# Certificate “GNPCV Type Mean”



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China

**Toknav T10pro integrated GNSS receiver**
**TOKT10PRO NONE**
**GNPCV Type Mean from Absolute Calibrations with a Robot**

- GNSS Antenna Calibration Method
- Calibration Procedure
- Calibration Results
- Additional Photos
- PCV Plots

**Geo++® GmbH**
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**www.geopp.com**

# Calibration of GNSS Antenna
# Toknav T10 Pro NONE
# GNPCV Type Mean from Absolute Calibrations with a Robot

(IGS Name*: TOKT10PRO_____NONE)




**GNSS Antenna Calibration Method**

The Geo++® calibration method with a robot determines the absolute antenna phase center offsets in horizontal and vertical position as well as the absolute elevation and azimuth dependent phase center (PCV) and group delay variations (GDV) for multiple frequencies of GNSS antennas. The resulting PCV and GDV are completely independent from the reference antenna used in the calibration procedure (absolute calibration). Both results allow for a complete correction of the receiving characteristic of the antenna.

Scope of the applied absolute GNSS antenna calibration:

- absolute offsets, PCV and GDV
- special approach with inclined and rotated antenna (robot)
- elimination of multipath
- coverage of the complete elevation from 0° to 90°
- coverage of complete antenna hemisphere
- precise determination of PCV/GDV using a large number of different antenna orientations
- simultaneous estimation of GNSS PCV/GDV for multiple frequencies
- calibration patterns are provided per frequency
- up to 11 frequencies are supported
- frequency 1202.025 MHz is not provided due to lack of constellation to generate stable absolute PCV/GDV and offsets
- calibrations given for one frequency code are valid for all frequency codes at the same frequency according to the following table:

* It is not officially included in the IGS naming convention at writing of this protocol. Check rcvr_ant.tab or gpp_rcvr_ant.tab.

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| Freq.[MHz] | Freq. Codes |
|---|---|
| 1602.000 | R01 R04 |
| 1575.420 | G01 E01 J01 S01 C01 |
| 1561.098 | C02 |
| 1278.750 | E06 J06 |
| 1268.520 | C06 |
| 1246.000 | R02 R06 |
| 1227.600 | G02 J02 |
| 1207.140 | E07 C07 |
| 1202.025 | R03 |
| 1191.795 | E08 C08 |
| 1176.450 | G05 E05 J05 C05 S05 I05 |

- weather independent measurements
- at least four redundant calibrations per individual antenna

Basic concept of the calibration method is the separation between multipath and phase center variation. A special observation procedure with different antenna orientations is used for the determination of absolute PCV/GDV and for multipath elimination.

The processing is done in post-processing. Primary result is a spherical harmonic expansion of the PCV/GDV as function of zenith distance and azimuth with complete variance-covariance data. Finally, absolute horizontal and vertical mean offsets as well as absolute elevation and azimuth dependent phase observation corrections for the calibrated antenna are derived.

### Calibration Procedure

A sample of individual TOKT10PRO_____NONE calibrations conducted with the Geo++® calibration method with a robot is the basis for the calculation of the type mean. The individual calibrations are rigorously adjusted considering the full variance-covariance information.

Scope of the GNPCV type calibration:

- individual calibrations of at least five antennas of same manufacturing series
- adjustment of a type mean using entire variance–covariance data

The type mean of the TOKT10PRO_____NONE antenna is derived from five individual antennas with serial numbers Z32336861003698, Z32336861003713, Z32336861003939, Z32336861003952 and Z32336861004017.

### GNPCV Type Mean

The GNPCV Type Mean is the adjusted mean of the five individual TOKT10PRO_____NONE GNSS antennas. The Antenna Reference Point (ARP) is the reference point used in the calibration. The reference direction to north is defined by the Man Machine Interface (MMI). The antenna height has to be measured to the ARP, which is vertically defined to the bottom of antenna mount (BAM) and horizontally to the rotation axis defined by the center of 5/8“ thread.

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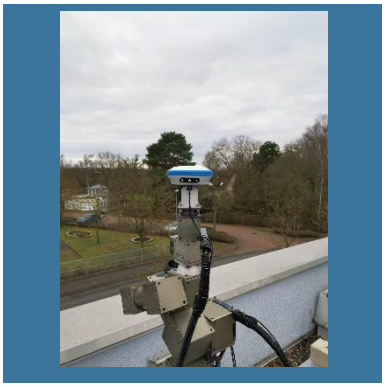
## Additional Photos



*Antenna during calibration on robot*




*Antenna label*

## Calibration Results

Only results for absolute PCV are currently provided by Geo++. Group delay variations (GDV) are available on request. Plots of the absolute PCV pattern for all frequencies are attached in the annex.

As a numerical reference, the pure elevation dependent PCV are listed below in the international ANTEX format (see ANTEX format description for details). However, the complete model of the antenna consists of elevation and azimuth dependent PCV values.

```
     1.4            M                                   ANTEX VERSION / SYST
A                                                       PCV TYPE / REFANT
                                                         END OF HEADER
                                                        START OF ANTENNA
TOKT10PRO       NONE                                    TYPE / SERIAL NO
ROBOT               Geo++ GmbH              5    2023-04-19METH / BY / # / DATE
     5.0                                                DAZI
     0.0  90.0   5.0                                    ZEN1 / ZEN2 / DZEN
    10                                                  # OF FREQUENCIES
                                                        COMMENT
   G01                                                  START OF FREQUENCY
      0.38     -1.14     60.07                         NORTH / EAST / UP
   NOAZI    0.00   -0.03   -0.09   -0.12   -0.02    0.23    0.59    0.95    1.15    1.06    0.64    0.03   -0.55   -0.83   -0.65
-0.07    0.54    0.62   -0.38
   G01                                                  END OF FREQUENCY
   G01                                                  START OF FREQ RMS
   NOAZI    0.00    0.00    0.01    0.02    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.04    0.04    0.04
0.04    0.04    0.04    0.04
   G01                                                  END OF FREQ RMS
   R01                                                  START OF FREQUENCY
      0.70     -0.86     59.70                         NORTH / EAST / UP
   NOAZI    0.00   -0.06   -0.19   -0.32   -0.34   -0.18    0.14    0.54    0.84    0.89    0.62    0.11   -0.46   -0.79   -0.69
-0.18    0.47    0.73    0.04
```

