Certificate “GNPCV Type Mean”



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Toknav T5 integrated GNSS receiver
TOKT5 NONE
GNPCV Type Mean from Absolute Calibrations with a Robot

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

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Calibration of GNSS Antenna
Toknav T5 NONE
GNPCV Type Mean from Absolute Calibrations with a Robot

(IGS Name*: TOKT5_____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 TOKT5_____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 TOKT5_____NONE antenna is derived from five individual antennas with serial numbers Z32376861005938, Z32376861006233, Z32376861006358, Z32376861006687 and Z32386861006225.

GNPCV Type Mean

The GNPCV Type Mean is the adjusted mean of the five individual TOKT5_____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 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
TOKT5           NONE                                     TYPE / SERIAL NO
ROBOT               Geo++ GmbH              5    2023-04-28METH / BY / # / DATE
     5.0                                                 DAZI
     0.0  90.0   5.0                                     ZEN1 / ZEN2 / DZEN
    10                                                   # OF FREQUENCIES
                                                         COMMENT
   G01                                                   START OF FREQUENCY
     -0.66     -0.93     65.53                           NORTH / EAST / UP
   NOAZI    0.00   -0.03   -0.10   -0.08    0.12    0.53    1.09    1.62    1.90    1.76    1.19    0.36   -0.45   -0.91   -0.83
-0.32    0.25    0.30   -0.72
   G01                                                   END OF FREQUENCY
   G01                                                   START OF FREQ RMS
   NOAZI    0.00    0.00    0.01    0.02    0.03    0.04    0.04    0.03    0.03    0.03    0.04    0.04    0.04    0.04    0.04
0.04    0.04    0.04    0.05
   G01                                                   END OF FREQ RMS
   R01                                                   START OF FREQUENCY
     -0.24     -1.36     65.00                           NORTH / EAST / UP
   NOAZI    0.00   -0.07   -0.24   -0.38   -0.33   -0.03    0.51    1.10    1.53    1.59    1.19    0.44   -0.38   -0.91   -0.92
-0.41    0.28    0.57   -0.17
```

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```
   R01                                                 END OF FREQUENCY
   R01                                                 START OF FREQ RMS
   NOAZI    0.00    0.01    0.02    0.05    0.06    0.07    0.07    0.07    0.06    0.06    0.07    0.07    0.07    0.07    0.07
0.07    0.08    0.09    0.09   R01
   R01                                                 END OF FREQ RMS
   C02                                                 START OF FREQUENCY
     -0.89    -0.72    65.82                           NORTH / EAST / UP
   NOAZI    0.00   -0.01   -0.02    0.08    0.36    0.83    1.41    1.90    2.09    1.85    1.19    0.30   -0.49   -0.90   -0.78
-0.26    0.24    0.14   -1.03
   C02                                                 END OF FREQUENCY
   C02                                                 START OF FREQ RMS
   NOAZI    0.00    0.01    0.02    0.04    0.05    0.06    0.06    0.06    0.05    0.05    0.06    0.06    0.06    0.06    0.06
0.06    0.06    0.07    0.07
   C02                                                 END OF FREQ RMS
   E06                                                 START OF FREQUENCY
      0.84    -1.07    56.91                           NORTH / EAST / UP
   NOAZI    0.00   -0.06   -0.22   -0.46   -0.76   -1.09   -1.41   -1.65   -1.69   -1.41   -0.74    0.20    1.12    1.60    1.35
0.41   -0.65   -0.76    1.22
   E06                                                 END OF FREQUENCY
   E06                                                 START OF FREQ RMS
   NOAZI    0.00    0.01    0.04    0.07    0.10    0.11    0.11    0.11    0.11    0.11    0.11    0.12    0.12    0.12    0.12
0.12    0.12    0.14    0.14
   E06                                                 END OF FREQ RMS
   C06                                                 START OF FREQUENCY
      0.69    -1.14    57.45                           NORTH / EAST / UP
   NOAZI    0.00   -0.03   -0.13   -0.32   -0.58   -0.91   -1.26   -1.52   -1.53   -1.19   -0.47    0.47    1.30    1.63    1.22
0.21   -0.78   -0.71    1.45
   C06                                                 END OF FREQUENCY
   C06                                                 START OF FREQ RMS
   NOAZI    0.00    0.01    0.03    0.05    0.07    0.08    0.08    0.08    0.07    0.07    0.08    0.08    0.08    0.08    0.08
0.08    0.08    0.09    0.10
   C06                                                 END OF FREQ RMS
   R02                                                 START OF FREQUENCY
      0.38    -1.27    58.66                           NORTH / EAST / UP
   NOAZI    0.00    0.01    0.00   -0.08   -0.29   -0.63   -1.01   -1.25   -1.18   -0.70    0.11    1.00    1.60    1.58    0.85
-0.27   -1.07   -0.63    1.78
   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    0.05    0.05    0.05    0.05    0.05    0.05
0.05    0.06    0.06    0.07
   R02                                                 END OF FREQ RMS
   G02                                                 START OF FREQUENCY
      0.15    -1.32    59.72                           NORTH / EAST / UP
   NOAZI    0.00    0.04    0.12    0.13   -0.04   -0.37   -0.75   -0.96   -0.80   -0.21    0.66    1.47    1.83    1.49    0.51
-0.64   -1.24   -0.52    1.91
   G02                                                 END OF FREQUENCY
   G02                                                 START OF FREQ RMS
```

