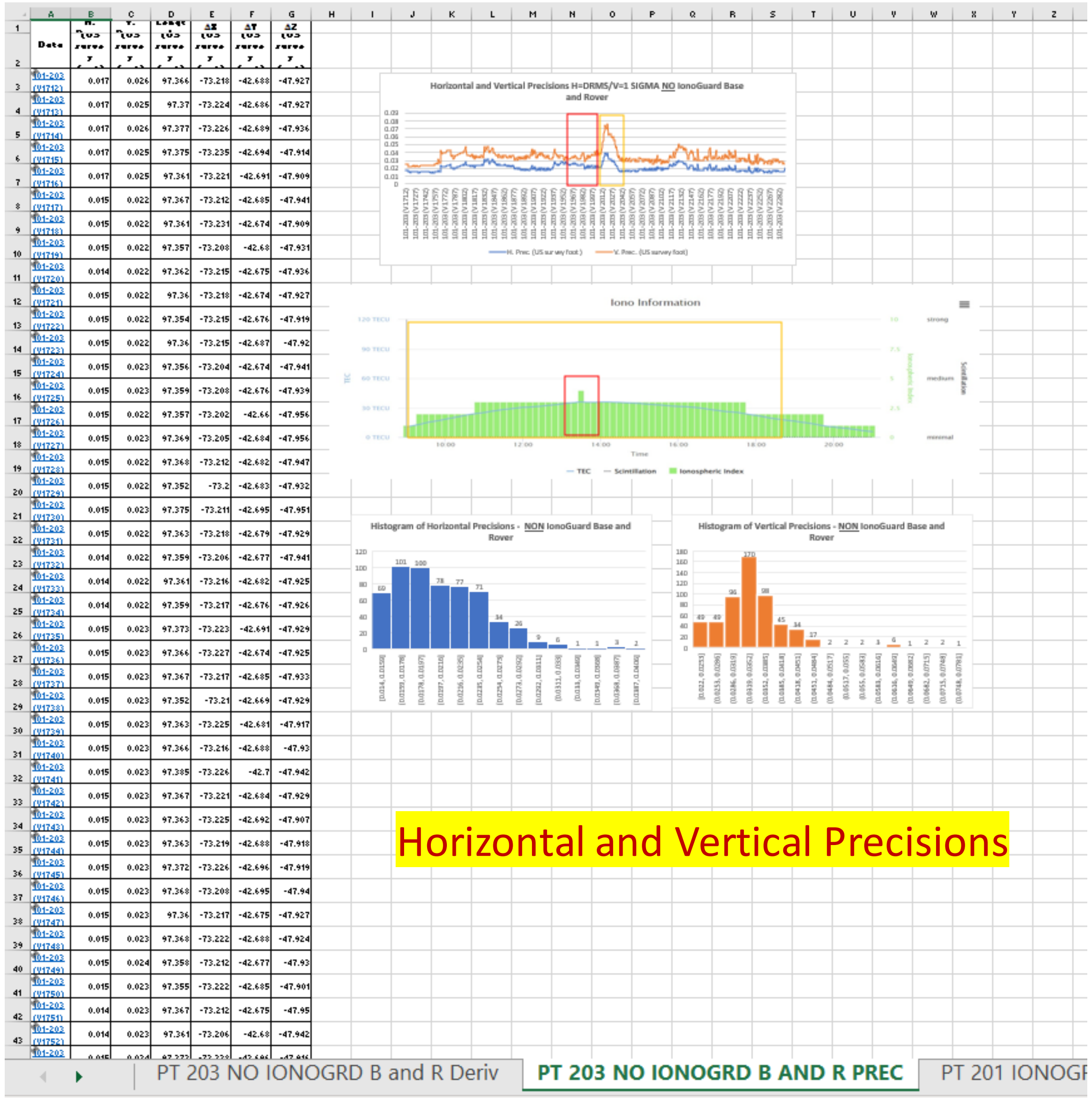



## NOVATEL



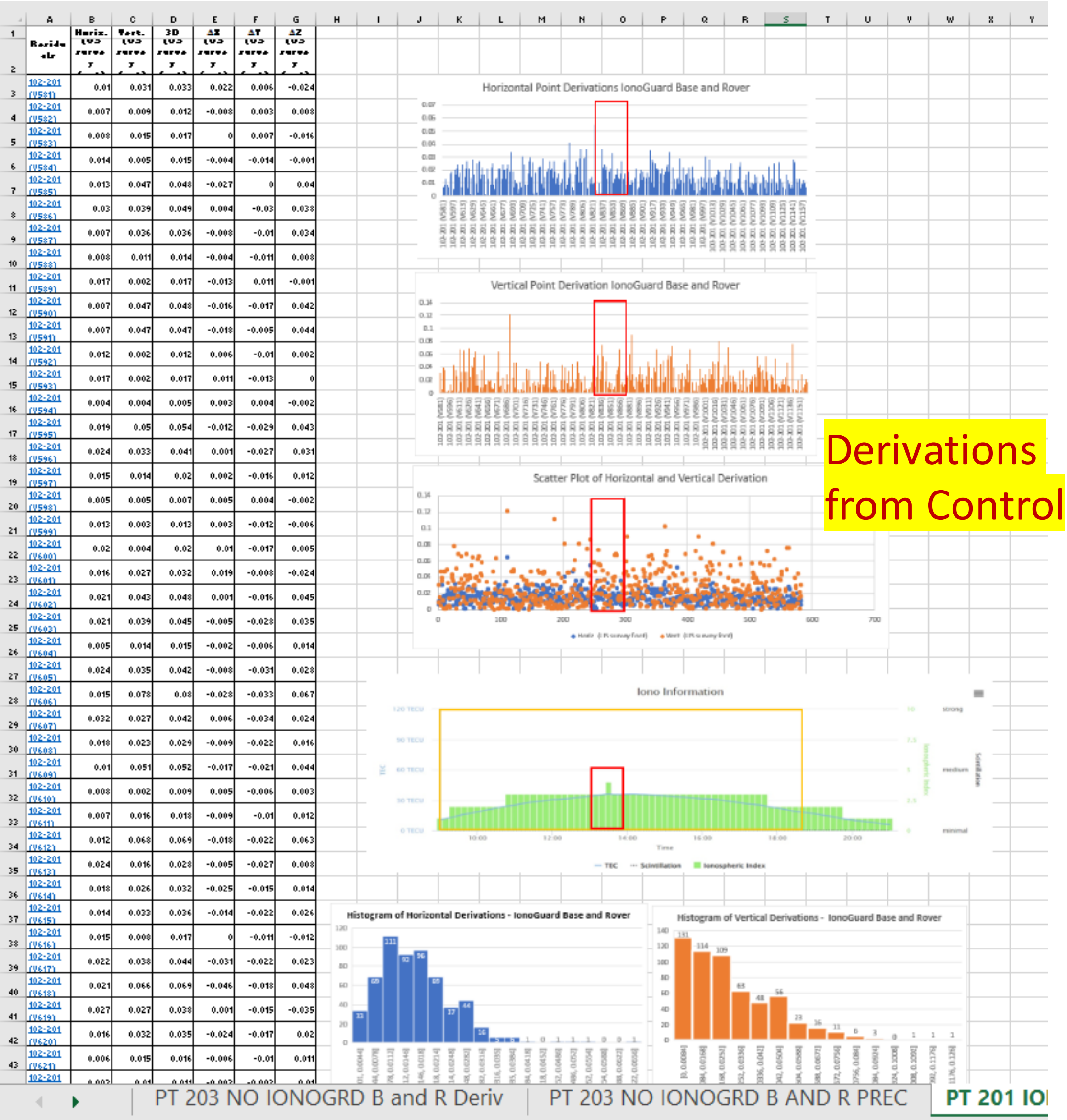
# Trimble IonoGuard Testing in Anchorage 2-3-24

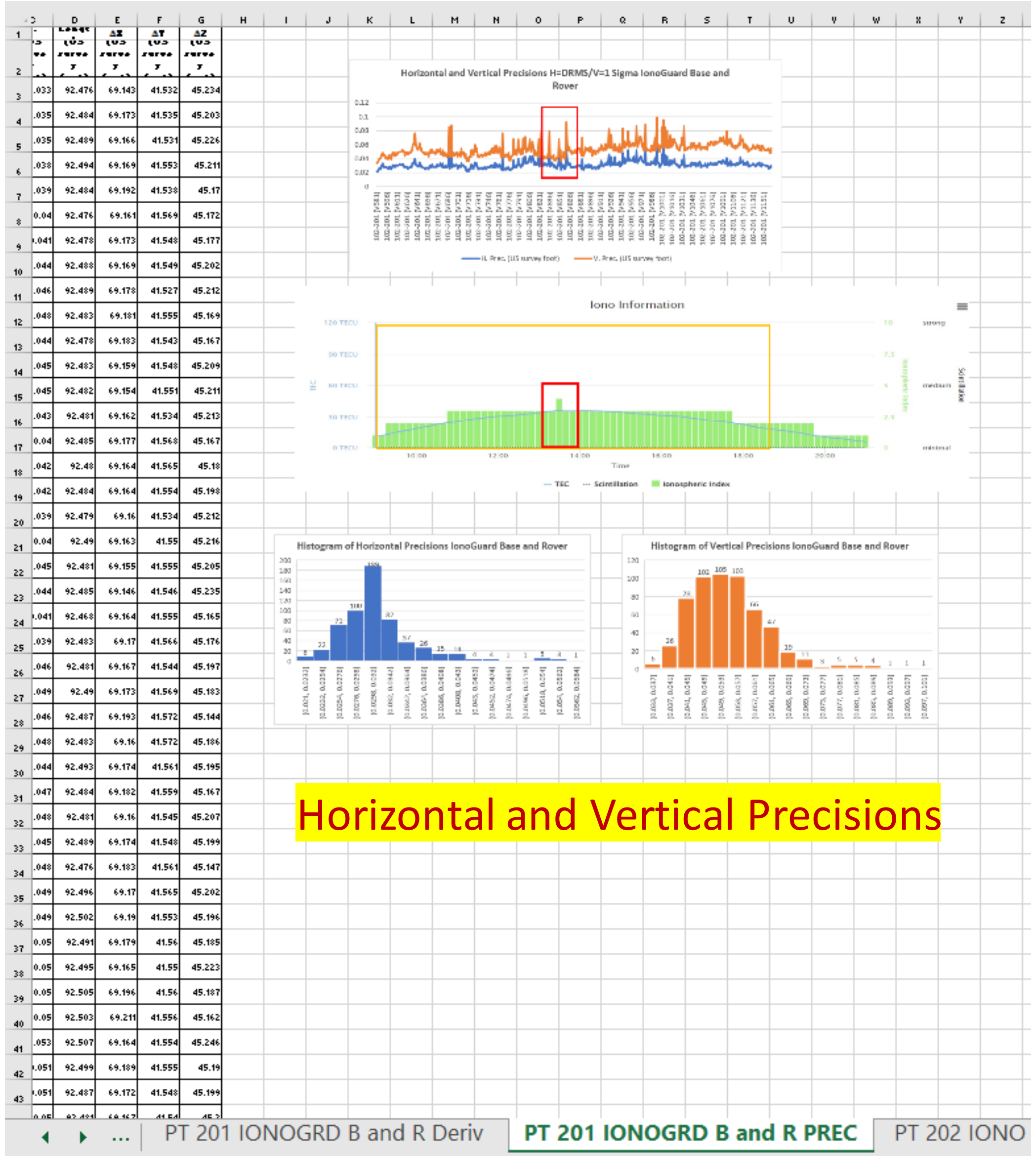



No IONOGUARD at Base and Rover

# Trimble IonoGuard Testing in Anchorage 2-3-24

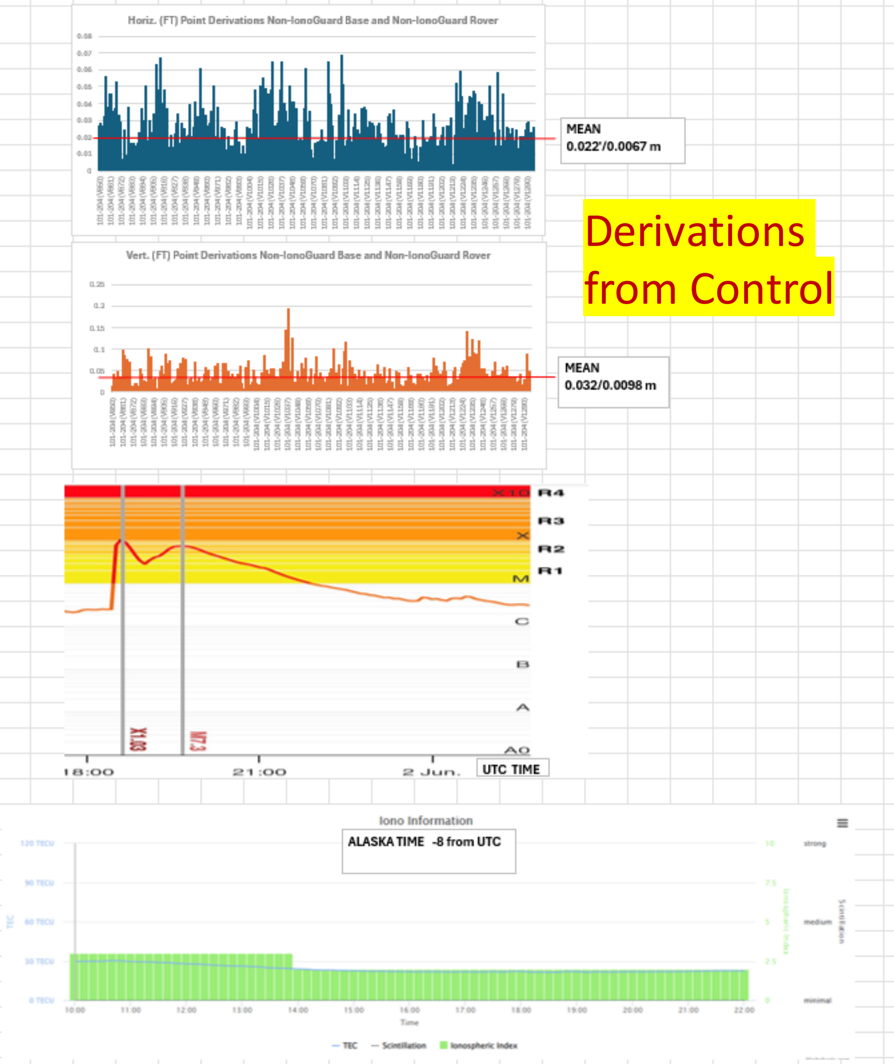



## IONOGUARD Base and Rover

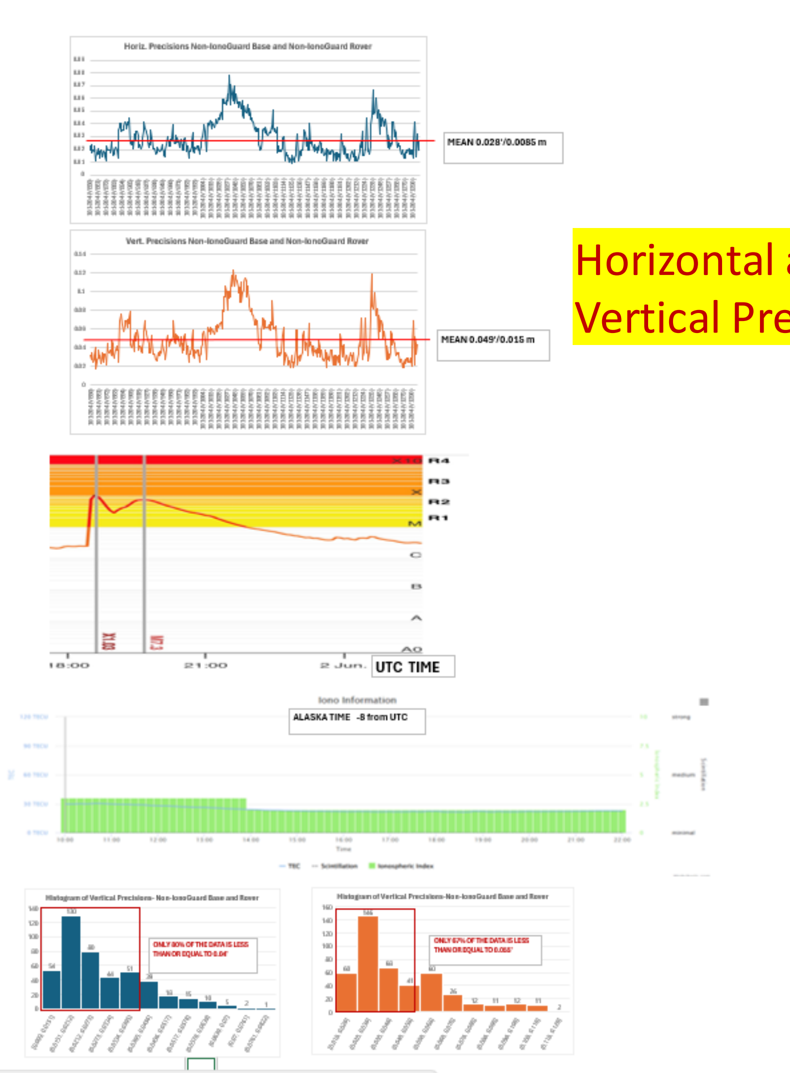
# Trimble IonoGuard Testing in Anchorage 6-1-24

| Residual | Horiz. (US survey feet) | Vert. (US survey feet) | 3D (US survey | ΔX (US survey | ΔY (US survey | ΔZ (US survey |
|---|---|---|---|---|---|---|
| 101-204 (V850) | 0.027 | 0.014 | 0.03 | 0.013 | -0.022 | 0.016 |
| 101-204 (V851) | 0.028 | 0.041 | 0.05 | 0.006 | -0.024 | 0.044 |
| 101-204 (V852) | 0.027 | 0.036 | 0.045 | -0.03 | -0.027 | 0.02 |
| 101-204 (V853) | 0.026 | 0.028 | 0.038 | -0.021 | -0.029 | 0.014 |
| 101-204 (V854) | 0.011 | 0.033 | 0.035 | 0.004 | 0.008 | -0.033 |
| 101-204 (V855) | 0.032 | 0.036 | 0.048 | 0 | -0.016 | -0.046 |
| 101-204 (V856) | 0.056 | 0.048 | 0.073 | -0.007 | -0.031 | -0.066 |
| 101-204 (V857) | 0.033 | 0.022 | 0.04 | -0.016 | -0.009 | -0.036 |
| 101-204 (V858) | 0.038 | 0.035 | 0.052 | -0.02 | 0.007 | -0.048 |
| 101-204 (V859) | 0.025 | 0.011 | 0.027 | -0.018 | 0.004 | -0.02 |
| 101-204 (V860) | 0.046 | 0.002 | 0.046 | -0.027 | -0.029 | -0.023 |
| 101-204 (V861) | 0.041 | 0.072 | 0.083 | -0.005 | 0.009 | -0.082 |
| 101-204 (V862) | 0.046 | 0.098 | 0.108 | 0.004 | 0.006 | -0.108 |
| 101-204 (V863) | 0.035 | 0.085 | 0.092 | 0.009 | 0.005 | -0.091 |
| 101-204 (V864) | 0.025 | 0.051 | 0.057 | -0.001 | 0.015 | -0.055 |
| 101-204 (V865) | 0.028 | 0.015 | 0.032 | -0.017 | -0.005 | -0.027 |
| 101-204 (V866) | 0.037 | 0.075 | 0.084 | 0.009 | -0.005 | -0.083 |
| 101-204 (V867) | 0.053 | 0.064 | 0.083 | -0.008 | -0.016 | -0.081 |
| 101-204 (V868) | 0.023 | 0.071 | 0.074 | 0.013 | 0.005 | -0.073 |
| 101-204 (V869) | 0.018 | 0.003 | 0.018 | -0.012 | -0.007 | -0.011 |
| 101-204 (V870) | 0.033 | 0.011 | 0.035 | -0.014 | -0.02 | -0.025 |
| 101-204 (V871) | 0.029 | 0.005 | 0.029 | -0.002 | 0.027 | 0.012 |
| 101-204 (V872) | 0.02 | 0.015 | 0.025 | -0.012 | 0.007 | -0.021 |
| 101-204 (V873) | 0.005 | 0.006 | 0.008 | -0.003 | -0.006 | 0.003 |
| 101-204 (V874) | 0.007 | 0.019 | 0.02 | 0.007 | -0.002 | -0.019 |
| 101-204 (V875) | 0.02 | 0.013 | 0.024 | -0.004 | -0.022 | 0.006 |
| 101-204 (V876) | 0.024 | 0.02 | 0.031 | 0.004 | 0.013 | 0.028 |
| 101-204 (V877) | 0.009 | 0.012 | 0.015 | -0.011 | -0.008 | 0.006 |
| 101-204 (V878) | 0.007 | 0.009 | 0.011 | -0.001 | -0.002 | -0.011 |
| 101-204 (V879) | 0.038 | 0.013 | 0.04 | 0.008 | 0.029 | 0.026 |
| 101-204 (V880) | 0.02 | 0.053 | 0.057 | 0.024 | 0.031 | -0.04 |
| 101-204 (V881) | 0.008 | 0.043 | 0.044 | 0.021 | 0.003 | -0.039 |
| 101-204 (V882) | 0.01 | 0.021 | 0.023 | 0.002 | 0 | -0.023 |
| 101-204 (V883) | 0.016 | 0.022 | 0.027 | -0.004 | -0.001 | -0.027 |
| 101-204 (V884) | 0.013 | 0.027 | 0.03 | 0.012 | -0.006 | -0.027 |
| 101-204 (V885) | 0.016 | 0.009 | 0.018 | -0.01 | 0.007 | -0.013 |
| 101-204 (V886) | 0.008 | 0.015 | 0.017 | -0.001 | 0.002 | 0.017 |
| 101-204 (V887) | 0.013 | 0.022 | 0.026 | -0.008 | -0.018 | 0.017 |
| 101-204 (V888) | 0.015 | 0.023 | 0.028 | -0.013 | -0.019 | 0.015 |
| 101-204 (V889) | 0.016 | 0.1 | 0.101 | -0.04 | -0.009 | 0.093 |