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```
   R01                                                 END OF FREQUENCY
   R01                                                 START OF FREQ RMS
   NOAZI    0.00    0.01    0.02    0.04    0.05    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06    0.06
0.06    0.07    0.07    0.08
   R01                                                 END OF FREQ RMS
   C02                                                 START OF FREQUENCY
      0.20    -1.29    60.26                           NORTH / EAST / UP
   NOAZI    0.00   -0.02   -0.04    0.00    0.16    0.47    0.86    1.20    1.34    1.17    0.67    0.00   -0.59   -0.83   -0.60
0.01    0.59    0.57   -0.57
   C02                                                 END OF FREQUENCY
   C02                                                 START OF FREQ RMS
   NOAZI    0.00    0.00    0.02    0.03    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.06    0.06    0.06
0.06    0.06    0.06    0.07
   C02                                                 END OF FREQ RMS
   E06                                                 START OF FREQUENCY
     -0.13    -0.57    54.92                           NORTH / EAST / UP
   NOAZI    0.00   -0.05   -0.16   -0.32   -0.47   -0.62   -0.76   -0.88   -0.91   -0.71   -0.20    0.57    1.35    1.74    1.46
0.53   -0.43   -0.31    2.15
   E06                                                 END OF FREQUENCY
   E06                                                 START OF FREQ RMS
   NOAZI    0.00    0.01    0.03    0.07    0.09    0.10    0.11    0.10    0.10    0.10    0.10    0.11    0.11    0.11    0.11
0.11    0.12    0.13    0.13
   E06                                                 END OF FREQ RMS
   C06                                                 START OF FREQUENCY
     -0.31    -0.58    55.33                           NORTH / EAST / UP
   NOAZI    0.00   -0.04   -0.14   -0.29   -0.47   -0.67   -0.88   -1.04   -1.03   -0.76   -0.19    0.58    1.28    1.53    1.10
0.12   -0.77   -0.50    2.05
   C06                                                 END OF FREQUENCY
   C06                                                 START OF FREQ RMS
   NOAZI    0.00    0.01    0.02    0.05    0.06    0.07    0.07    0.07    0.07    0.07    0.07    0.08    0.08    0.08    0.08
0.08    0.08    0.09    0.09
   C06                                                 END OF FREQ RMS
   R02                                                 START OF FREQUENCY
     -0.67    -0.60    56.28                           NORTH / EAST / UP
   NOAZI    0.00   -0.01   -0.04   -0.13   -0.31   -0.56   -0.82   -0.99   -0.92   -0.53    0.14    0.89    1.39    1.34    0.64
-0.45   -1.19   -0.60    2.15
   R02                                                 END OF FREQUENCY
   R02                                                 START OF FREQ RMS
   NOAZI    0.00    0.00    0.02    0.03    0.04    0.05    0.05    0.05    0.05    0.04    0.05    0.05    0.05    0.05    0.05