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   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    0.08    0.08
   G02                                                 END OF FREQ RMS
   E07                                                 START OF FREQUENCY
     -0.08    -1.34    60.97                           NORTH / EAST / UP
   NOAZI    0.00    0.08    0.25    0.34    0.24   -0.08   -0.44   -0.58   -0.30    0.42    1.32    1.99    2.04    1.32    0.08
-1.05   -1.36   -0.36    1.87
   E07                                                 END OF FREQUENCY
   E07                                                 START OF FREQ RMS
   NOAZI    0.00    0.01    0.02    0.04    0.05    0.06    0.06    0.06    0.06    0.05    0.06    0.06    0.06    0.06    0.06
0.06    0.06    0.07    0.08
   E07                                                 END OF FREQ RMS
   E08                                                 START OF FREQUENCY
     -0.25    -1.32    61.95                           NORTH / EAST / UP
   NOAZI    0.00    0.10    0.32    0.46    0.39    0.09   -0.23   -0.30    0.10    0.91    1.83    2.36    2.13    1.10   -0.31
-1.38   -1.45   -0.27    1.70
   E08                                                 END OF FREQUENCY
   E08                                                 START OF FREQ RMS
   NOAZI    0.00    0.00    0.02    0.03    0.04    0.04    0.04    0.04    0.04    0.04    0.04    0.05    0.05    0.05    0.05
0.05    0.05    0.06    0.06
   E08                                                 END OF FREQ RMS
   G05                                                 START OF FREQUENCY
     -0.40    -1.30    62.98                           NORTH / EAST / UP
   NOAZI    0.00    0.11    0.36    0.54    0.49    0.21   -0.06   -0.03    0.50    1.43    2.33    2.68    2.14    0.79   -0.79
-1.77   -1.55   -0.21    1.36
   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    0.05    0.05    0.05    0.05    0.06    0.06    0.06
0.06    0.06    0.07    0.07
   G05                                                 END OF FREQ RMS
                                                       END OF ANTENNA
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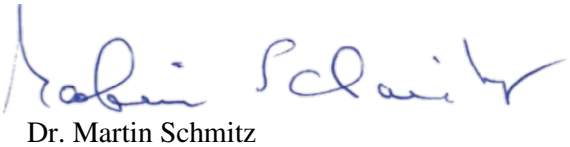