Derivations from Control

PT 204 DERIV. NON IONO B and R | PT 204 PREC. NON IONO B and R | PT202 Deriv. IONO B and

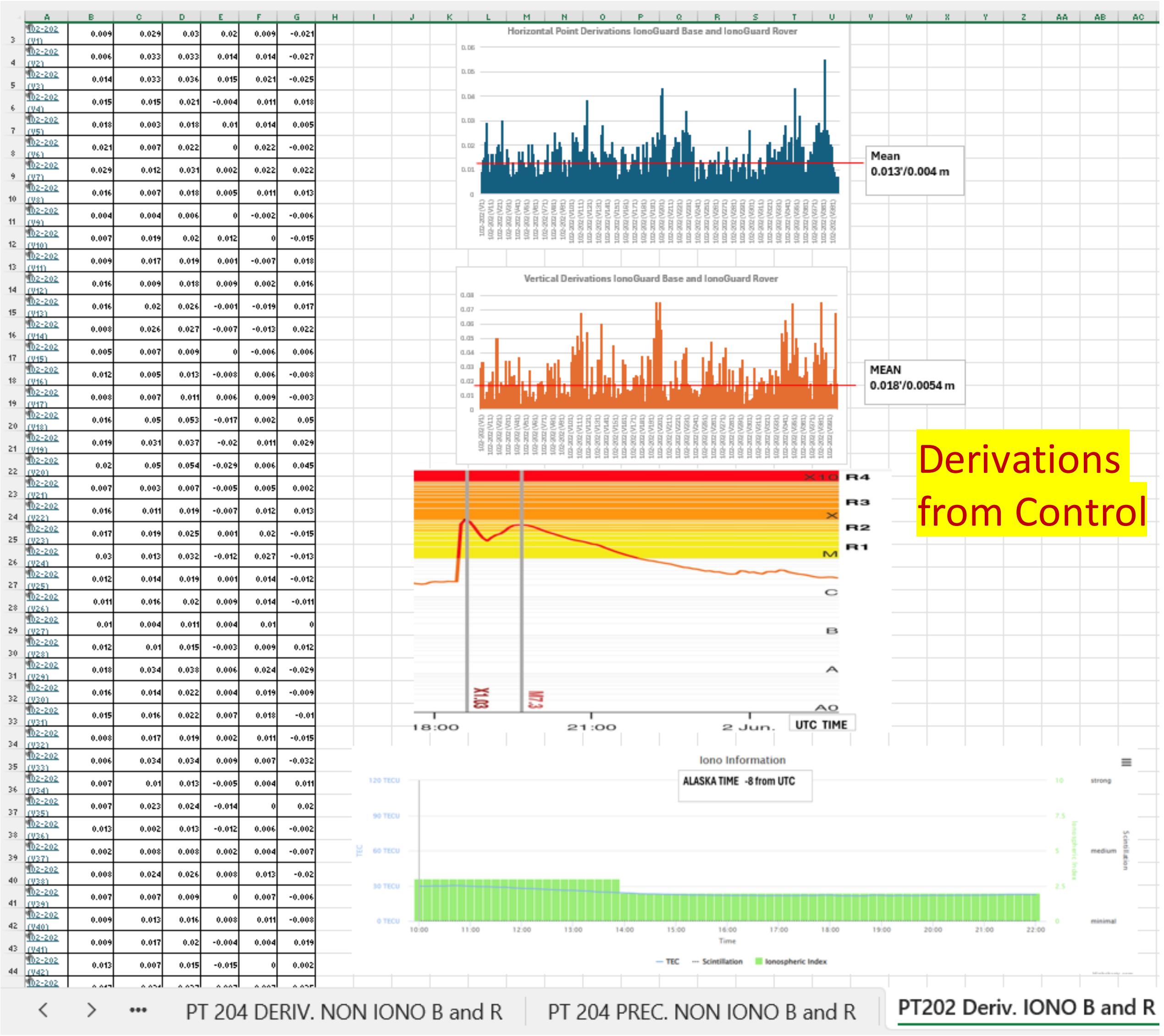



Horizontal and Vertical Precisions

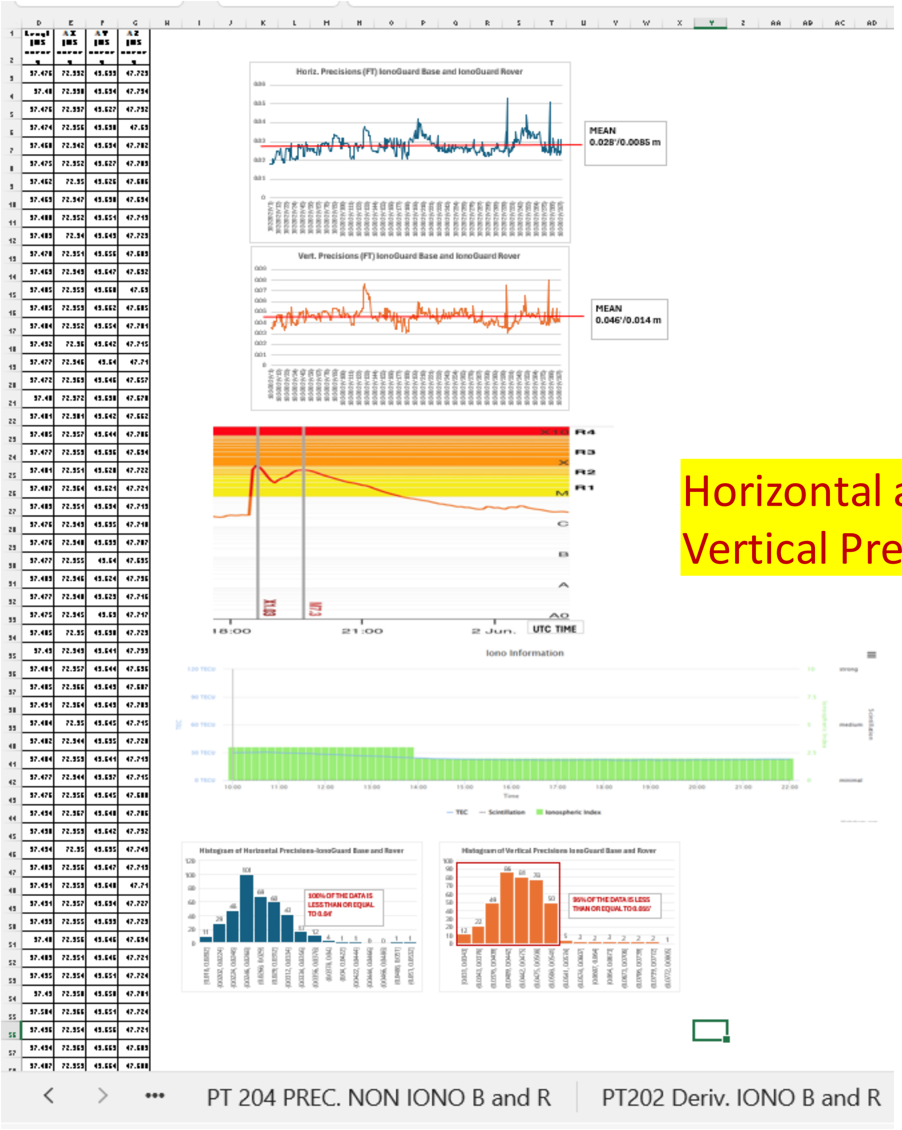
PT 204 DERIV. NON IONO B and R | PT 204 PREC. NON IONO B and

No IONOGUARD at Base and Rover

# Trimble IonoGuard Testing in Anchorage 6-1-24




Derivations from Control




Horizontal and Vertical Precisions

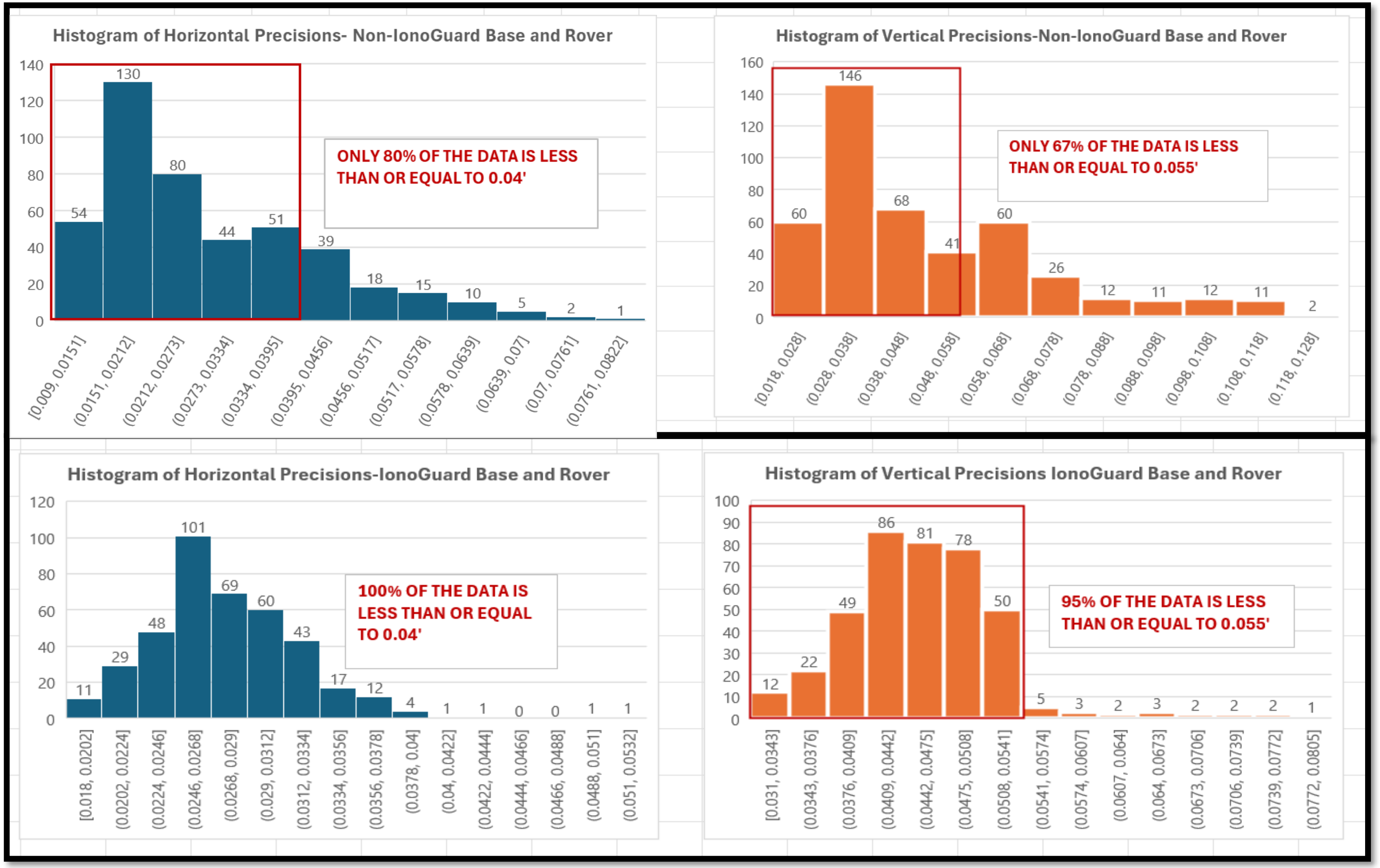
IONOGUARD at Base and Rover

# Trimble IonoGuard Testing in Anchorage 6-1-24

## Precision Histogram Details

NON - IONOGUARD

IONOGUARD



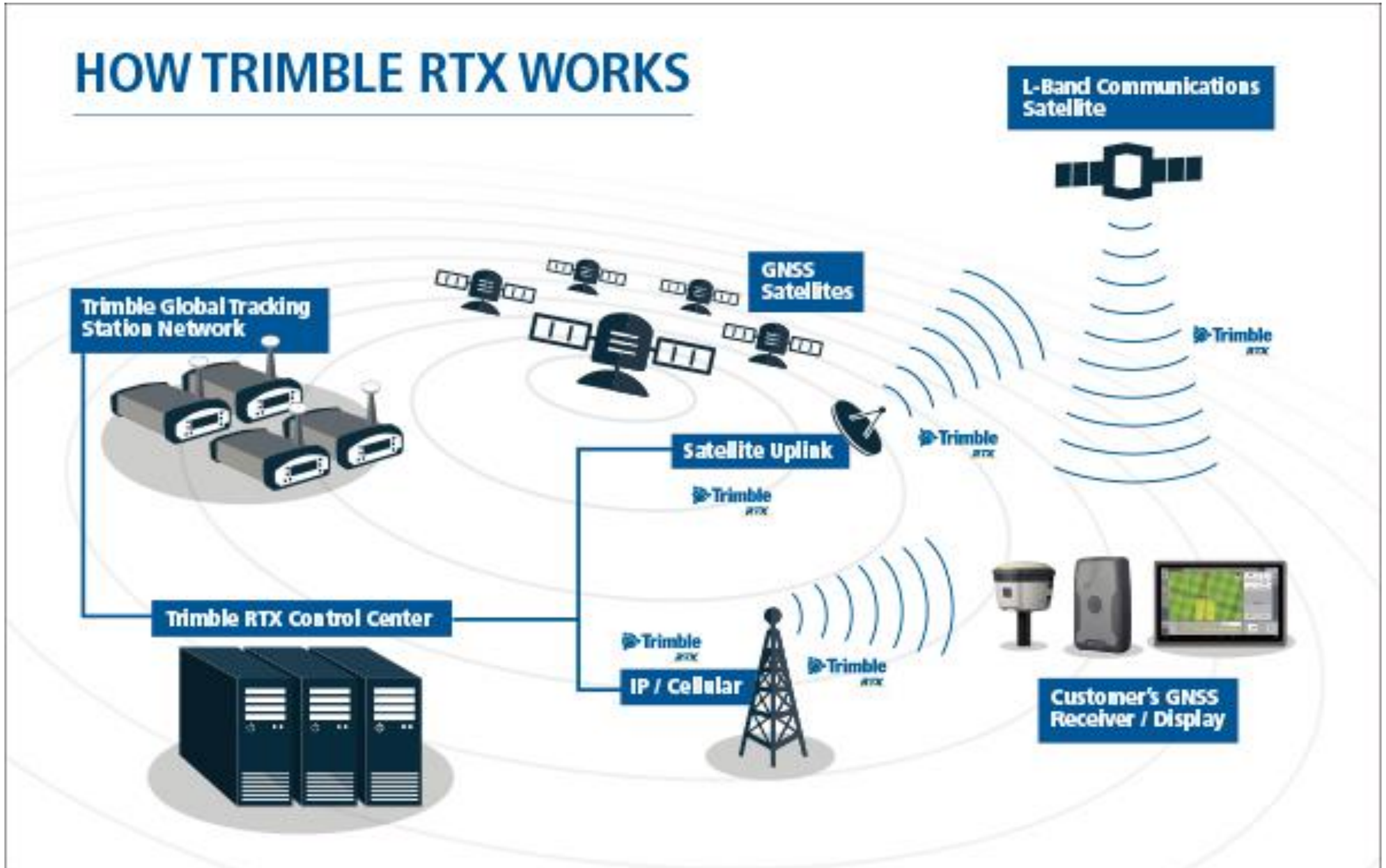
# WHAT IS PRECISE POINT POSITIONING (PPP)RTX™

**W**ide **A**rea **A**ugmentation **S**ystem **WAAS** was Certified By the FAA in 2003. Currently 3 Satellites in orbit. Prior to President Bill Clinton discontinuing Selective Availability autonomous GPS was +/- 100meters.