0.05    0.05    0.06    0.06
   R02                                                 END OF FREQ RMS
   G02                                                 START OF FREQUENCY
     -0.92    -0.60    57.09                           NORTH / EAST / UP
   NOAZI    0.00    0.02    0.06    0.04   -0.09   -0.34   -0.61   -0.75   -0.62   -0.14    0.57    1.25    1.57    1.26    0.35
-0.76   -1.32   -0.49    2.31
   G02                                                 END OF FREQUENCY
   G02                                                 START OF FREQ RMS
```

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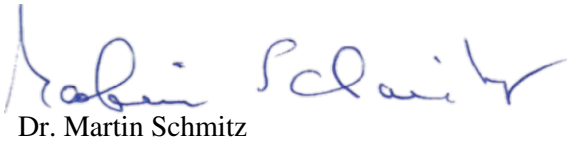
```
   NOAZI    0.00    0.01    0.02    0.03    0.05    0.05    0.06    0.05    0.05    0.05    0.05    0.06    0.06    0.06    0.06
0.06    0.06    0.07    0.07
   G02                                                 END OF FREQ RMS
   E07                                                 START OF FREQUENCY
     -1.16    -0.60    58.07                           NORTH / EAST / UP
   NOAZI    0.00    0.06    0.19    0.27    0.20   -0.02   -0.28   -0.38   -0.17    0.40    1.13    1.69    1.74    1.11    0.00
-1.08   -1.38   -0.28    2.42
   E07                                                 END OF FREQUENCY
   E07                                                 START OF FREQ RMS
   NOAZI    0.00    0.00    0.02    0.03    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.06    0.06    0.06