**OmniSTAR** is a satellite-based augmentation system (SBAS) service provider. OmniSTAR correction signals are proprietary, and a subscription must be bought from the OmniSTAR corporation to receive a subscription authorization. OmniSTAR uses geostationary satellites in eight regions covering most of the landmass of each inhabited continent on Earth:

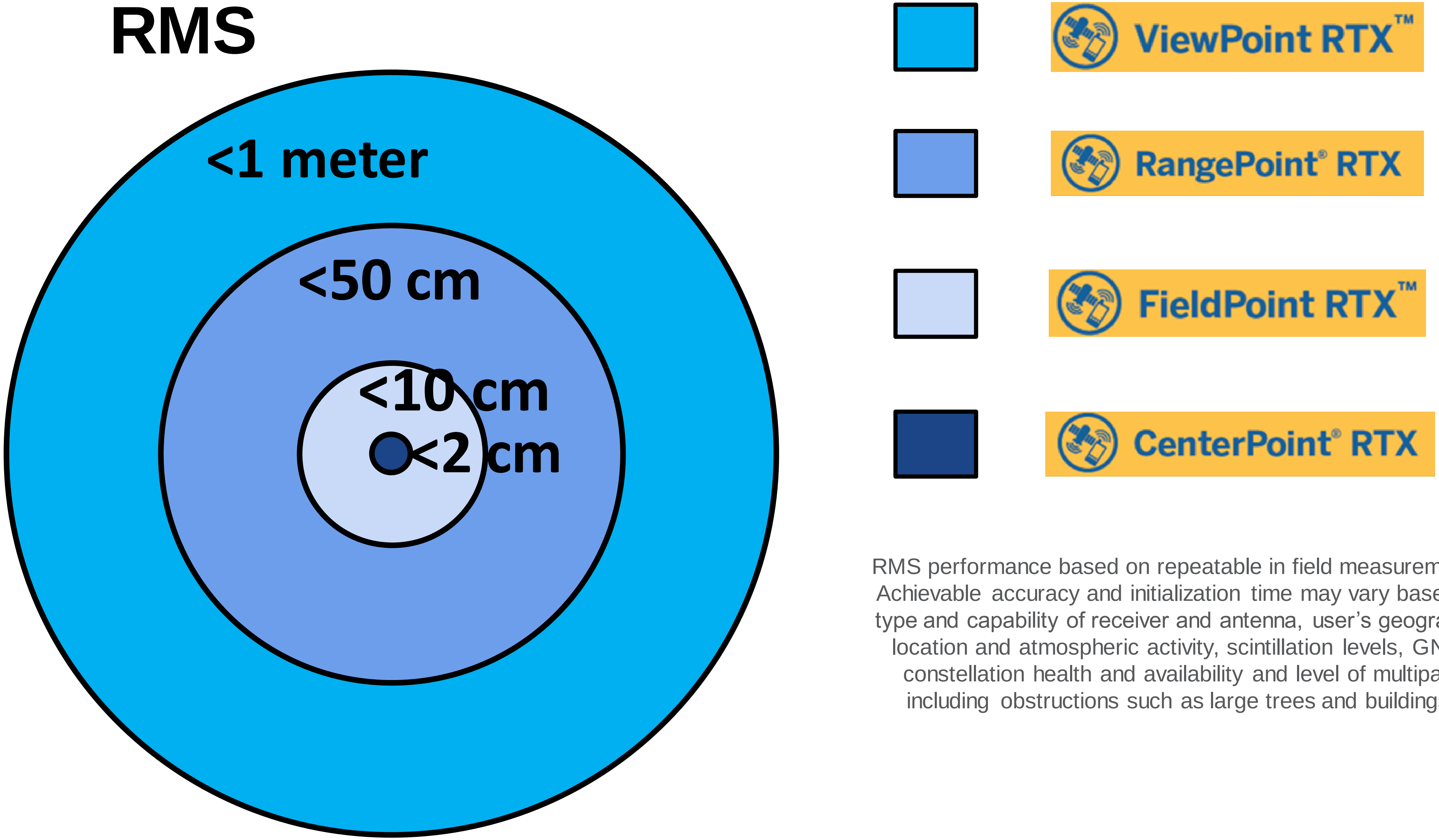
**HEXAGON TERRASTAR** “RTK From The Sky” PPP Technology
**Sub-Inch Accuracy**: TerraStar offers centimeter-level positioning accuracy for applications like **precision agriculture**. This high precision is available **worldwide.**
**Multi-Constellation Corrections**: TerraStar provides corrections for multiple satellite constellations. These corrections are accessible through compatible **NovAtel GNSS/GPS receivers**

# TRIMBLE RTX – HOW IT WORKS



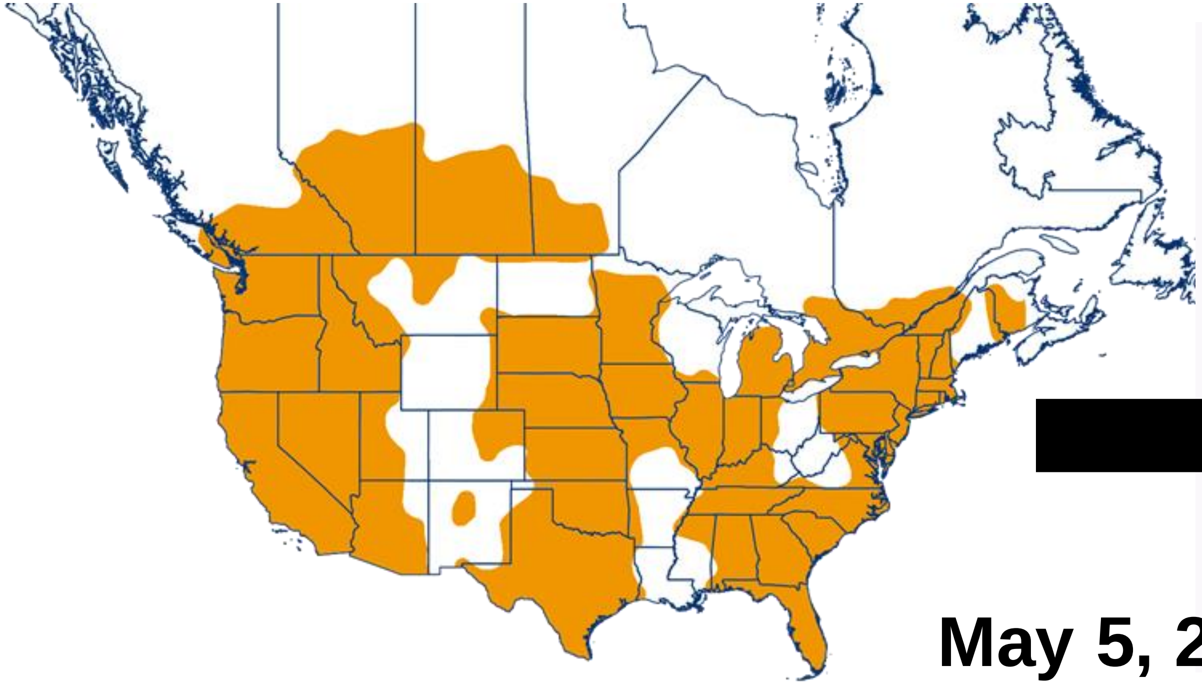

## RTN/ORGN INFILL SOLUTIONS

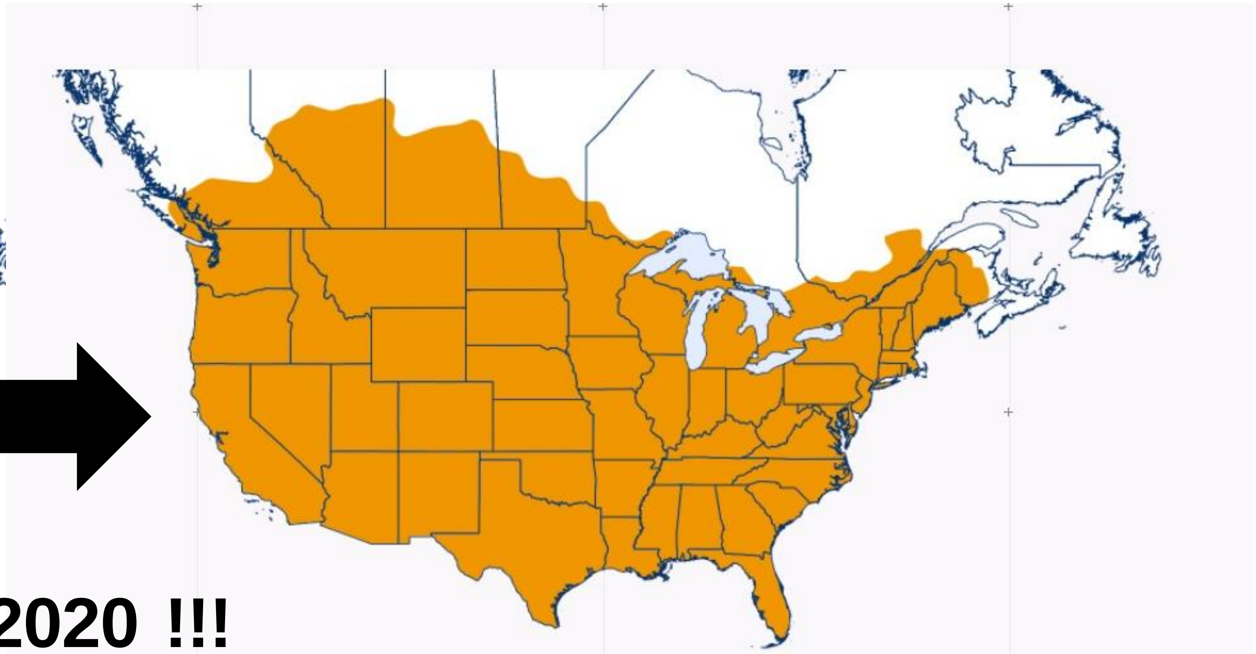
# RMS




RMS performance based on repeatable in field measurements. Achievable accuracy and initialization time may vary based on type and capability of receiver and antenna, user's geographic location and atmospheric activity, scintillation levels, GNSS constellation health and availability and level of multipath including obstructions such as large trees and buildings.

# RTX FAST SERVICE COMPLETED FOR CONUS!!





**May 5, 2020 !!!**

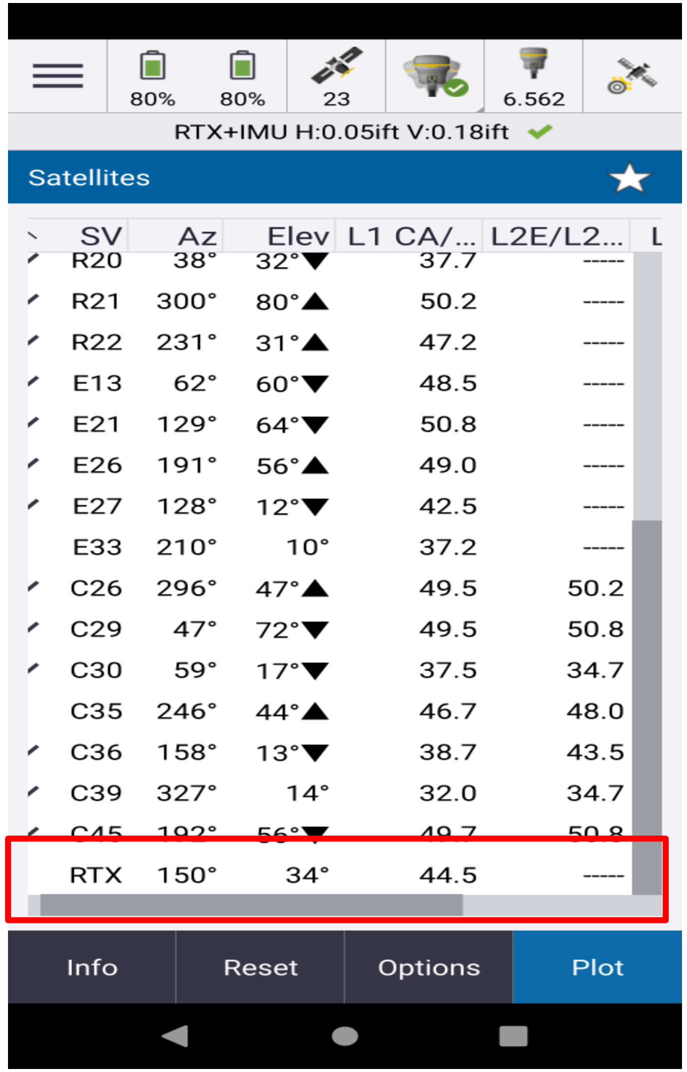
ND | SD | MN | CO | AK | MT | ID | HI | WY | UT | OR | WA
FRONTIER PRECISION
AN EMPLOYEE-OWNED COMPANY

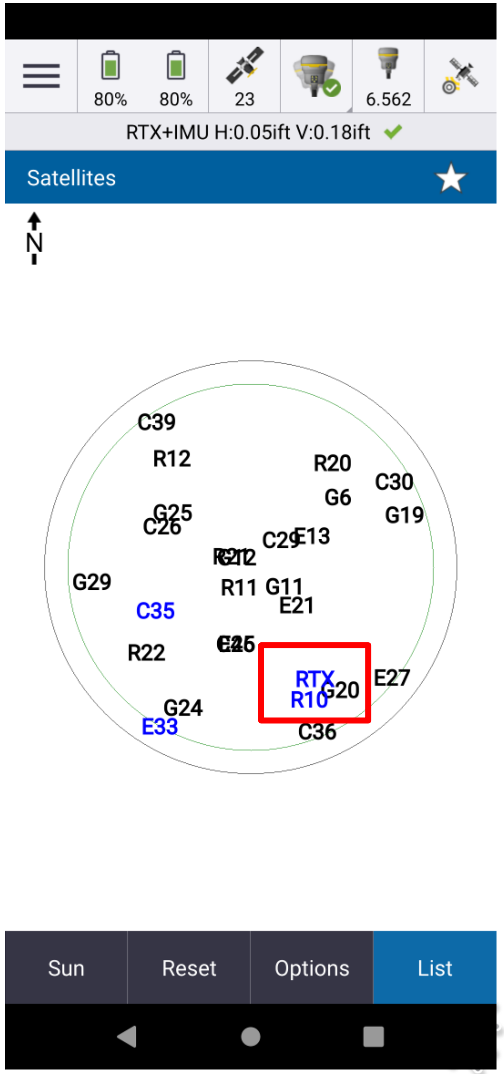
# NO BASE STATION, VRS OR CELL REQUIRED

**Topography, boundary work, stakeout or as-built**
**Large Boundaries & Asset Mapping, Cadastral Mapping**

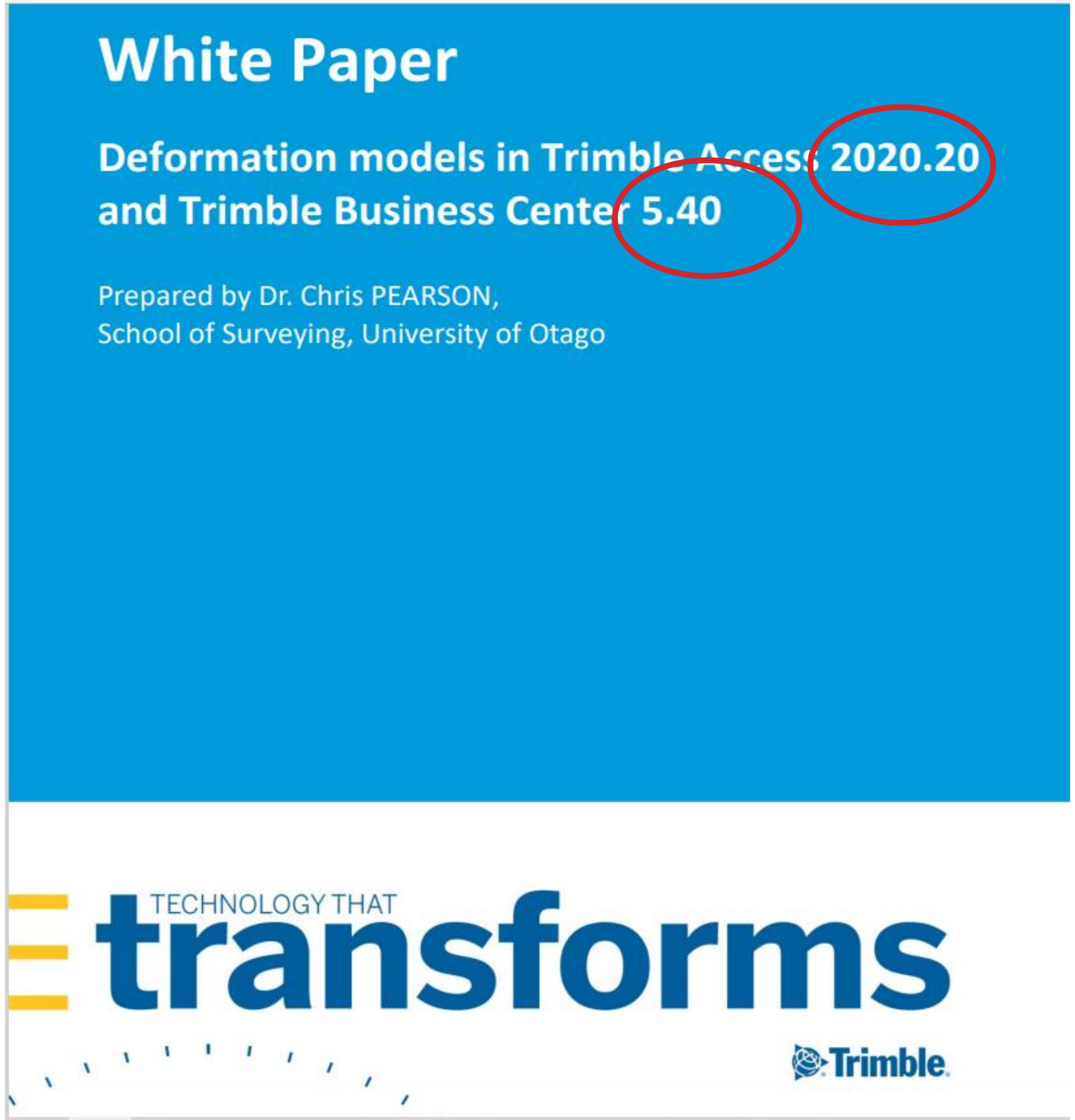
<u>RTX Requirements</u>

- GNSS Satellite visibility
- Good view of the southern sky (Location of the L-band satellite)
- RTX Compliant GNSS Receiver
- Mission Planning
- Be Careful working around Obstrucations
  - Tall Buildings, Canyons and Heavy Canopy



# INCORPORATION OF HTDP 3.2.9 TA 2020.20




- Our support for deformation models allows TGL to develop accurate coordinates in tectonically active areas. In practice both the velocity and earthquake shifts are stored as a series of grid files, which are used to estimate the appropriate values for an arbitrary point by linear interpolation. The basic idea of a National Deformation Model is illustrated in Figure 1, which shows the trajectory of a point affected by a constant velocity and two earthquake shifts which are combined to estimate the total displacement. These are then used to correct the coordinates back to the reference epoch. In addition, the models can also correct for post-seismic deformation.

The correction equation is:

$$m_k(t,\theta,\varphi) = v(\theta,\varphi)_k t + E(\theta,\varphi)_{ki} H(t-t_i) + P(\theta,\varphi)_{ki} H(t-t_i)\left(1 - e^{-\frac{(t-t_i)}{tc_i}}\right)$$

*Equation 1*

- Where m is the displacement
- v is the velocity (ndm)
- E is the earthquake shift (patch)
- P post-seismic decay
- H is the step function

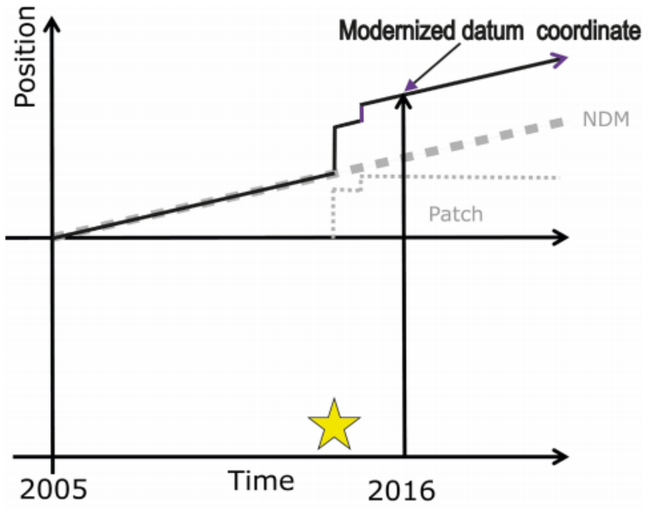



*Figure 1 Schematic diagram of a dynamic datum. Heavy dashed gray line shows the secular velocity. Yellow star indicates an earthquake. Thin gray dotted line co-seismic contribution the deformation model. The solid black line shows the deformation model with both contributions combined*

# QUALITY CONTROL QC1, QC2 AND QC3

| | |
|---|---|
| **Receiver type** | R12i |
| **Serial number** | 6042F00575 |
| **Firmware version** | 6.1 |
| **Antenna type** | R12i Internal |
| **Measurement method** | Bottom of quick release |
| **Tape adjustment** | 0.000 |
| **Horizontal offset** | 0.000 |
| **Vertical offset** | 0.588 |

QC3 = Sigma North, East and Elevation with Corresponding Error Ellipse Components

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Point** | RC SOUTH 1 | **RTX X** | -4243289.263 | **RTX Y** | -15892613.892 | **RTX Z** | 12899422.919 | **Code** | HINGE SIDE CASING |
| | | **Method** | RTX | **Type** | Topo point | **Search class** | Normal | | |
| **Antenna height** | 6.562 | **Type** | Uncorrected | **Tilt distance** | 0.913 | **Hz Prec** | 0.043 | **Vt Prec** | 0.161 |
| **QC 1** | | **PDOP** | 1.2 | **GDOP** | 2.0 | **HDOP** | 0.6 | **VDOP** | 1.0 |
| | | **Base data age** | 4.8000001907349 | **Satellites** | 23 | **Positions used** | 7 | | |
| **QC 3** | | **σ North** | 0.009 | **σ East** | 0.009 | **σ Elevation** | 0.049 | **Covariance** | 0.000 |
| | | **Semi-major axis** | 0.009 | **Semi-minor axis** | 0.009 | **Orientation** | ? | **Unit variance** | 1.000 |

Initialization event: RTX not converged

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **GPS week** | 2188 | **Seconds** | 420945 | **Initialization type** | On the fly | **Survey type** | Real-time | | |

Initialization event: RTX converged

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **GPS week** | 2188 | **Seconds** | 421040 | **Initialization type** | On the fly | **Survey type** | Real-time | | |

Initialization event: RTX not converged

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **GPS week** | 2188 | **Seconds** | 421108 | **Initialization type** | On the fly | **Survey type** | Real-time | | |

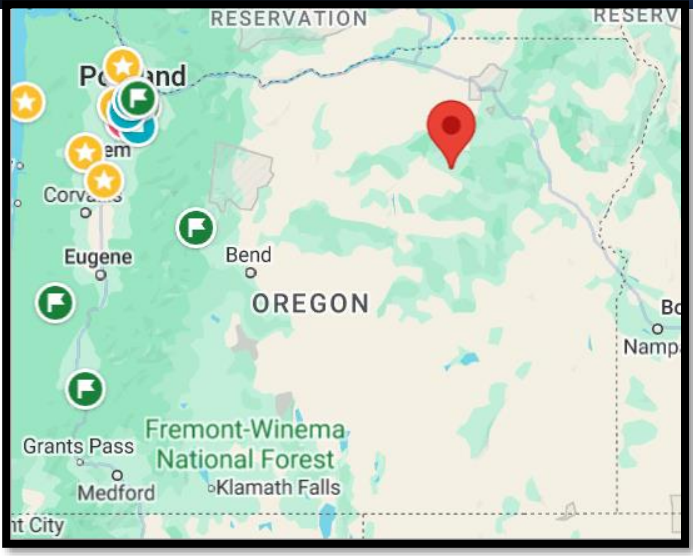
Initialization event: RTX converged

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **GPS week** | 2188 | **Seconds** | 421391 | **Initialization type** | On the fly | **Survey type** | Real-time | | |

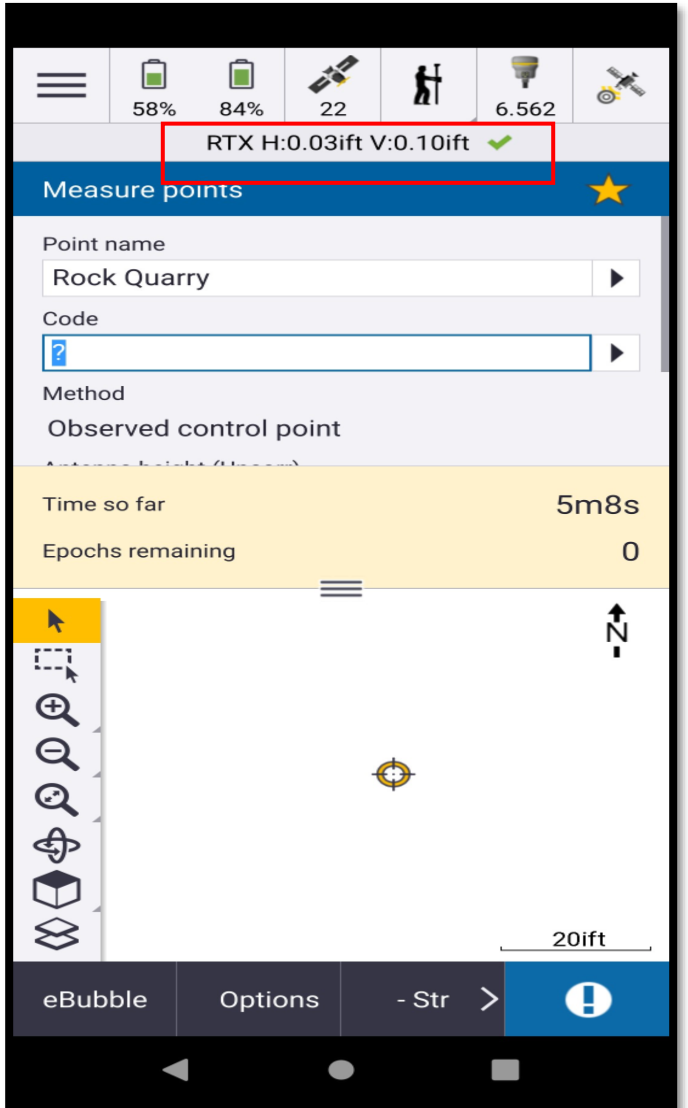
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Point** | RC SOUTH 2 | **RTX X** | -4243562.620 | **RTX Y** | -15893166.803 | **RTX Z** | 12898681.842 | **Code** | HINGE SIDE CASING |
| | | **Method** | RTX | **Type** | Topo point | **Search class** | Normal | | |
| **Antenna height** | 6.562 | **Type** | Uncorrected | **Tilt distance** | 0.372 | **Hz Prec** | 0.050 | **Vt Prec** | 0.123 |
| **QC 1** | | **PDOP** | 1.1 | **GDOP** | 1.9 | **HDOP** | 0.6 | **VDOP** | 0.9 |
| | | **Base data age** | 7.8000001907349 | **Satellites** | 24 | **Positions used** | 7 | | |
| **QC 2** | | **VCV xx ($m^2$)** | 0.000246 | **VCV xy ($m^2$)** | 0.000253 | **VCV xz ($m^2$)** | -0.000218 | | |
| | | | | **VCV yy ($m^2$)** | 0.000789 | **VCV yz ($m^2$)** | -0.000613 | | |
| | | | | | | **VCV zz ($m^2$)** | 0.000605 | | |

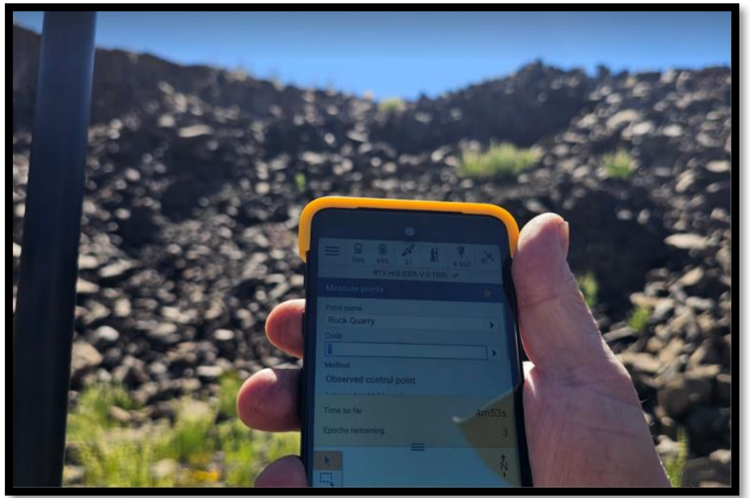
QC2 = Variance Co Variance unbiased statistical values used in a Network Adjustment

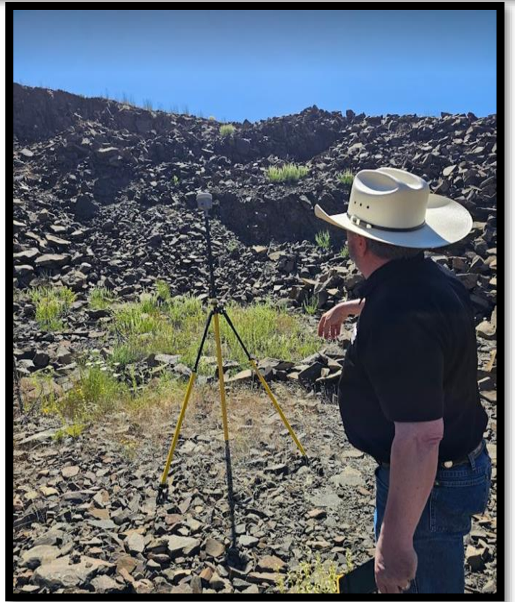
# OREGON PPP/RTX ACCESS FIELD TEST
# ROCK QUARRY



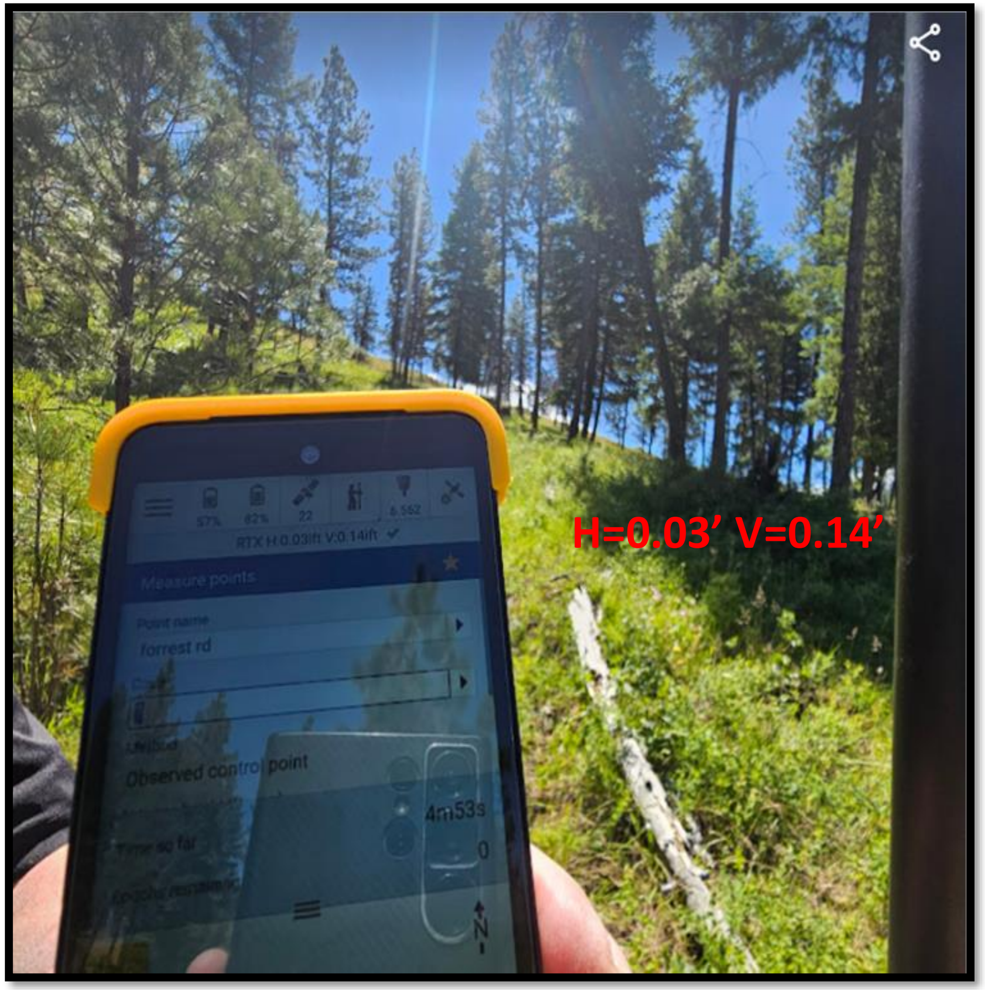






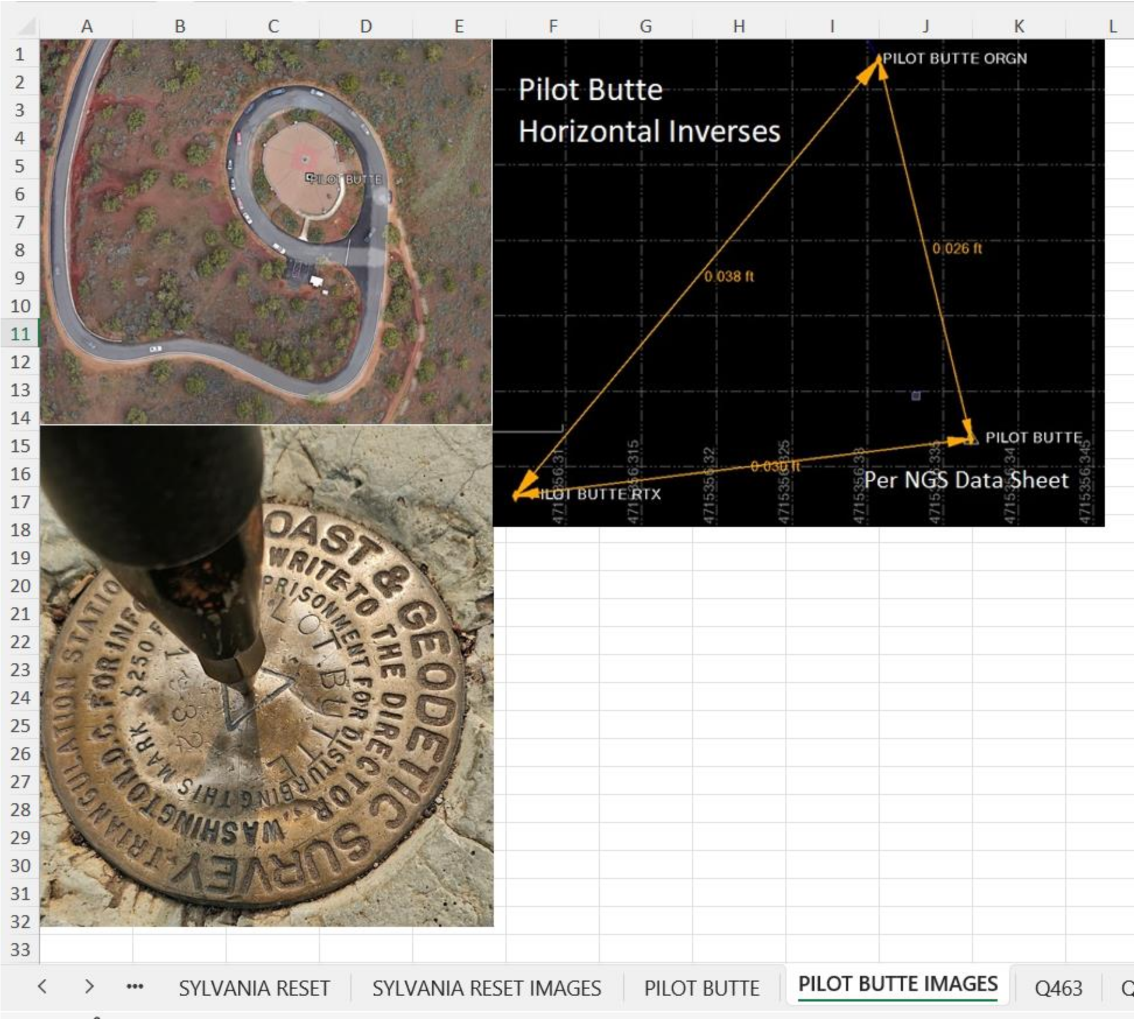
# OREGON PPP/RTX ACCESS FIELD TEST
# FOREST ROAD


# OREGON PPP/RTX/ORGN ACCESS FIELD TEST
# NGS "PILOT BUTTE"

| PILOT BUTTE (NGS) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| RTX | | | | | | | | | |
| Point | PILOT BUTTE RTX | RTX X | -7822576.41 | RTX Y | -12874352.89 | RTX Z | 14480918.81 | Code | |
| | | Method | RTX | Type | Observed control point | Search class | Normal | | |
| Antenna height | 6.562 | Type | Uncorrected | Tilt distance | N/A | Hz Prec (1 sigma) | 0.021 | Vt Prec (1 sigma) | 0.099 |
| QC 1 | | PDOP | 1.1 | GDOP | 1.8 | HDOP | 0.5 | VDOP | 0.9 |
| | | Base data age | 8.800000191 | Satellites | 26 | Positions used | 182 | | |
| QC 3 | | σ North | 0.007 | σ East | 0.006 | σ Elevation | 0.03 | Covariance | 0 |
| | | Semi-major axis | 0.007 | Semi-minor axis | 0.005 | Orientation | ? | Unit variance | 1 |
| ORGN | | | | | | | | | |
| Point | PILOT BUTTE ORGN | ΔX | 1442.36 | ΔY | -9917 | ΔZ | -7162.398 | Code | |
| | | Method | Network RTK | Type | Observed control point | Search class | Normal | | |
| Antenna height | 6.562 | Type | Uncorrected | Tilt distance | N/A | Hz Prec (1 sigma) | 0.015 | Vt Prec (1 sigma) | 0.045 |
| QC 1 | | PDOP | 1.2 | GDOP | 1.7 | HDOP | 0.6 | VDOP | 1 |
| | | Base data age | 2.799999952 | Satellites | 20 | Positions used | 183 | | |
| QC 2 | | VCV xx (m²) | 0.000034 | VCV xy (m²) | 0.000041 | VCV xz (m²) | -0.000037 | | |
| | | | | VCV yy (m²) | 0.000102 | VCV yz (m²) | -0.000073 | | |
| | | | | | | VCV zz (m²) | 0.000094 | | |