0.06    0.06    0.06    0.07
   E07                                                 END OF FREQ RMS
   E08                                                 START OF FREQUENCY
     -1.31    -0.59    58.87                           NORTH / EAST / UP
   NOAZI    0.00    0.09    0.28    0.43    0.40    0.18   -0.07   -0.13    0.16    0.79    1.52    1.94    1.74    0.84   -0.43
-1.43   -1.46   -0.13    2.36
   E08                                                 END OF FREQUENCY
   E08                                                 START OF FREQ RMS
   NOAZI    0.00    0.00    0.01    0.03    0.04    0.04    0.04    0.04    0.04    0.04    0.04    0.04    0.04    0.04    0.04
0.04    0.05    0.05    0.05
   E08                                                 END OF FREQ RMS
   G05                                                 START OF FREQUENCY
     -1.42    -0.58    59.71                           NORTH / EAST / UP
   NOAZI    0.00    0.11    0.37    0.59    0.60    0.41    0.18    0.17    0.55    1.25    1.95    2.20    1.70    0.51   -0.90
-1.78   -1.50    0.05    2.26
   G05                                                 END OF FREQUENCY
   G05                                                 START OF FREQ RMS
   NOAZI    0.00    0.00    0.02    0.03    0.04    0.05    0.05    0.05    0.04    0.04    0.05    0.05    0.05    0.05    0.05
0.05    0.06    0.06    0.07
   G05                                                 END OF FREQ RMS