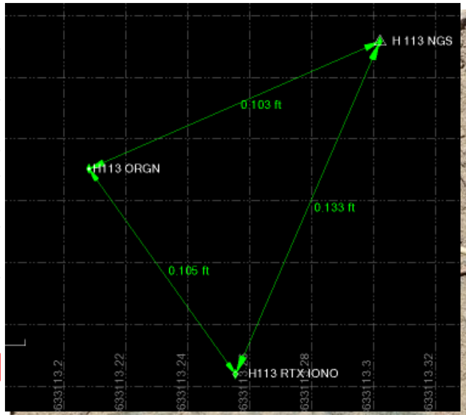
| Point ID | SPC OR S Northing iFT | SPC OR S Easting iFT | NAVD 88 Elevation iFT | Feature Code | Horz Prec 1 Sigma iFT | Vert Prec 1 Sigma iFT |
|---|---|---|---|---|---|---|
| PB_RTX | 873436.748 | 4715356.307 | 4141.919 | BRASS CAP | 0.021 | 0.099 |
| PB_ORGN | 873436.777 | 4715356.331 | 4142.073 | BRASS CAP | 0.015 | 0.045 |
| Diff-Feet | -0.029 | -0.024 | -0.154 | | 0.006 | 0.054 |

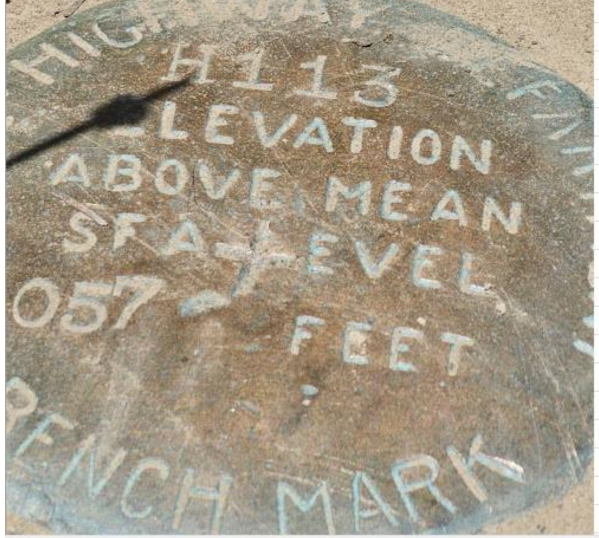


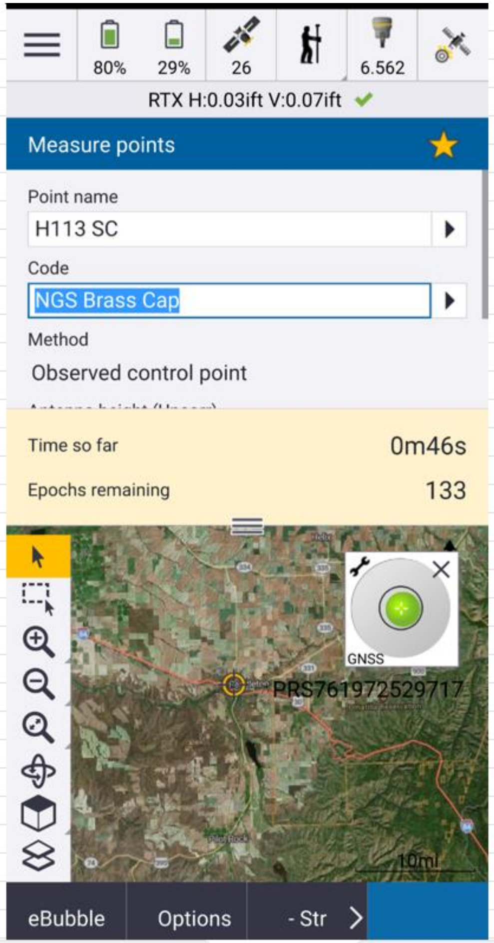
# OREGON PPP/RTX/ORGN ACCESS FIELD TEST
# NGS "H 113"

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Point | H113 RTX IONO | RTX X | -7059647.7 | RTX Y | -12834153.6 | RTX Z | 14895471.09 | Code | NGS Brass Cap |
| 4 | | | Method | RTX | Type | Observed control point | Search class | Normal | | |
| 5 | Antenna height | 6.562 | Type | Uncorrected | Tilt distance | 0.022 | Hz Prec (DRMS) | 0.03 | Vt Prec (1 sigma) | 0.073 |
| 6 | QC 1 | | PDOP | 1.1 | GDOP | 1.7 | HDOP | 0.6 | VDOP | 0.9 |
| 7 | | | Base data age | 7.80000019 | Satellites | 26 | Positions used | 194 | | |
| 8 | QC 3 | | σ North | 0.007 | σ East | 0.006 | σ Elevation | 0.022 | Covariance | 0 |
| 9 | | | Semi-major axis | 0.007 | Semi-minor axis | 0.006 | Orientation | ? | Unit variance | 1 |
| 10 | ORGN | | | | | | | | | |
| 11 | Point | H113 ORGN | ΔX | -11751.948 | ΔY | 8779.611 | ΔZ | 1574.698 | Code | NGS Brass Cap |
| 12 | | | Method | Network RTK | Type | Observed control point | Search class | Normal | | |
| 13 | Antenna height | 6.562 | Type | Uncorrected | Tilt distance | 0.023 | Hz Prec (DRMS) | 0.022 | Vt Prec (1 sigma) | 0.038 |
| 14 | QC 1 | | PDOP | 1.1 | GDOP | 1.5 | HDOP | 0.6 | VDOP | 0.9 |
| 15 | | | Base data age | 3.79999995 | Satellites | 23 | Positions used | 192 | | |
| 16 | QC 3 | | σ North | 0.006 | σ East | 0.004 | σ Elevation | 0.012 | Covariance | 0 |
| 17 | | | Semi-major axis | 0.006 | Semi-minor axis | 0.004 | Orientation | ? | Unit variance | 1 |
| 18–19 | Point ID | SPC OR N Northing iFT | SPC OR N Easting iFT | NAVD 88 Elevation iFT | Feature Code | Horz Prec DRMS iFT | Vert Prec 1 Sigma iFT | | | |
| 20 | H113_RTX | 735946.264 | 8633113.255 | 1060.747 | BRASS CAP | 0.03 | 0.073 | | | |
| 21 | H113_ORGN | 735946.33 | 8633113.208 | 1060.813 | BRASS CAP | 0.022 | 0.038 | | | |
| 22 | Diff-Feet | -0.066 | 0.047 | -0.066 | | 0.008 | 0.035 | | | |
| 23 | | | | | | | | | | |
| 24 | | | | | | | | | | |
| 25 | | | | | | | | | | |

PILOT BUTTE | PILOT BUTTE IMAGES | Q463 | Q463 IMAGES | H 113 | H113 IMAGES



# CENTERPOINT RTX POST-PROCESSING SERVICE

- Better than 2 cm horizontal accuracy (1 hour of observation recommended, 24hr max)
- Now with BeiDou data
- Supports a variety of receivers and file formats
- User selectable reference frames
- Use now at [www.trimblertx.com](http://www.trimblertx.com)

Trimble CenterPoint RTX Post-Pr ×

trimblertx.com/UploadForm.aspx

Apps | Microsoft Office Ho... | Zoho CRM - Home... | Other bookmarks

Trimble.

CenterPoint RTX Post-Processing

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**WELCOME TO TRIMBLE CENTERPOINT® RTX POST-PROCESSING SERVICE**

Trimble RTX® is a global GNSS technology that provides centimeter-level positioning, worldwide, at any time.

This application allows you to upload GNSS observation data to the CenterPoint RTX post-processing service and receive positioning calculations. The positioning calculations are performed in the observation epoch (current epoch) of ITRF2008 for data sets that were collected prior to March 23rd 2017, and ITRF2014 for data sets that were collected on or after March 23rd 2017. Transformation can be performed by selecting a different coordinate system and tectonic plate. Complete the form below to receive your calculations via email.

**1. Select a coordinate system and tectonic plate:**

Coordinate System: NAD83-2011

Tectonic Plate: North America

**2. Select a file to upload:**

Choose File 62732400.T02

**New Enhancements**

The CenterPoint RTX post-processing service now supports all dual frequency GNSS receivers.

Antennas must be on the Supported Antennas list. The post-processing service will not process unsupported antennas. See also: Supported Antennas

Observation files must meet the following requirements:

- Data formats accepted include Trimble proprietary data formats (e.g. DAT, T01, T02, T04, Quark) and the standard RINEX 2 and RINEX 3 data formats
- For optimal processing results, it is recommended to provide at least 60 minutes of observations.
- Data files cannot exceed 24 hours in length
- Data files must be static only
- Data files must contain dual frequency pseudorange and carrier phase observations (L1 and L2)
- Data must have been collected after 14 May 2011
- BeiDou data is included since 04 Jun 2014
- Galileo data is included since 01 Jan 2017
- If your observation data consists of several files, please compress them to a ZIP archive and upload the zipped file. All files in the ZIP archive must belong to the same station.

**3. Provide your email address:**

Email: bob@frontierprecision.com

☑ I accept the terms of use listed in the Disclaimer section below.

Type here to search

1:10 PM 4/1/2020

# TRIMBLE RTX PP REPORT

Trimble

## Post-Processing Service Based on RTX Technology

TrimbleRTX.com

Contributor: bob@frontierprecision.com
Reference Name: 62732400.T02
Upload Date: 04/01/2020 18:56:52 UTC

Report Time Frame:
Start Time: 08/28/2019 16:03:45 UTC
End Time: 08/28/2019 20:54:05 UTC
Observation File Type(s): T02
Observation File(s): 62732400.T02
Antenna:
Name: TRM55971.00 NONE
Height: 5.582 m
Reference: Bottom of antenna mount
Receiver Name: TRIMBLE R7 GNSS
Coordinate Systems: NAD83-2011 & ITRF2014
Tectonic Plate: North America
Tectonic Plate Model: MORVEL56
Processing Interval: 10 s

### Statistics

| # Total Obs | # Usable Obs | # Used Obs | Percent |
|---|---|---|---|
| 3485 | 1742 | 1742 | 100 |

### Used Satellites

| | |
|---|---|
| # Total Satellites: | 30 |
| GPS: | G02 G05 G06 G10 G12 G13 G15 G16 G17 G19 G20 G21 G24 G25 G26 G27 G29 |
| GLONASS: | R01 R02 R03 R05 R09 R15 R16 R17 R18 R19 R20 R21 R24 |

### Processing Results

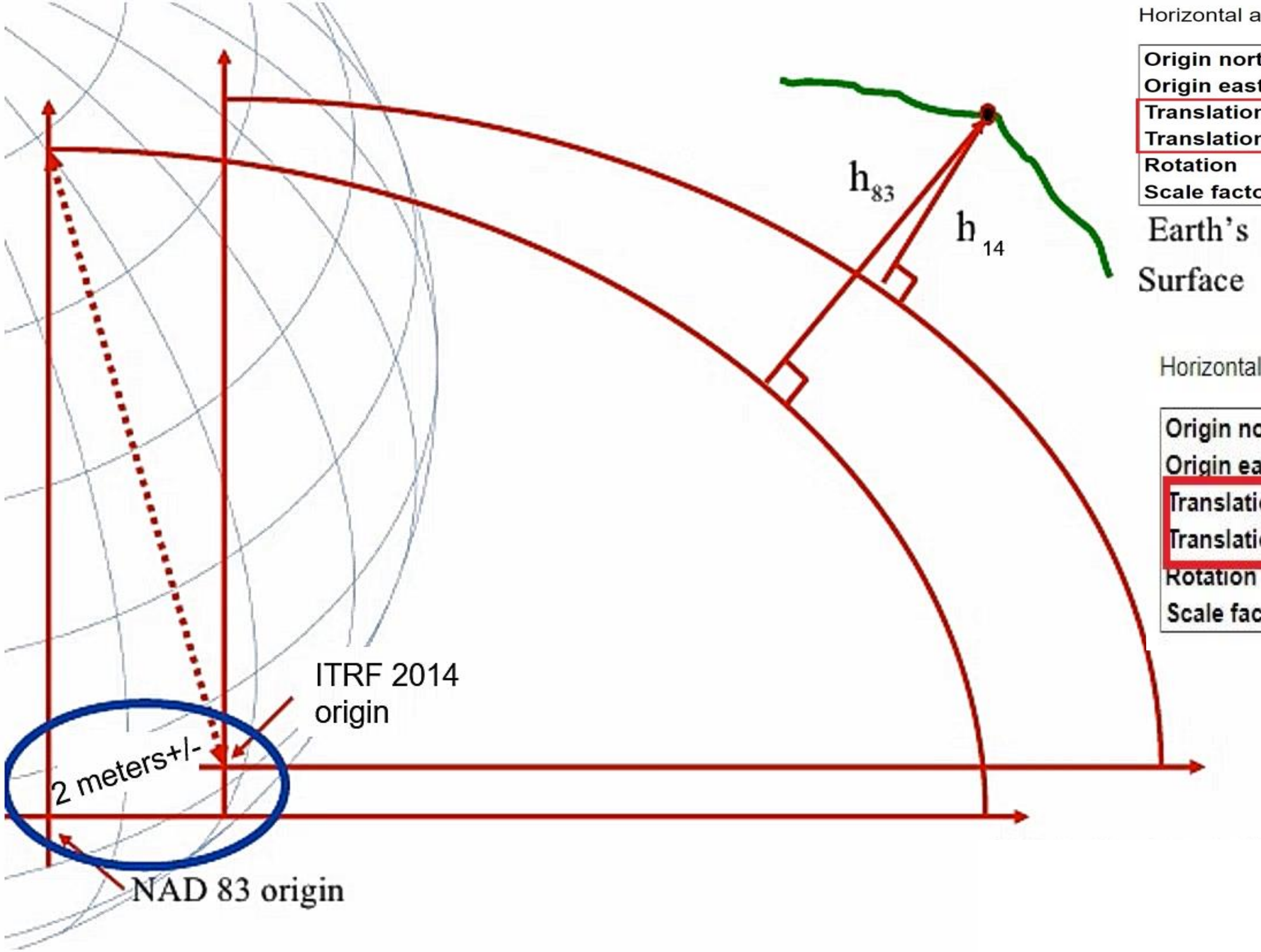
| NAD83-2011 at Epoch 2010.0 | | |
|---|---|---|
| Coordinate | Value | σ |
| X | -1212197.436 m | 0.004 m |
| Y | -4436066.494 m | 0.008 m |
| Z | 4406770.819 m | 0.008 m |
| Latitude | 43° 58' 16.52246" N | 0.004 m |
| Longitude | 105° 17' 0.59850" W | 0.004 m |
| El. Height | 1407.427 m | 0.011 m |

| ITRF2014 at Epoch 2019.66 | | |
|---|---|---|
| Coordinate | Value | σ |
| X | -1212198.380 m | 0.004 m |
| Y | -4436065.241 m | 0.008 m |
| Z | 4406770.712 m | 0.008 m |
| Latitude | 43° 58' 16.54156" N | 0.004 m |
| Longitude | 105° 17' 0.65418" W | 0.004 m |
| El. Height | 1406.662 m | 0.011 m |

### Report Information

Trimble RTX Solution ID: 22982339
Solution Type: Static
Software Version: 8.5.0.19198
Creation Date: 04/01/2020 18:57:35 UTC

# ITRF2014 (CURRENT EPOCH) TO NAD83 (2011)




Horizontal adjustment PRIOR TO TA 2020.00

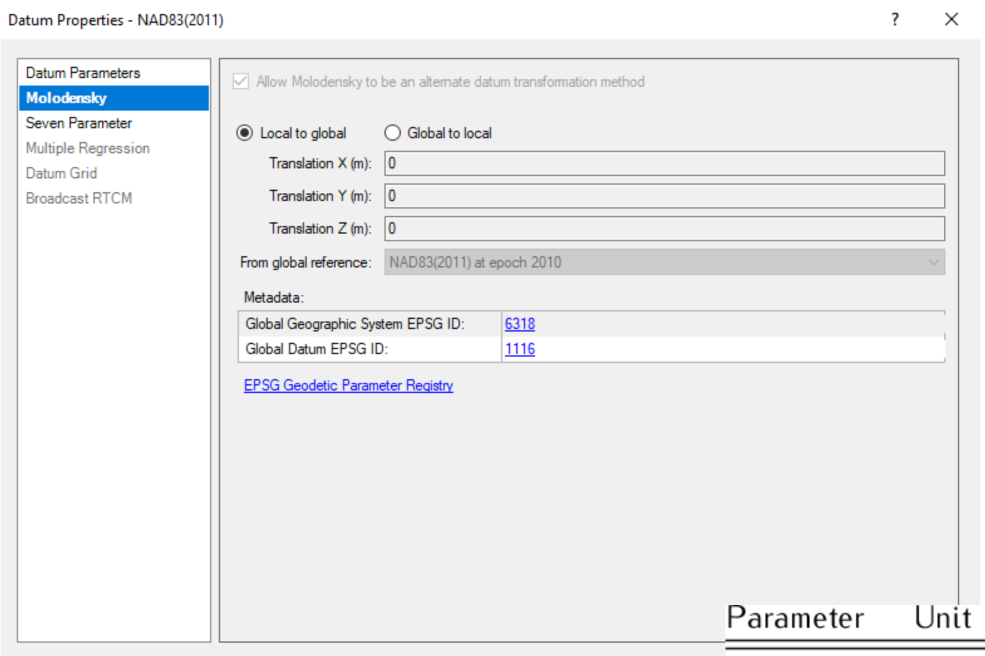
| | |
|---|---|
| Origin north | 1716489.618 |
| Origin east | 3104469.462 |
| Translation north | -2.303 |
| Translation east | 3.256 |
| Rotation | 0°00'00.0000" |
| Scale factor | 1.00000000 |

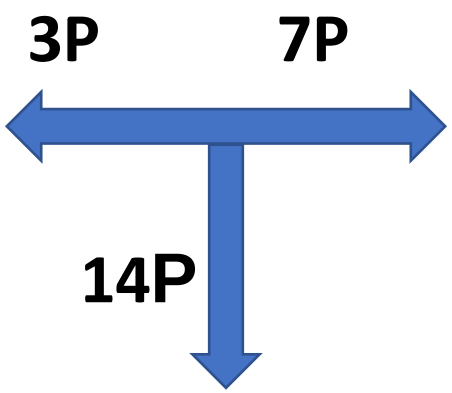
Horizontal adjustment PRIOR TO TA 2020.20

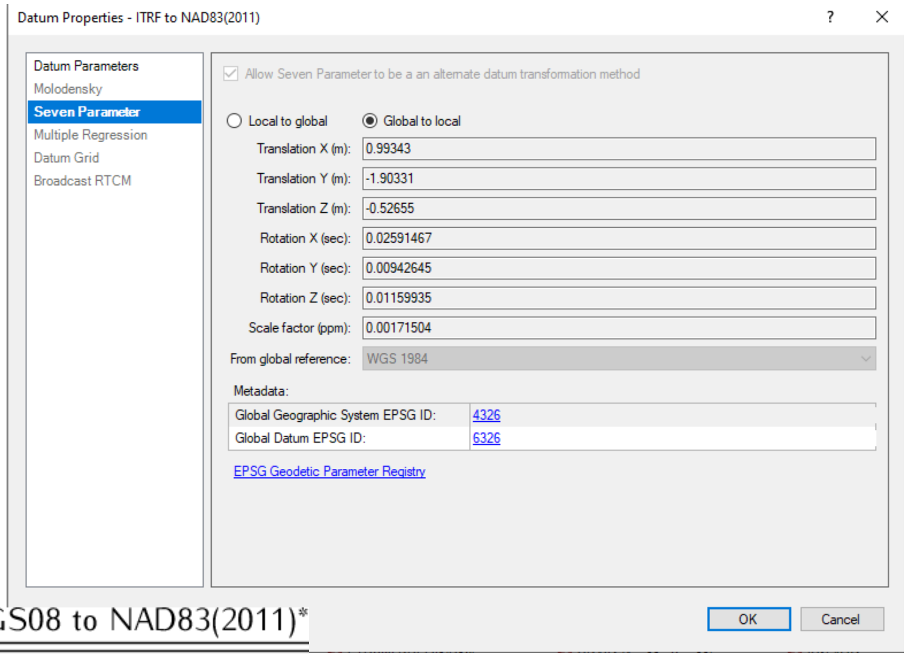
| | |
|---|---|
| Origin north | 1386088.649 |
| Origin east | 3192012.612 |
| Translation north | -0.163 |
| Translation east | -0.026 |
| Rotation | 0°00'00.0000" |
| Scale factor | 1.00000000 |

FRONTIER PRECISION – How You Measure Matters

# FYI: Data Collection/Coordinate System Settings

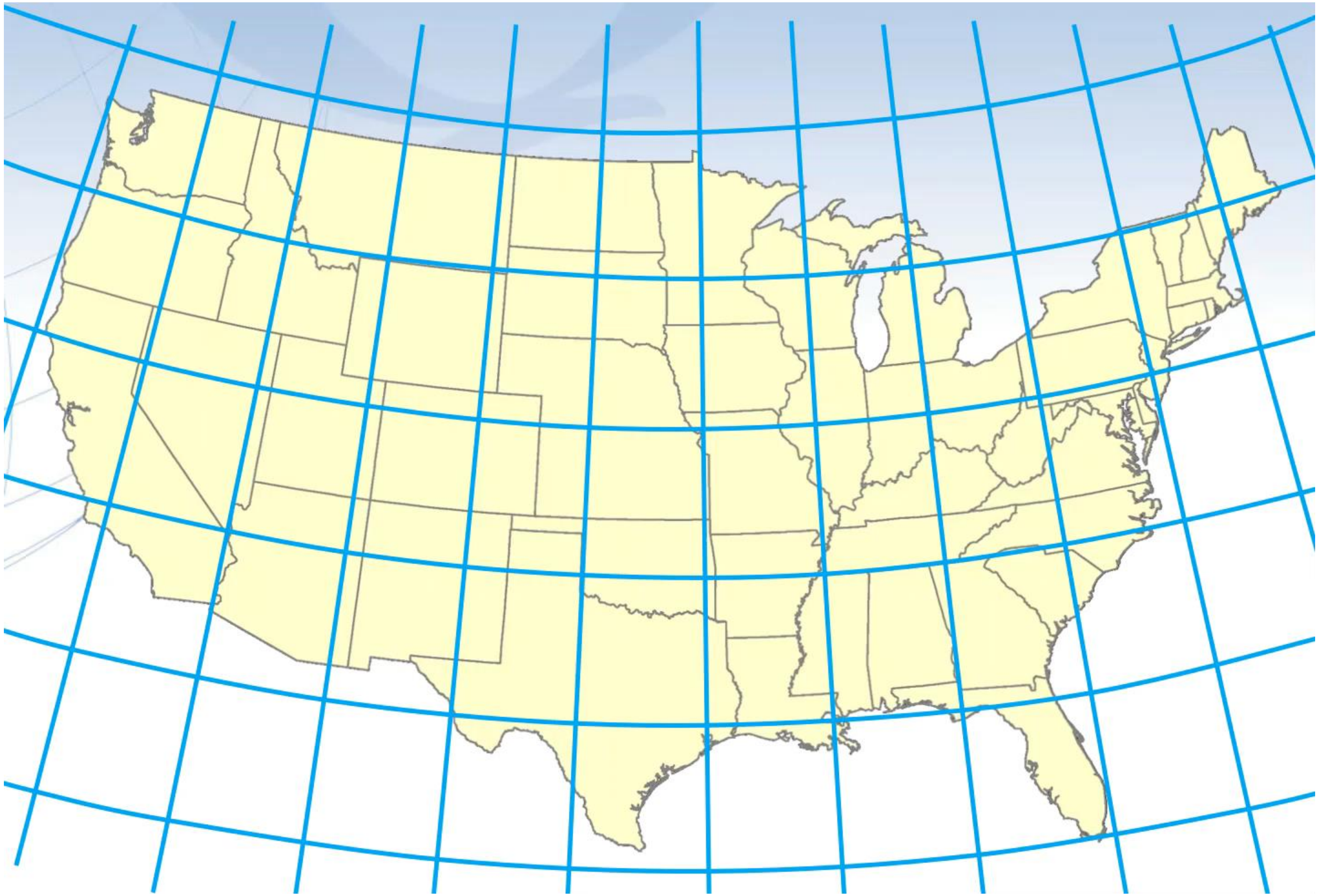


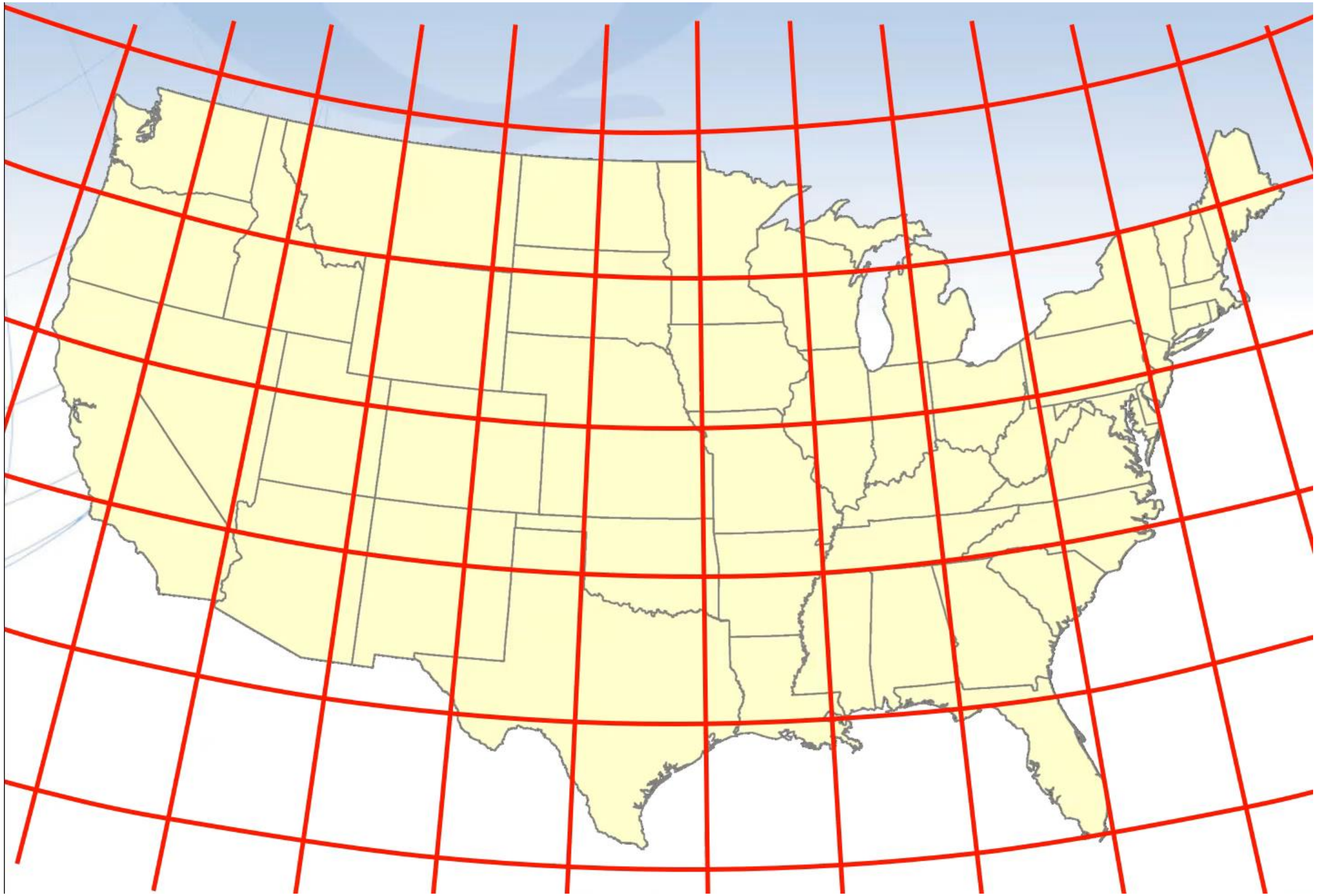




| Parameter | Unit | IGS08 to SHRF | | | IGS08 to NAD83(2011)* |
|---|---|---|---|---|---|
| | | t0=2000.0 | t0=2005.0 | t0=2012.0 | t0=1997.0 |
| $T_X(t_0)$ | cm | 12.87003 | 7.50752 | 0.00000 | 99.34300 |
| $T_Y(t_0)$ | cm | 12.70517 | 7.41135 | 0.00000 | -190.33100 |
| $T_Z(t_0)$ | cm | 42.54889 | 24.82019 | 0.00000 | -52.65500 |
| $R_X(t_0)$ ** | mas*** | -13.88693 | -8.10071 | 0.00000 | 25.91467 |
| $R_Y(t_0)$ | mas | 11.26615 | 6.57192 | 0.00000 | 9.42645 |
| $R_Z(t_0)$ | mas | 3.98693 | 2.32571 | 0.00000 | 11.59935 |
| $s(t_0)$ | ppb**** | -16.46596 | -9.60514 | 0.00000 | 1.71504 |

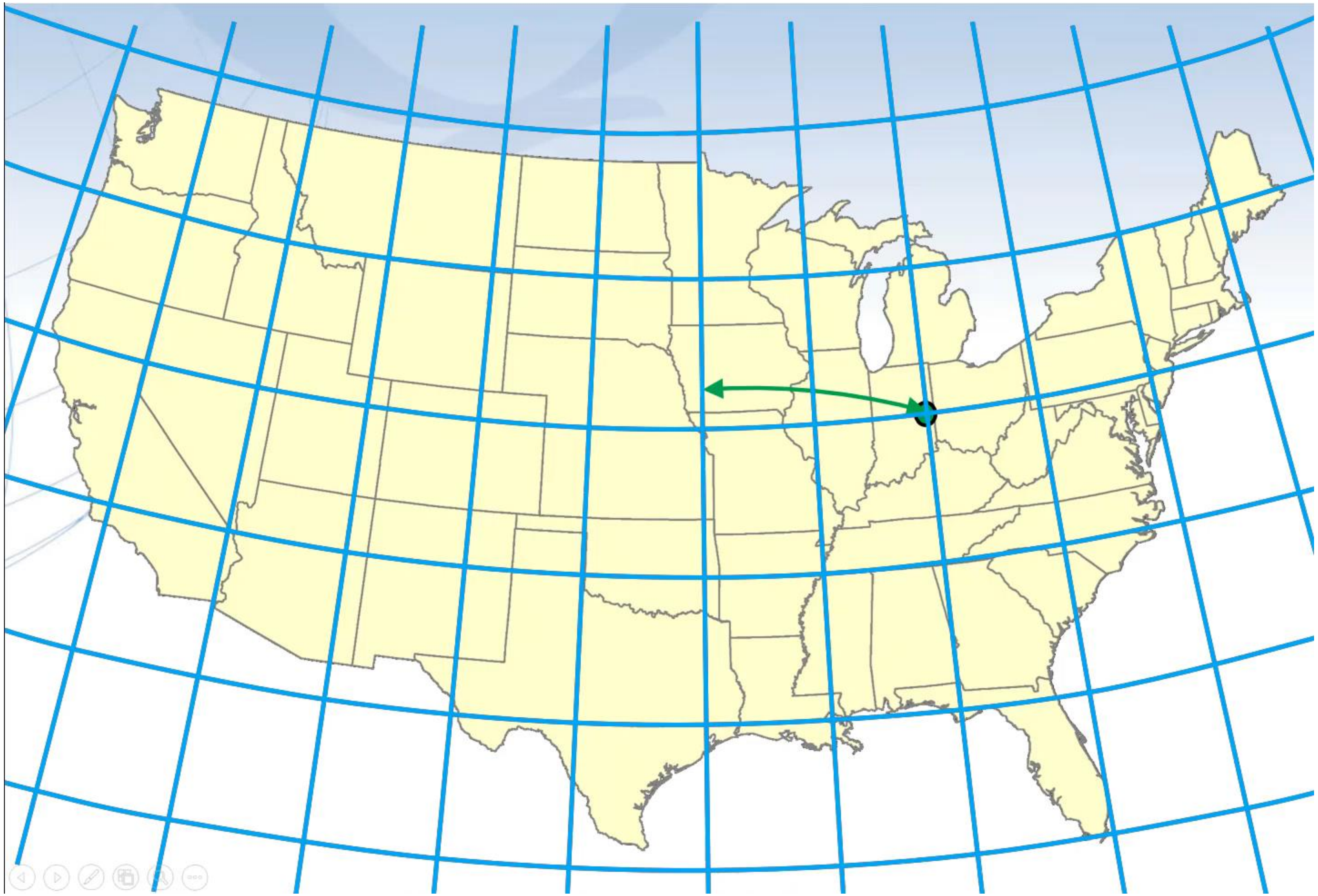
# ITRF2014 – constant frame, rotating plate



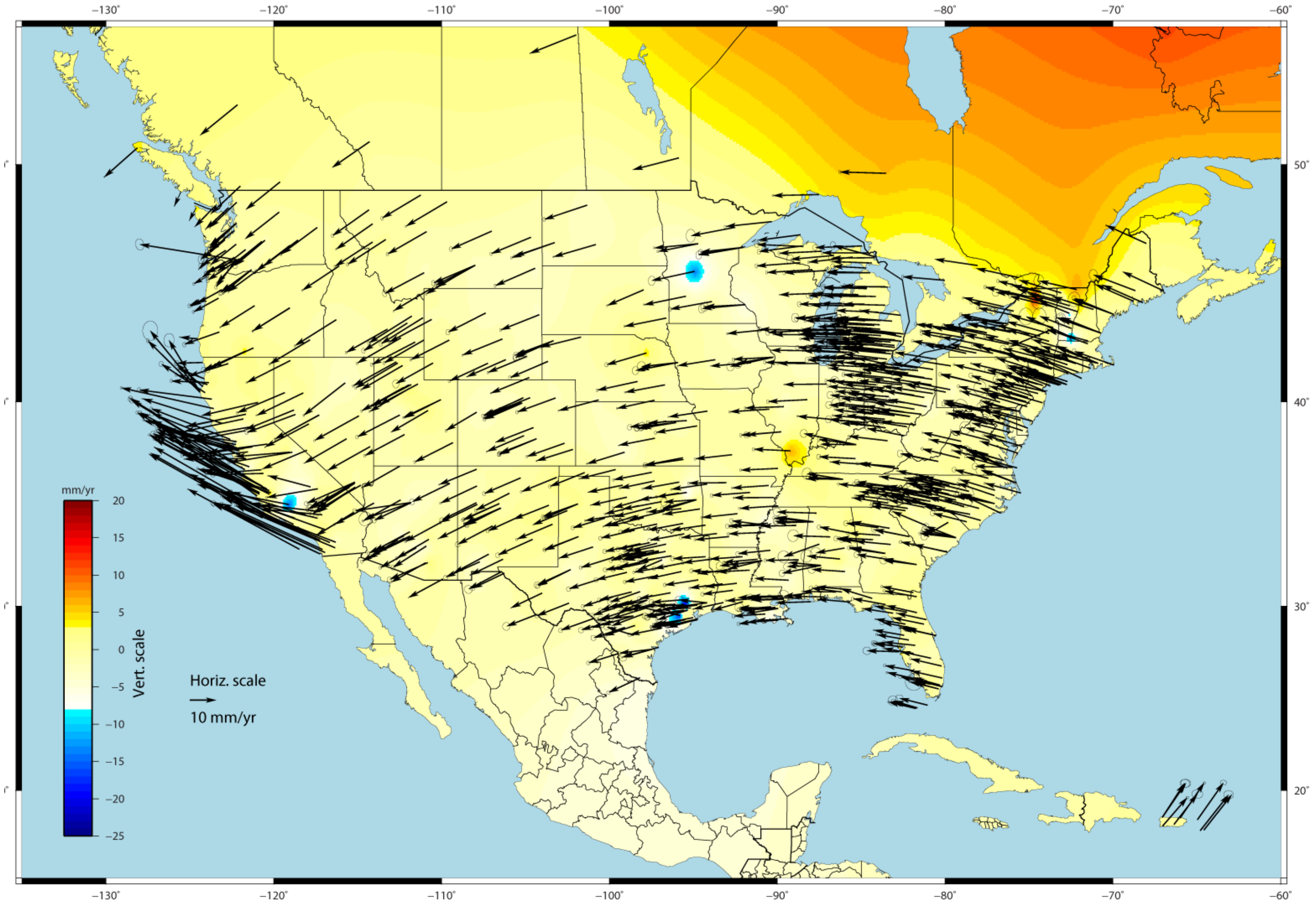
# NAD83 – rotating frame, constant with plate