                                                       END OF ANTENNA
```



Garbsen, June 16, 2023 Dr. Martin Schmitz

## Literature

Wübbena, G., M. Schmitz, F. Menge, G. Seeber, C. Völksen (1997). A New Approach for Field Calibration of Absolute Antenna Phase Center Variations. *Navigation*, Journal of The Institute of Navigation, Vol. 44, No. 2, 247-256.

Menge, F., G. Seeber, C. Völksen, G. Wübbena, M. Schmitz (1998). Results of Absolute Field Calibration of GPS Antenna PCV. Proceedings of International Technical Meeting, *ION GPS-98*, Nashville, Tennessee.

Wübbena, G., M. Schmitz, F. Menge, V. Böder, G. Seeber (2000). Automated Absolute Field Calibration of GPS Antennas in Real-Time. Proceedings of International Technical Meeting, *ION GPS-00*, Salt Lake City, Utah.

Schmitz, M., G. Wübbena, G. Boettcher (2002). Tests of phase center variations of various GPS antennas, and some results. *GPS Solutions*, Volume 6, Number 1-2, Springer, 18-27.

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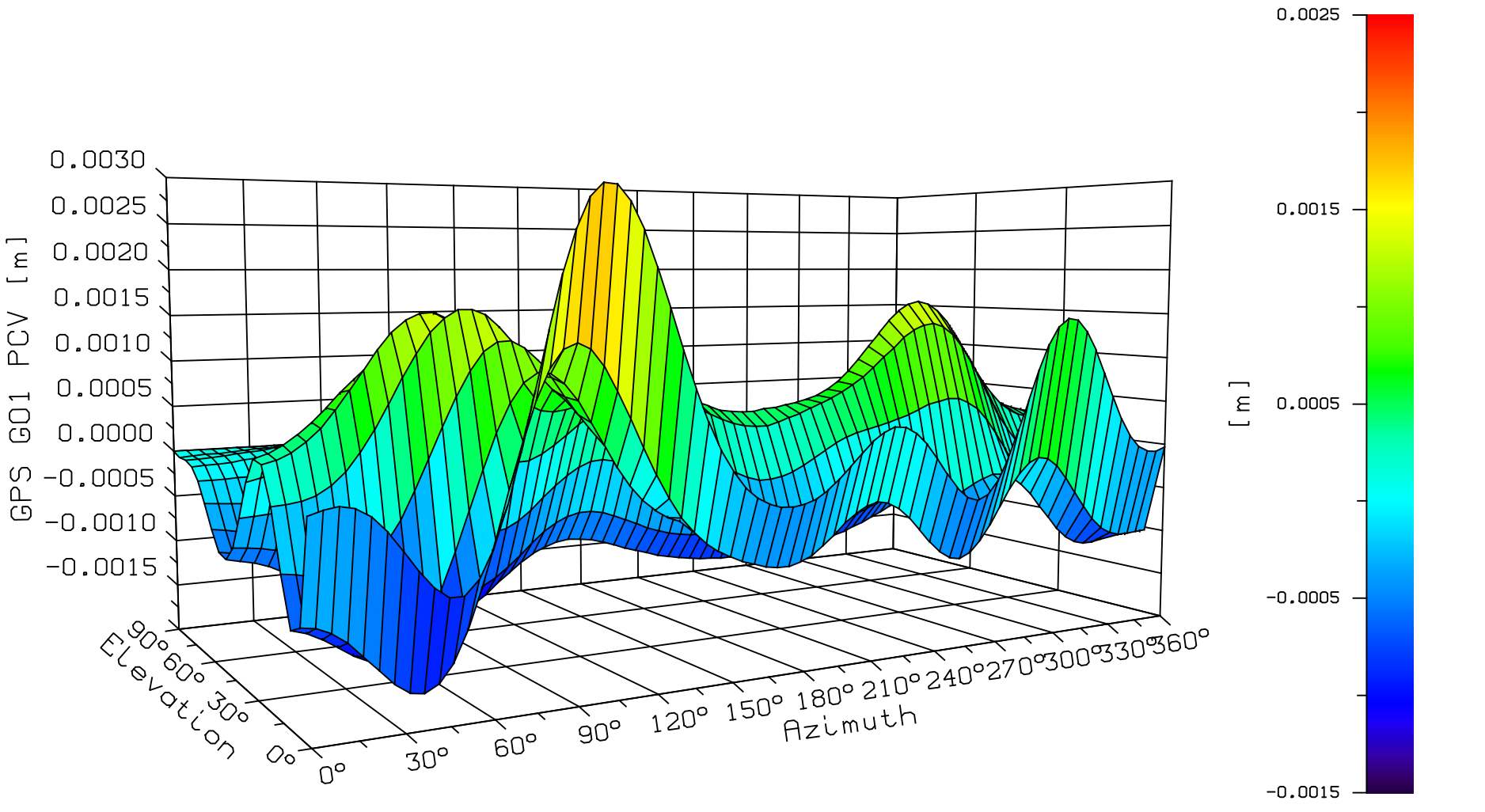
TOKT1OPRO_____NONE, SN:TYPE
GPS G01 PCV [m]

mean: -0.00016 [m]
StdDev:+0.00069 [m]
RMS: +0.00071 [m]

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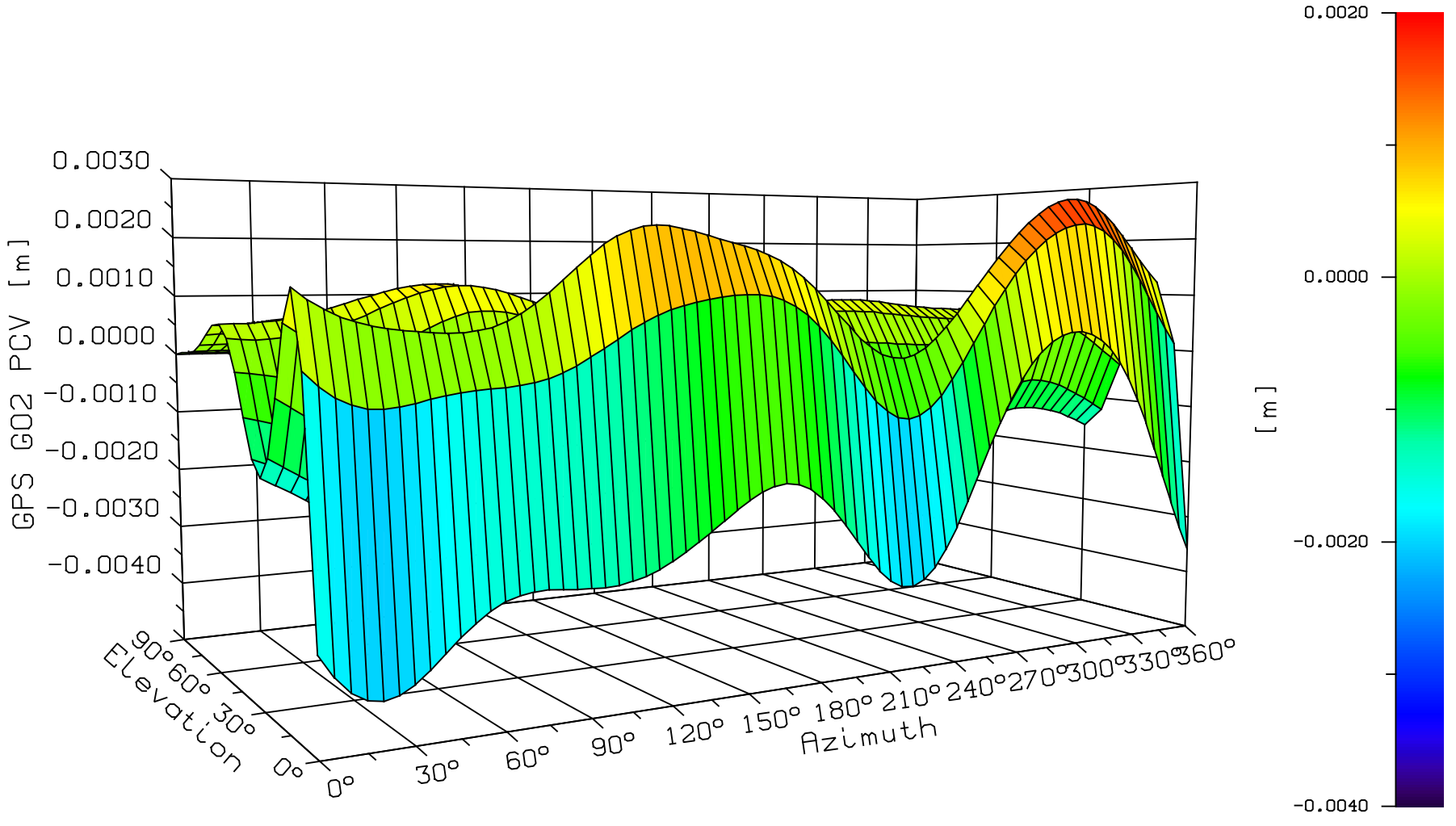
TOKT1OPRO_____NONE, SN:TYPE
GPS G02 PCV [m]

mean: -0.00012 [m]
StdDev:+0.00103 [m]
RMS: +0.00104 [m]

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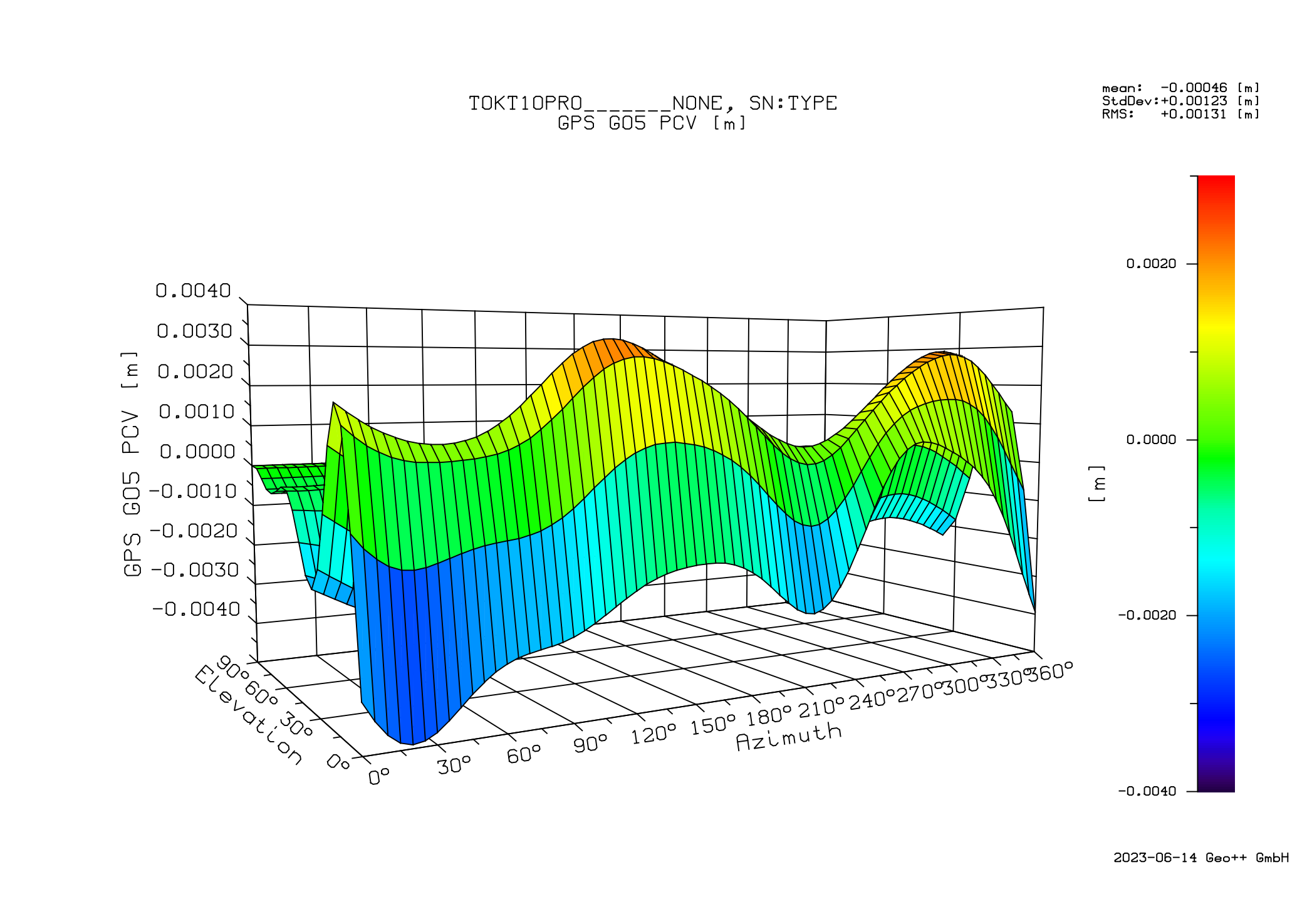
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StdDev:+0.00123 [m]