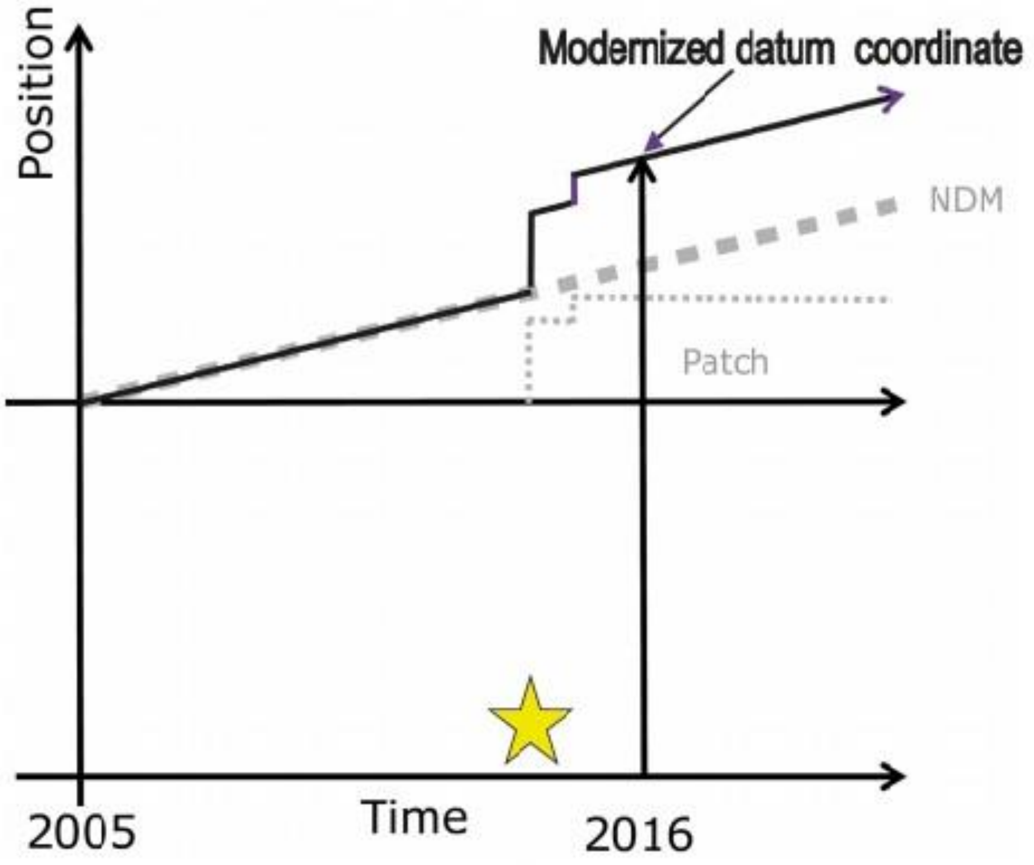
# ITRF2014 to/from NAD83



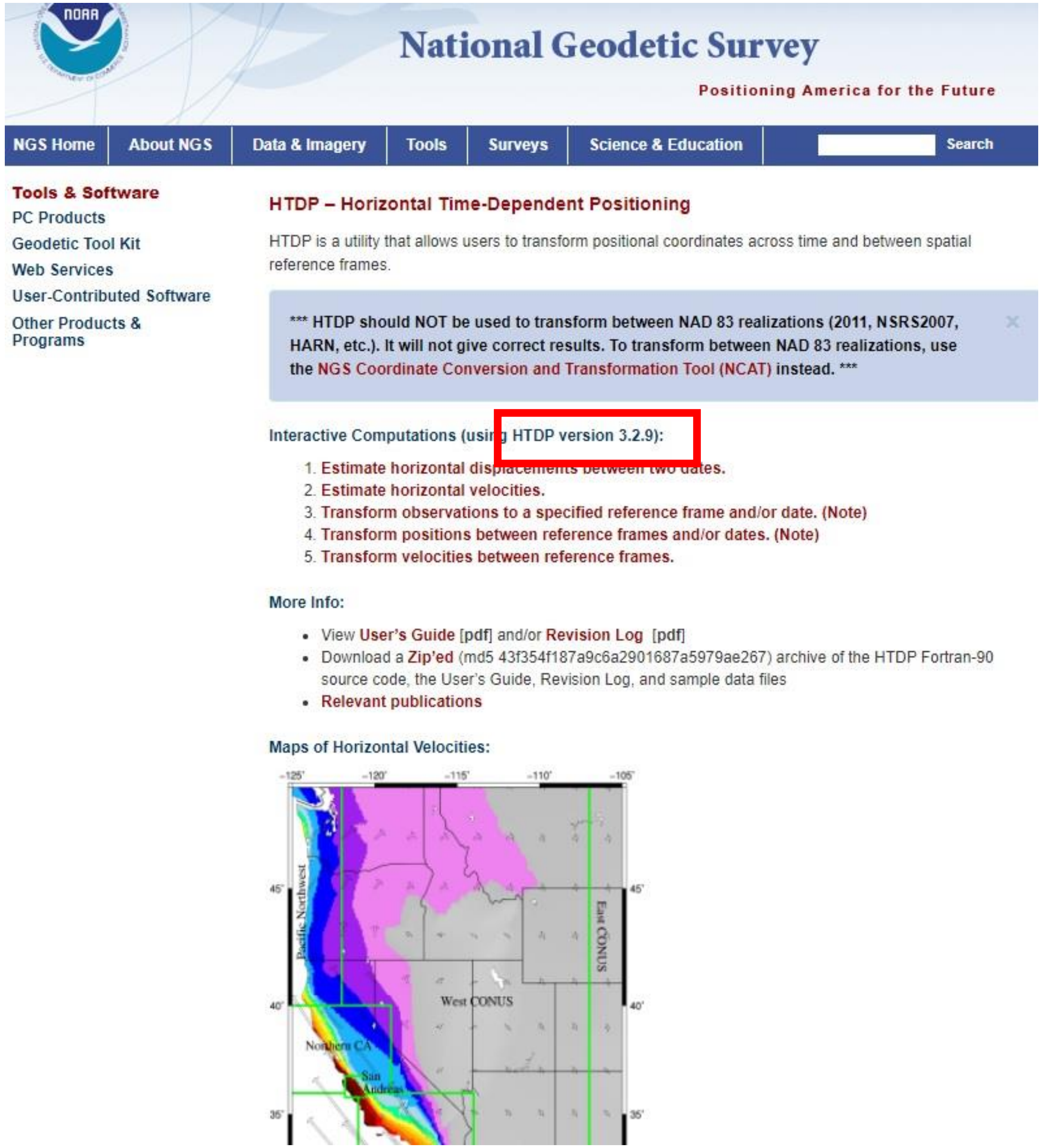
# North American and Pacific Plate Velocities



# DISPLACEMENT MODELS: HTDP 3.2.9 → 3.50




at https://frontierprecision.com/wp-content/uploads/Trimble-Def-Models.pdf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Positioning America for the Future

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Web Services
User-Contributed Software
Other Products & Programs

HTDP – Horizontal Time-Dependent Positioning

HTDP is a utility that allows users to transform positional coordinates across time and between spatial reference frames.

*** HTDP should NOT be used to transform between NAD 83 realizations (2011, NSRS2007, HARN, etc.). It will not give correct results. To transform between NAD 83 realizations, use the NGS Coordinate Conversion and Transformation Tool (NCAT) instead. ***

Interactive Computations (using HTDP version 3.2.9):

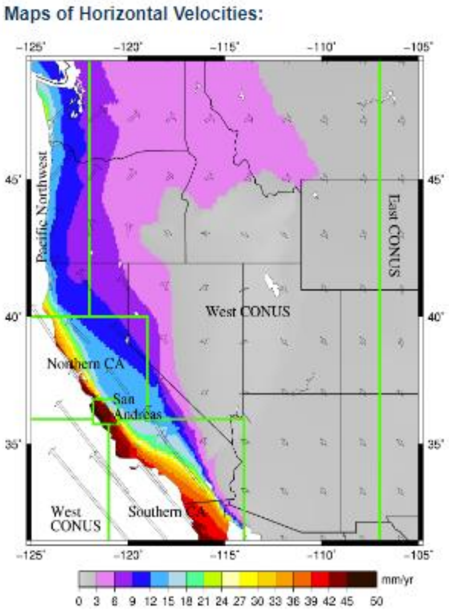
1. Estimate horizontal displacements between two dates.
2. Estimate horizontal velocities.
3. Transform observations to a specified reference frame and/or date. (Note)
4. Transform positions between reference frames and/or dates. (Note)
5. Transform velocities between reference frames.

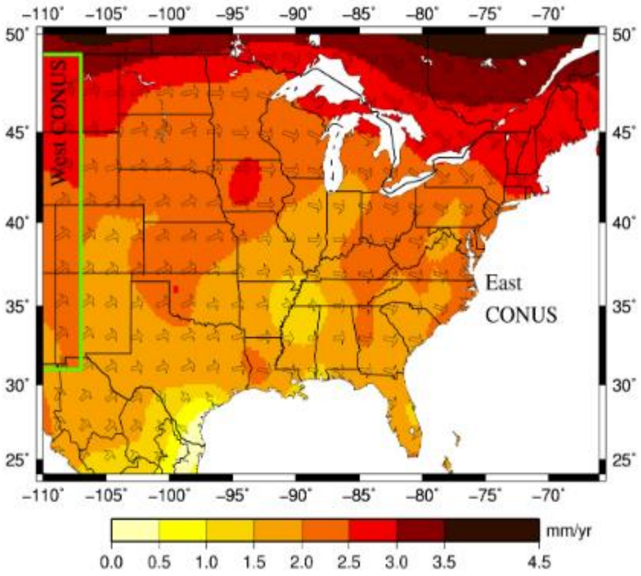
More Info:

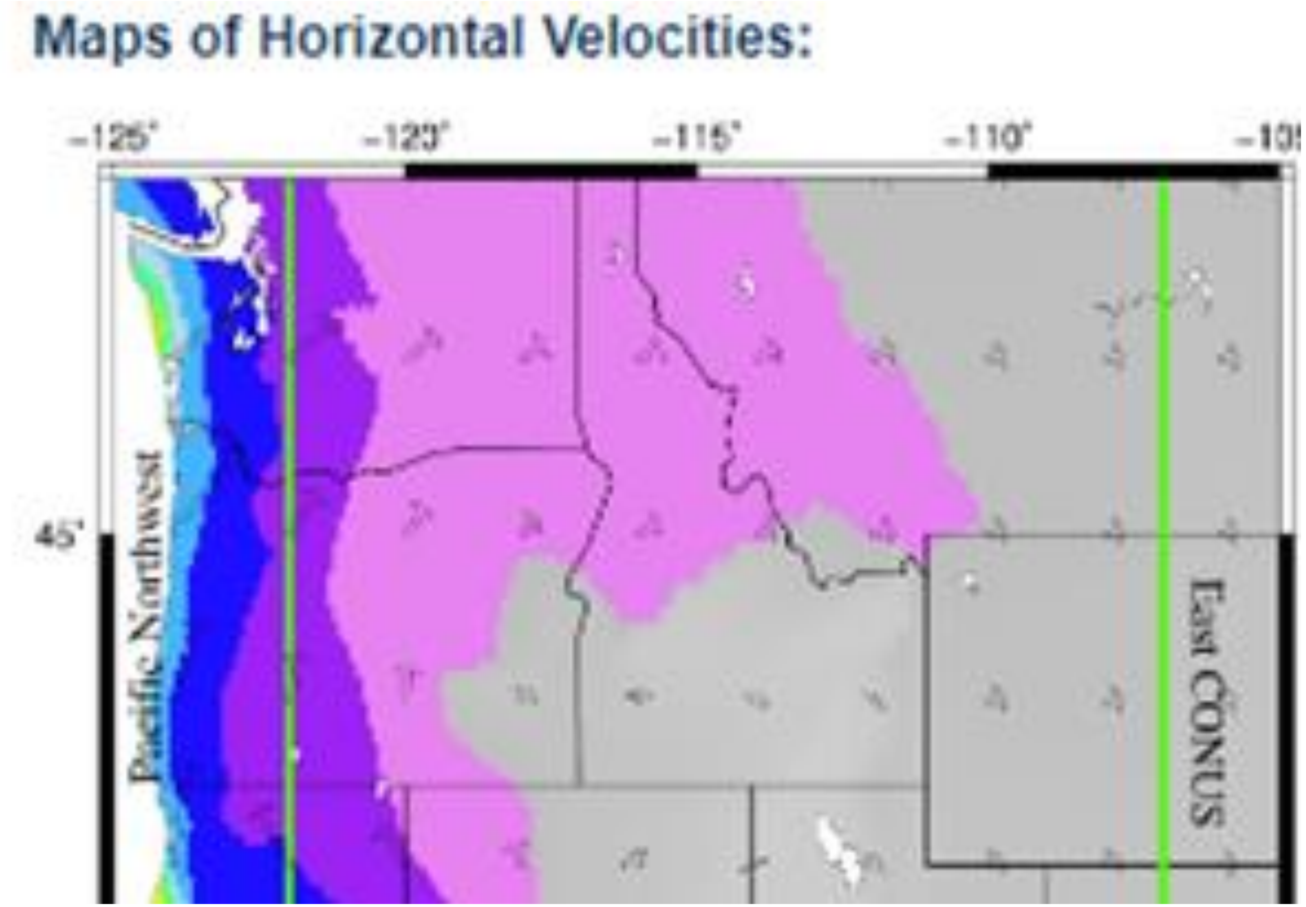
- View User's Guide [pdf] and/or Revision Log [pdf]
- Download a Zip'ed (md5 43f354f187a9c6a2901687a5979ae267) archive of the HTDP Fortran-90 source code, the User's Guide, Revision Log, and sample data files
- Relevant publications

Maps of Horizontal Velocities:

# DISPLACEMENT MODELS: HTDP 3.2.9 → 3.50

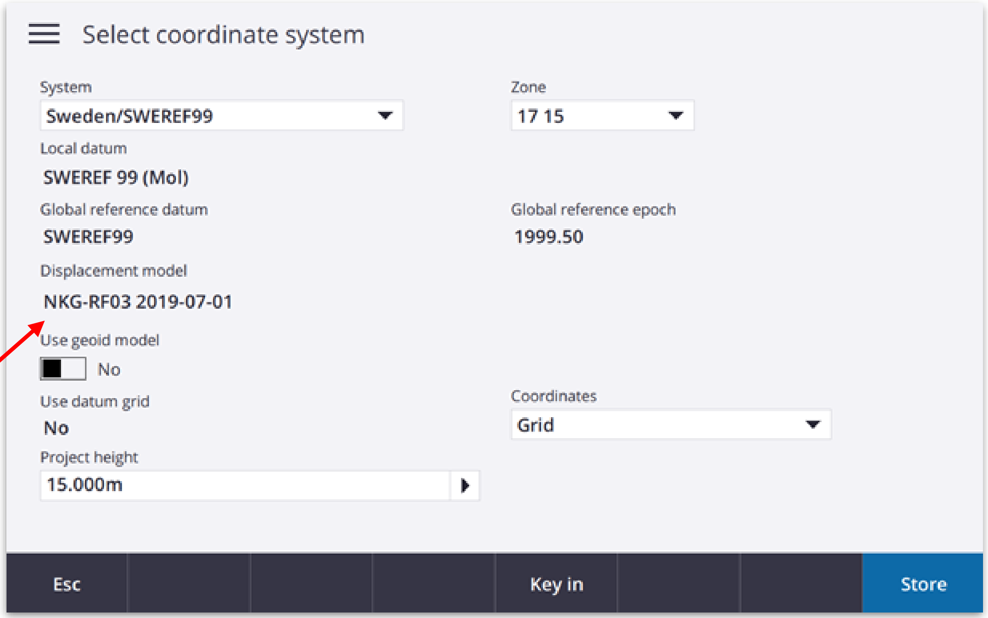


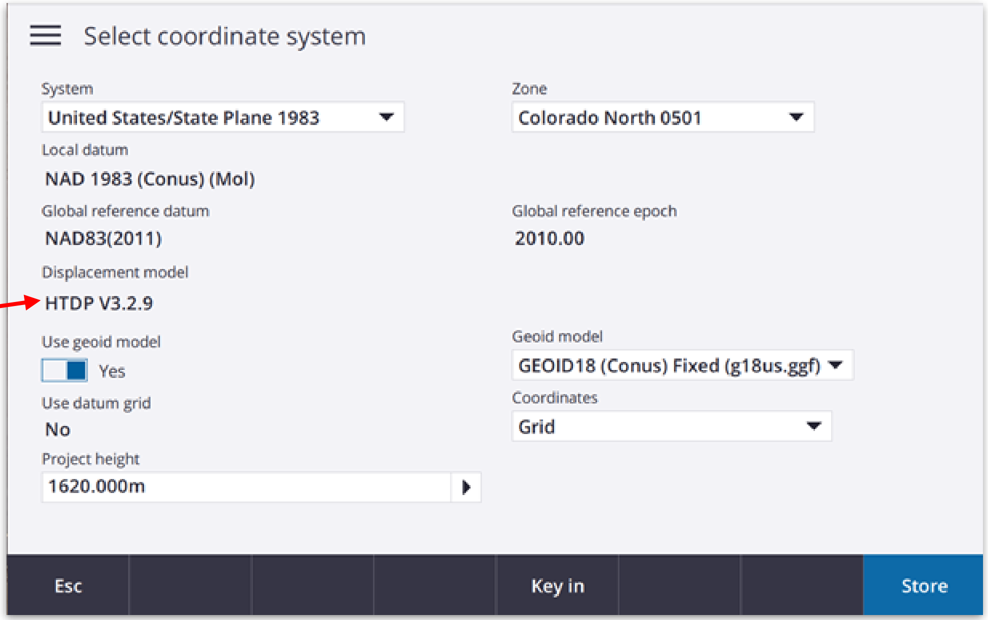



# Local displacement models

| Country | Reference frame | Local displacement model |
| --- | --- | --- |
| Brazil | SIRGAS2000 | VEMOS2009 |
| Denmark | EUREF-DK94 | NKG-RF03 |
| Estonia | EST97 | NKG-RF03 |
| Finland | EUREF-FIN | NKG-RF03 |
| Sweden | SWEREF99 | NKG-RF03 |
| Norway | EUREF89 | NKG-RF03 |
| Iceland | ISN2016 | ISN2016 |
| New Zealand | NZGD2000 | NZGD2000 Deformation Model |
| USA | NAD83(2011) | HTDP V3.2.9 |
| Canada | NAD83(CSRS)v7 | CSRS Velocity Grid V7.0 |



# Precise Point Positioning RTX Test Arvada, CO 6/7/2024

## Trimble IonoGuard

Protecting RTK GNSS from Ionospheric disturbances

Minimum Receiver Firmware Version 6.23/ProPoint

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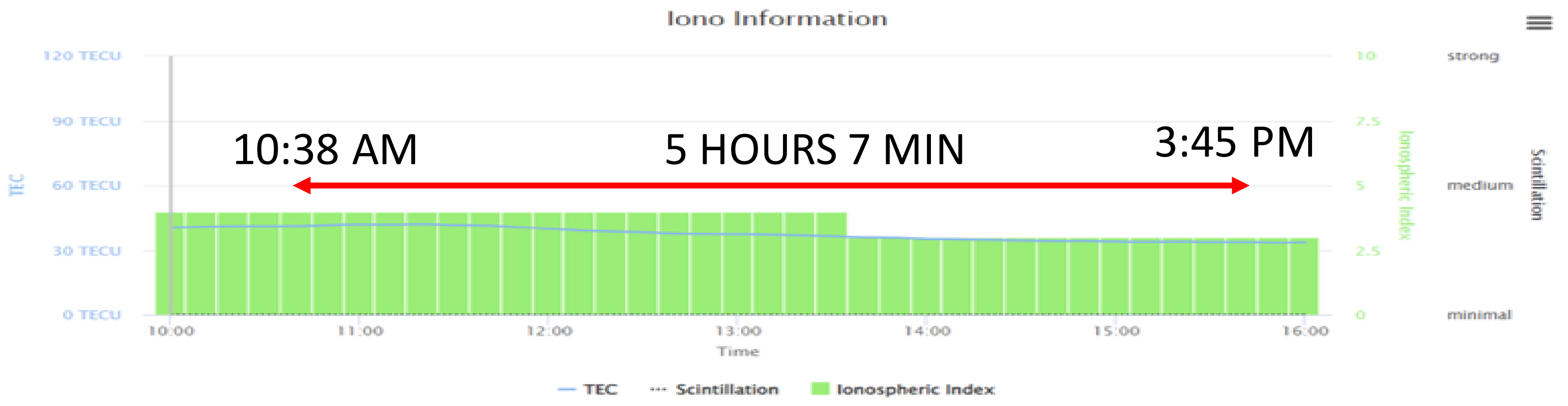
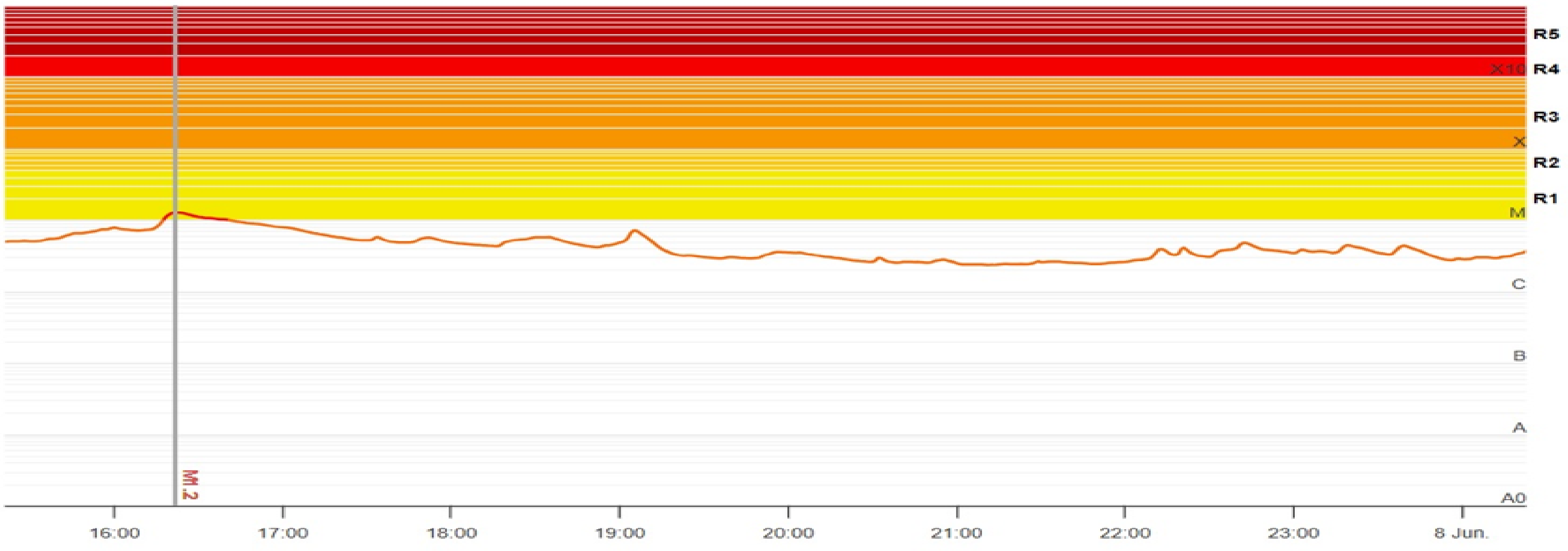
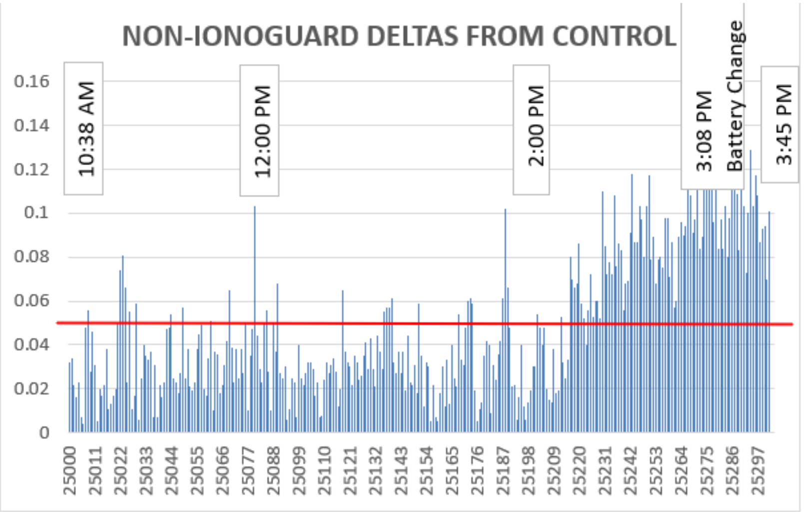
# PPP/RTX TESTING – SOLAR AND IONOSPHERIC ACTIVITY 6/7/2024

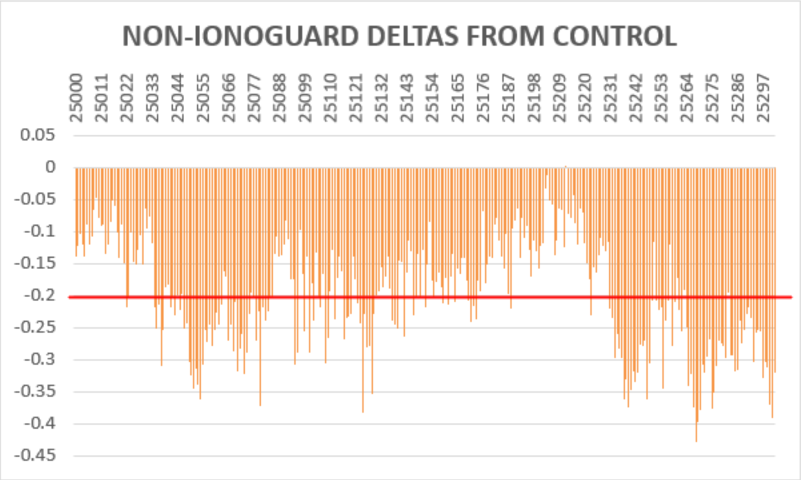


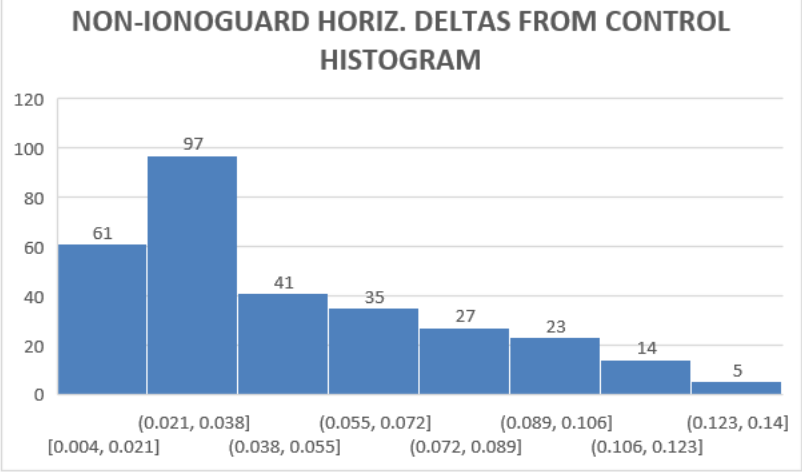
# PPP/RTX TESTING – DELTAS FROM CONTROL WITHOUT IONOGUARD TECHNOLOGY

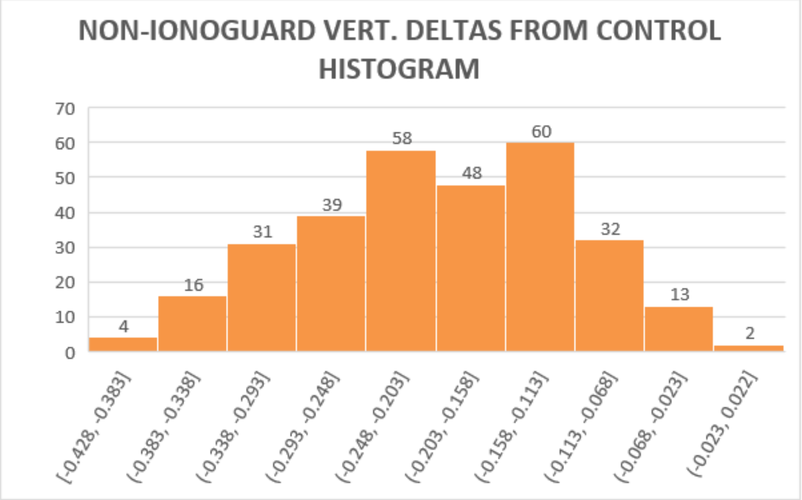



MEAN= 0.048'



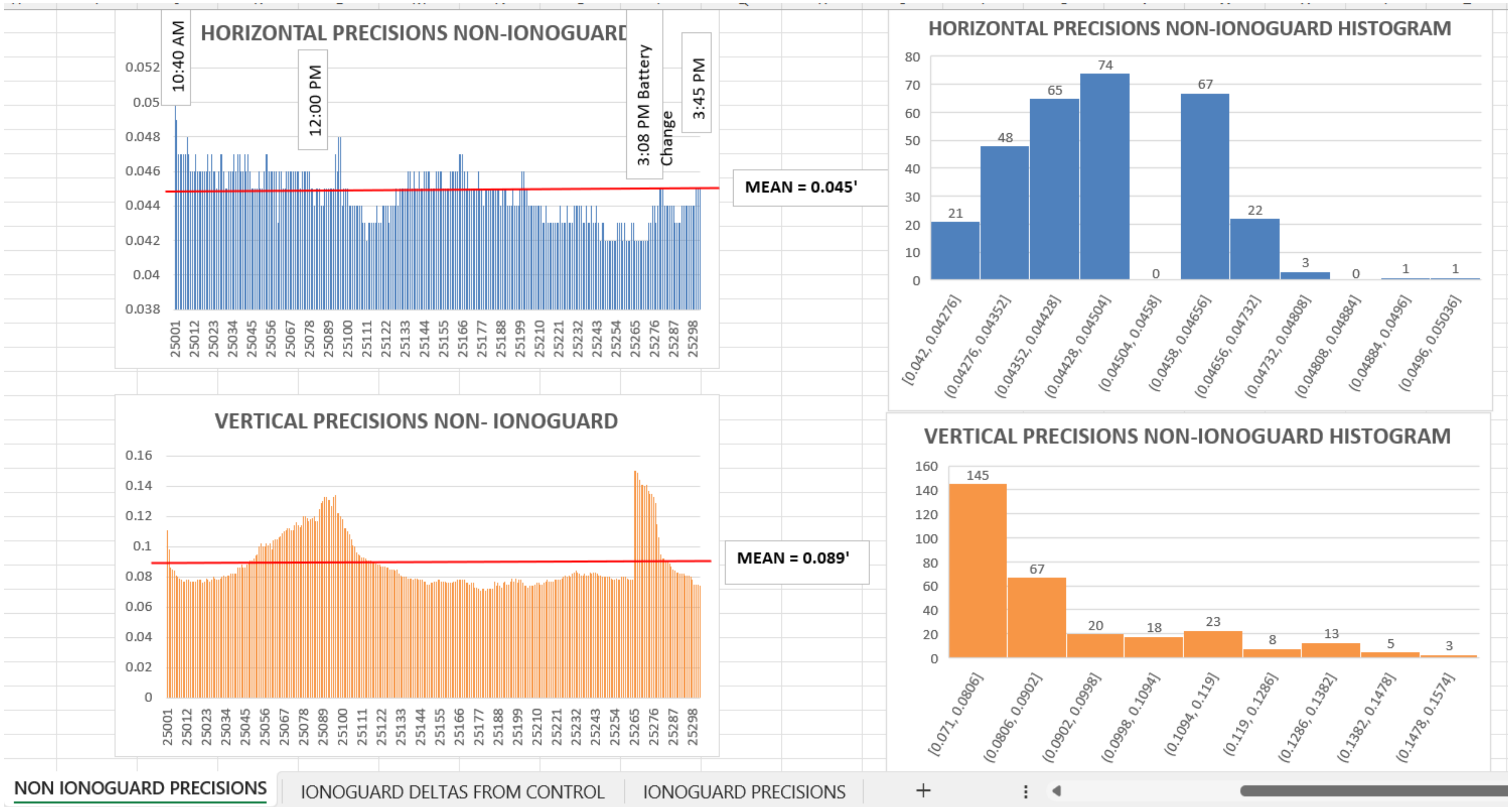

MEAN = -0.201'



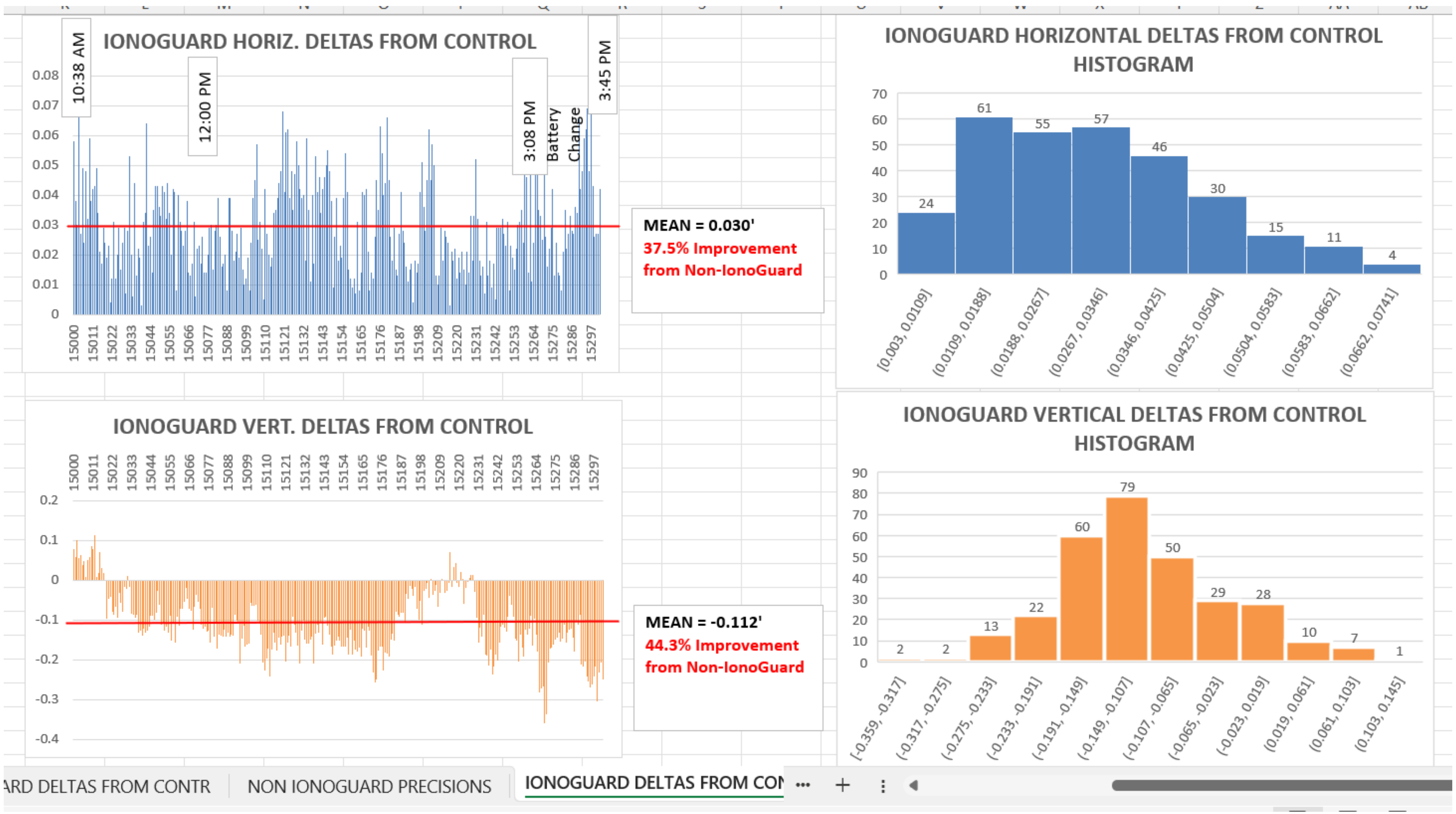




NON IONOGUARD DELTAS FROM CONTR | NON IONOGUARD PRECISIONS | IONOGUARD DELTAS FROM CON ••• +

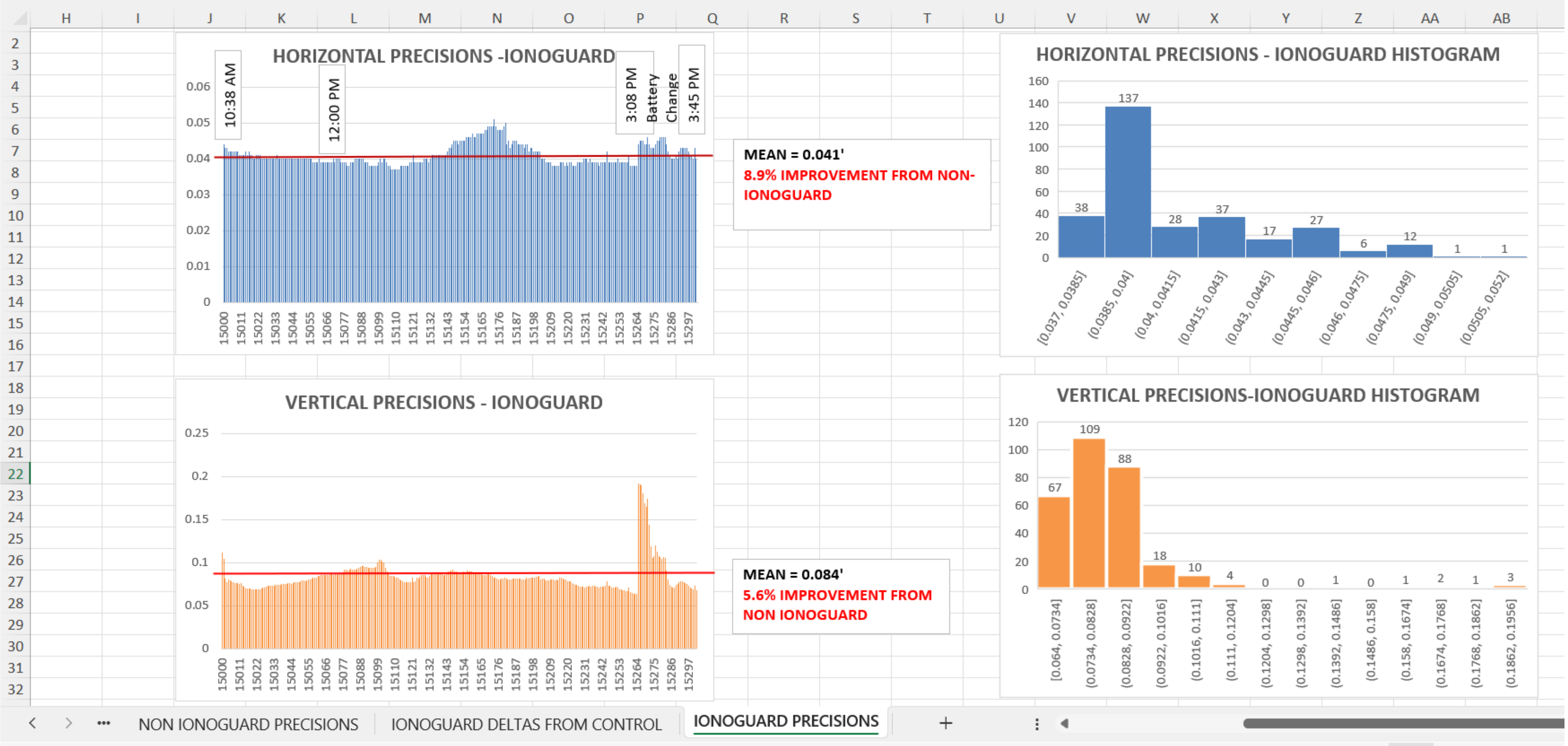
# PPP/RTX TESTING – PRECISIONS WITHOUT IONOGUARD TECHNOLOGY



# PPP/RTX TESTING – DELTAS FROM CONTROL WITH IONOGUARD TECHNOLOGY



# PPP/RTX TESTING - PRECISIONS WITH IONOGUARD TECHNOLOGY



# THANK YOU


- Bob Green, PLS Geospatial Analyst
- Bob@FrontierPrecision.com
- 303-728-4984