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GPS G05 PCV [m]
0.0040
0.0030
0.0020
0.0010
0.0000
-0.0010
-0.0020
-0.0030
-0.0040
Elevation
90°
60°
30°
0°
Azimuth
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
360°
[m]
0.0020
0.0000
-0.0020
-0.0040
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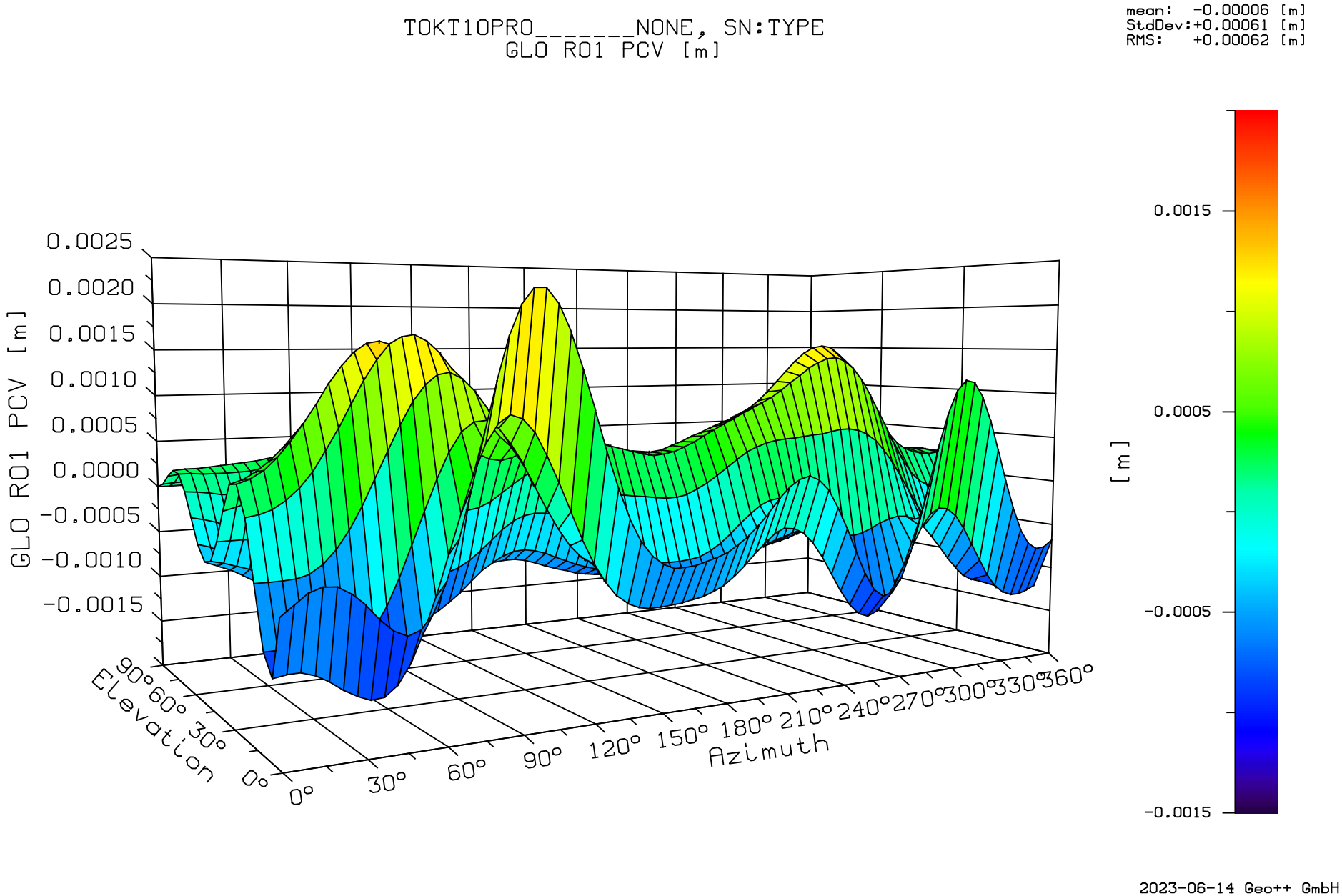
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StdDev:+0.00061 [m]
RMS: +0.00062 [m]
GLO R01 PCV [m]
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
-0.0005
-0.0010
-0.0015
Elevation
90°
60°
30°
0°
Azimuth
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
360°
[m]
0.0015
0.0005
-0.0005
-0.0015
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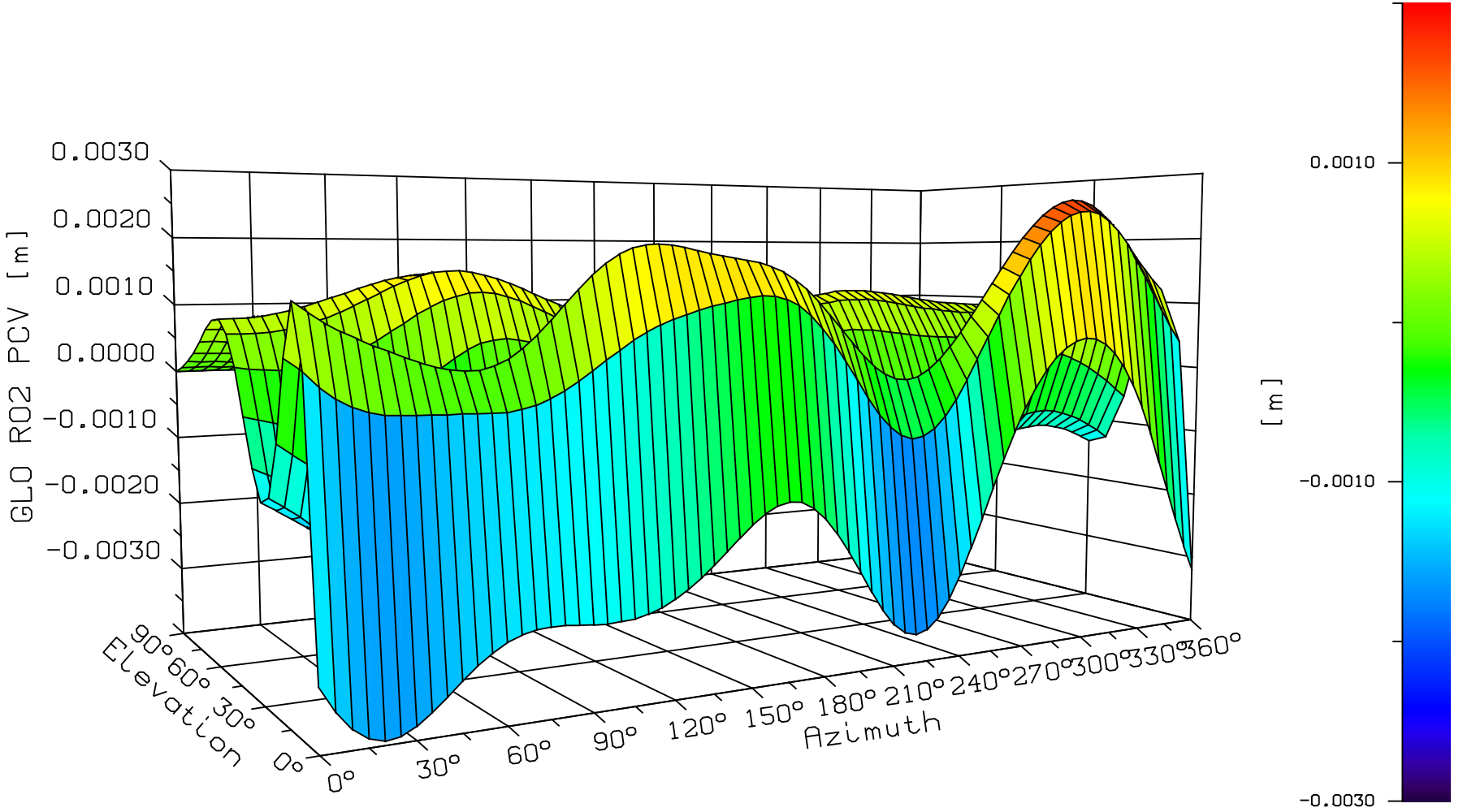
TOKT1OPRO_____NONE, SN:TYPE
GLO R02 PCV [m]

mean: +0.00000 [m]
StdDev:+0.00101 [m]
RMS: +0.00101 [m]

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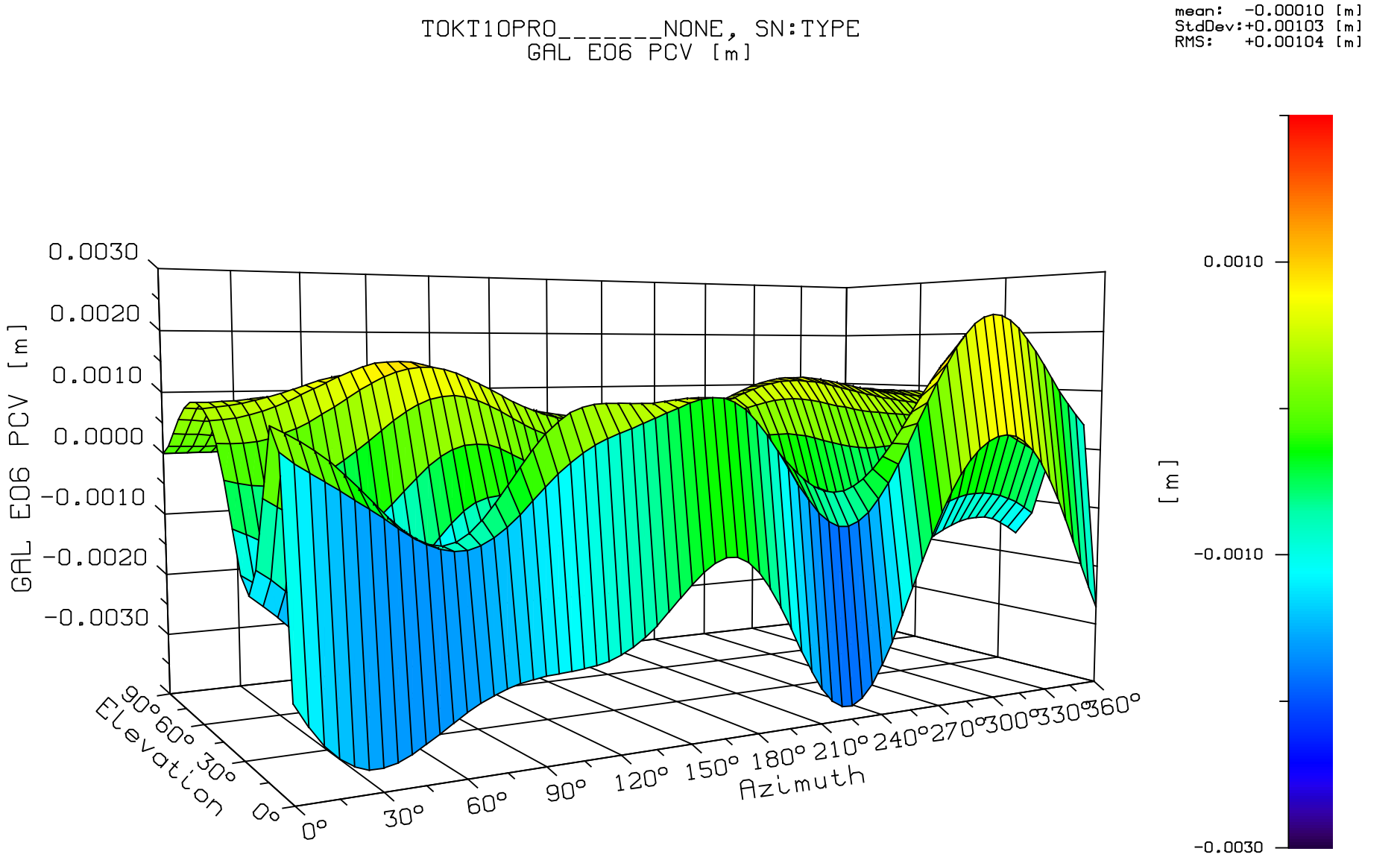
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StdDev:+0.00103 [m]
RMS: +0.00104 [m]
GAL E06 PCV [m]
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0.0020
0.0010
0.0000
-0.0010
-0.0020
-0.0030
Elevation
90°
60°
30°
0°
Azimuth
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
360°
[m]
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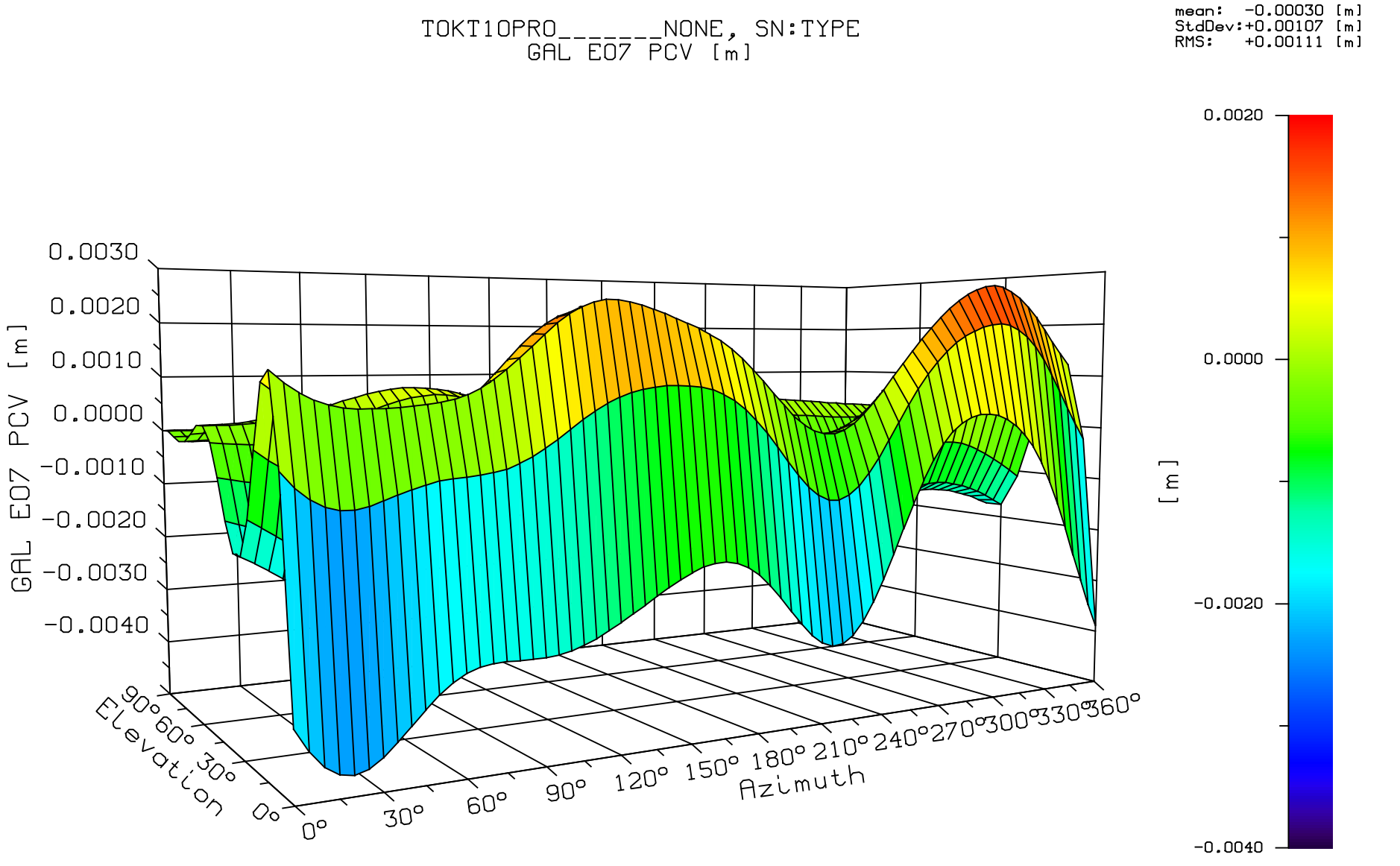
-0.0010
-0.0030
2023-06-14 Geo++ GmbH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StdDev:+0.00107 [m]
RMS: +0.00111 [m]
GAL E07 PCV [m]
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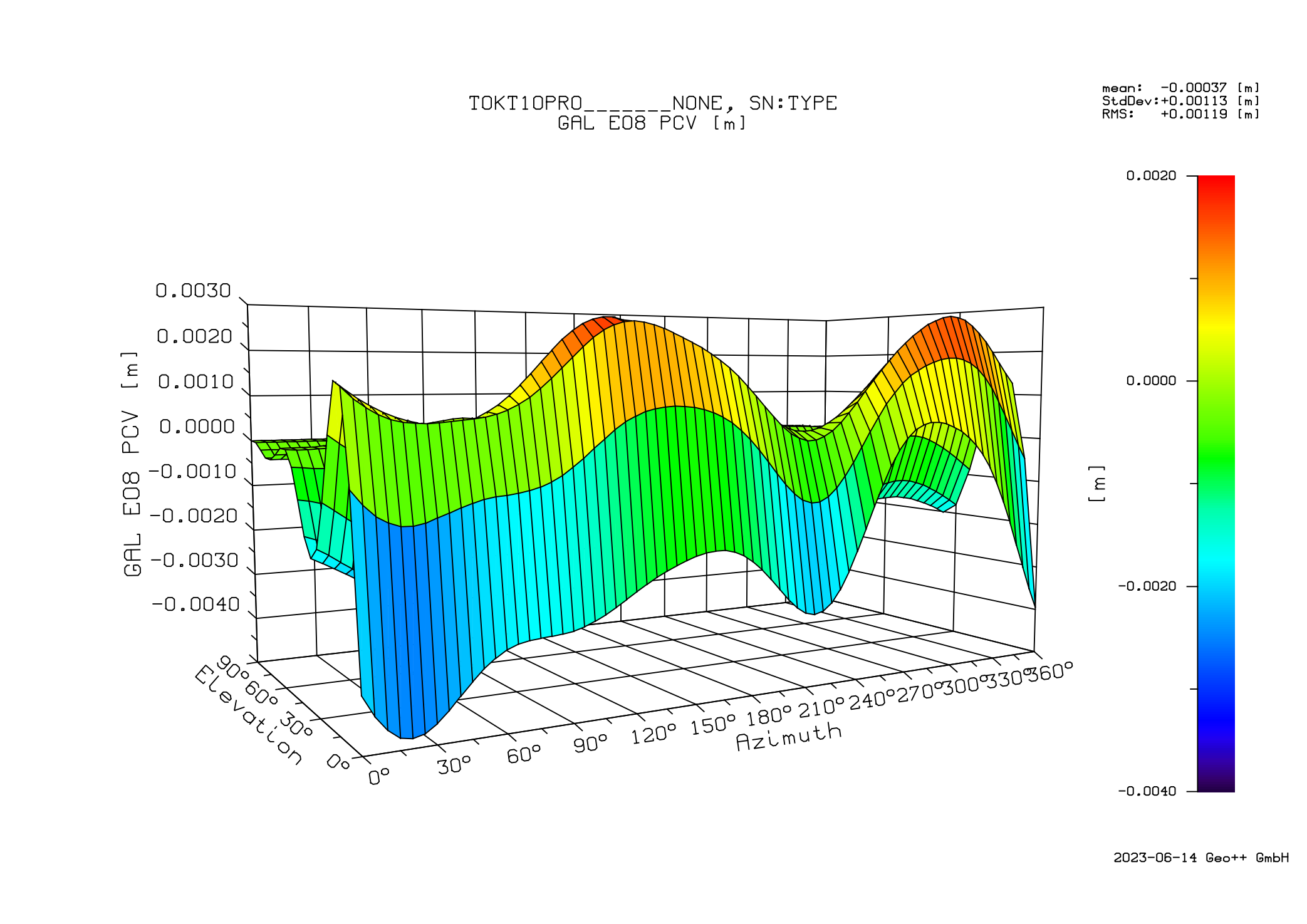
0.0020
0.0010
0.0000
-0.0010
-0.0020
-0.0030
-0.0040
Elevation
90°
60°
30°
0°
Azimuth
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
360°
[m]
0.0020
0.0000
-0.0020
-0.0040
2023-06-14 Geo++ GmbH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mean: -0.00037 [m]
StdDev:+0.00113 [m]
RMS: +0.00119 [m]
GAL E08 PCV [m]
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0.0020
0.0010
0.0000
-0.0010
-0.0020
-0.0030
-0.0040
Elevation
90°
60°
30°
0°
Azimuth
0°
30°
60°
90°
120°
150°
180°
210°
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330°
360°
[m]
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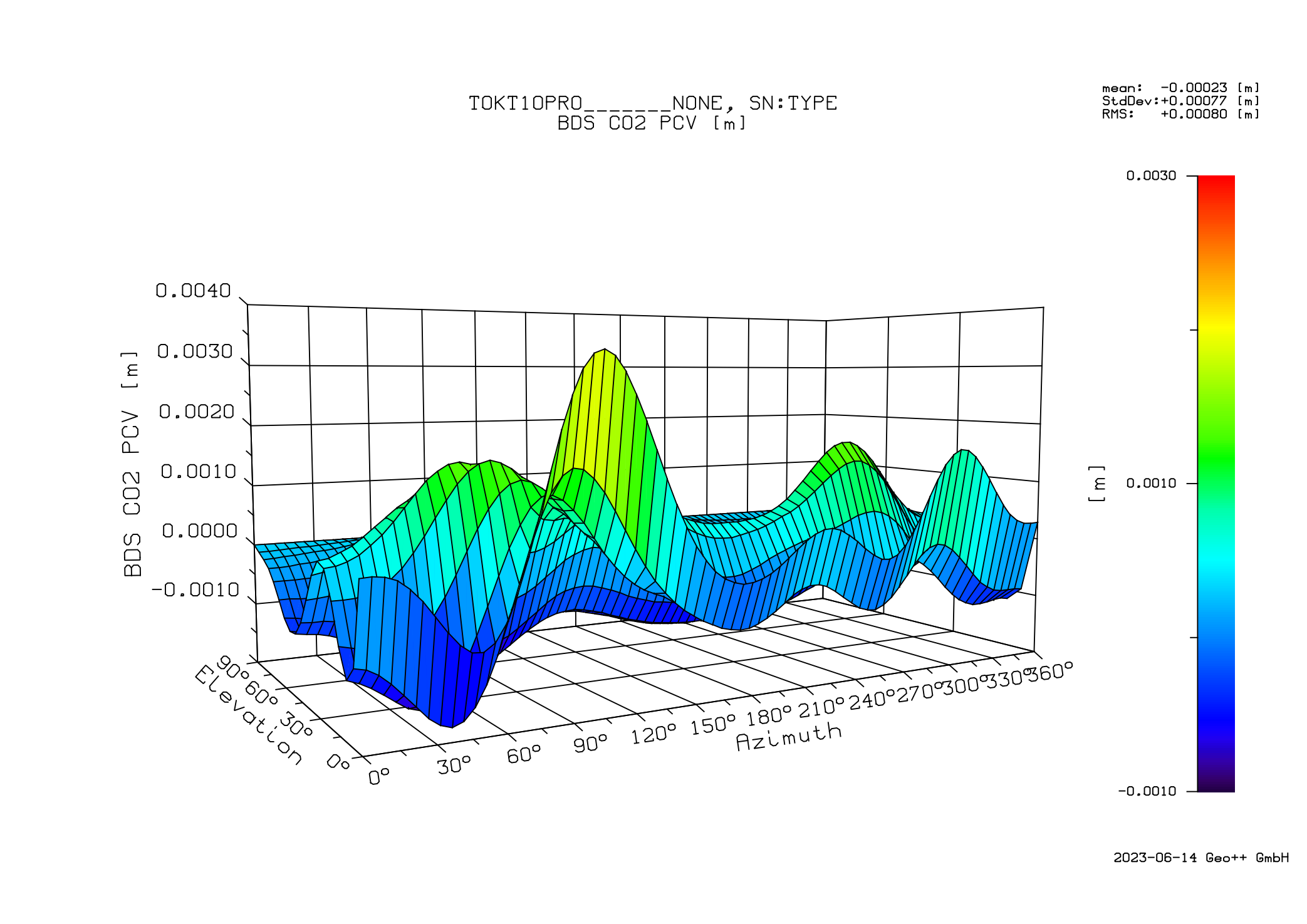
2023-06-14 Geo++ GmbH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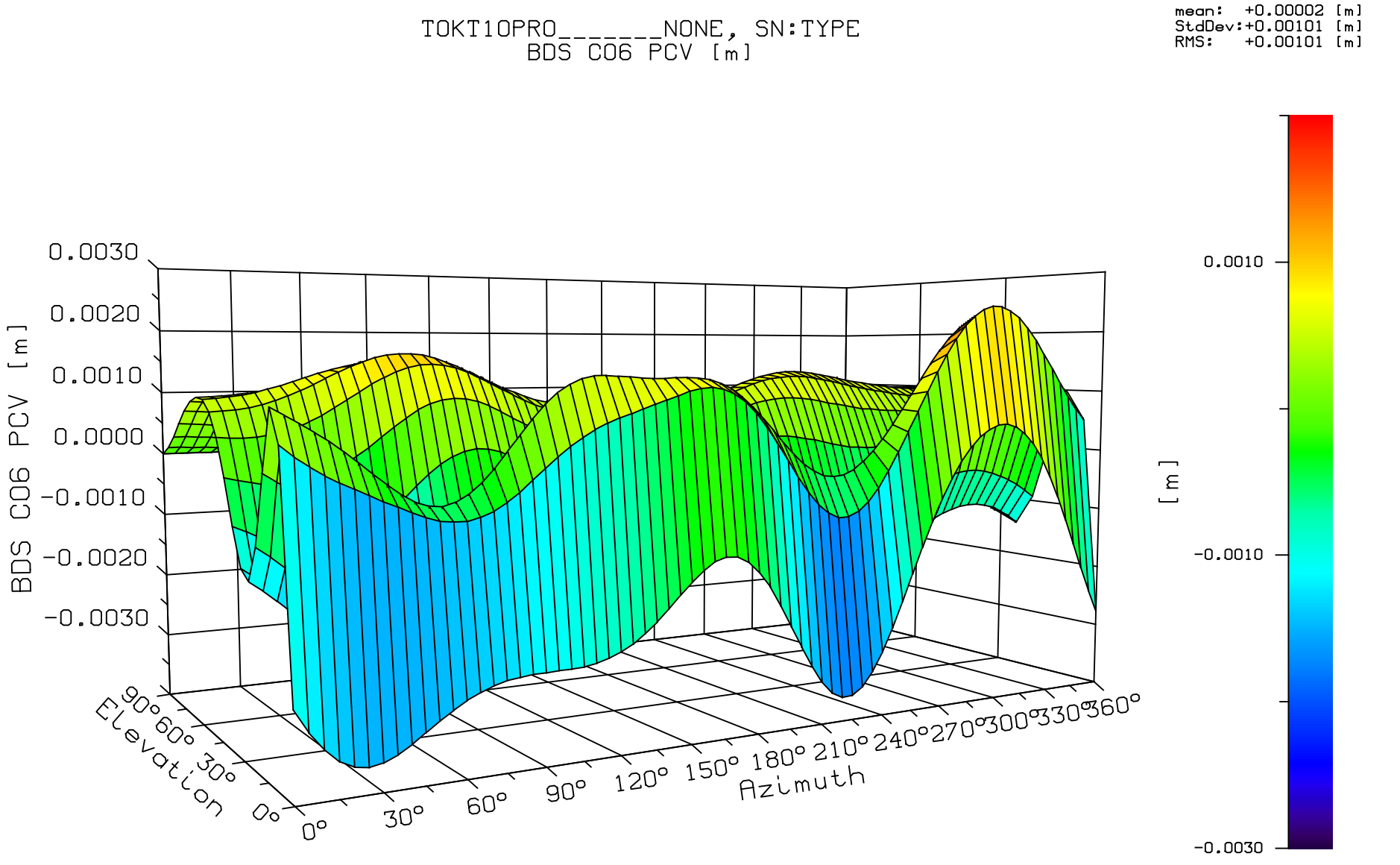
StdDev:+0.00077 [m]
RMS: +0.00080 [m]
0.0040
0.0030
0.0020
0.0010
0.0000
-0.0010
BDS CO2 PCV [m]
90°
60°
30°
0°
Elevation
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
360°
Azimuth
0.0030
0.0010
-0.0010
[m]
2023-06-14 Geo++ GmbH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StdDev:+0.00101 [m]
RMS: +0.00101 [m]
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0.0020
0.0010
0.0000
-0.0010
-0.0020
-0.0030
Elevation
90°
60°
30°
0°
Azimuth
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
360°
[m]
0.0010
-0.0010
-0.0030
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