Garbsen, June 16, 2023 Dr. Martin Schmitz

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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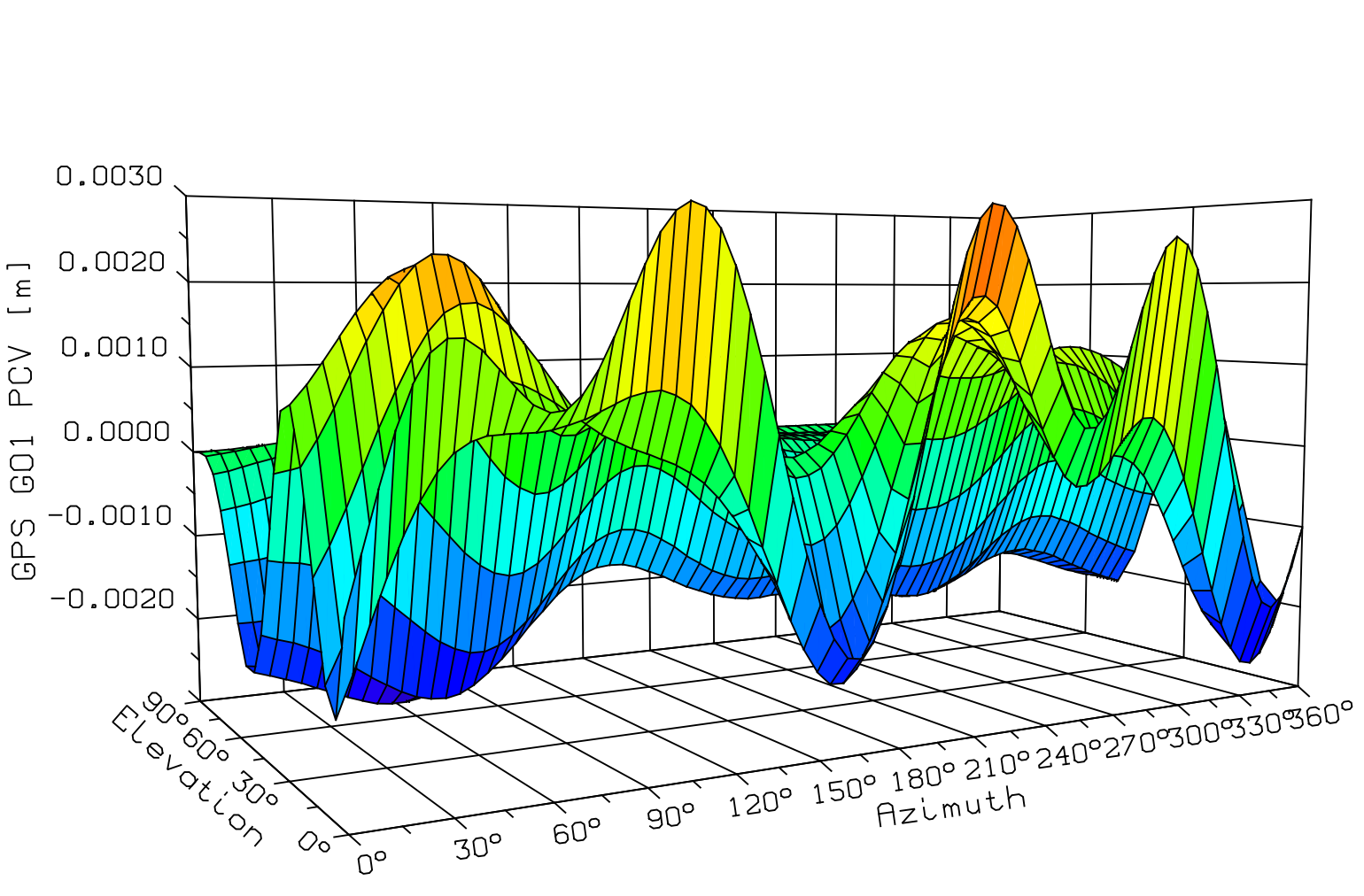
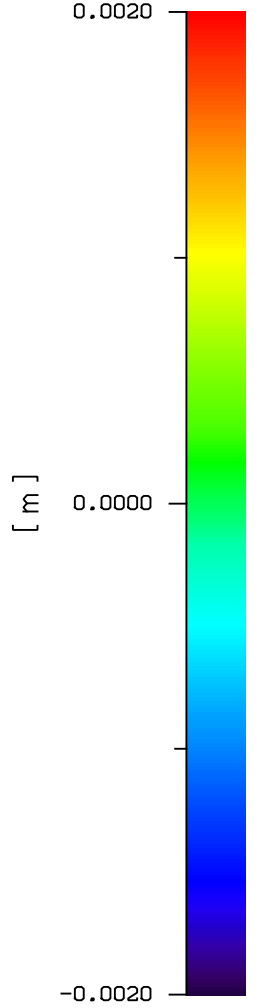
TOKT5_____NONE, SN:TYPE
GPS G01 PCV [m]

mean: -0.00030 [m]
StdDev:+0.00105 [m]
RMS: +0.00109 [m]





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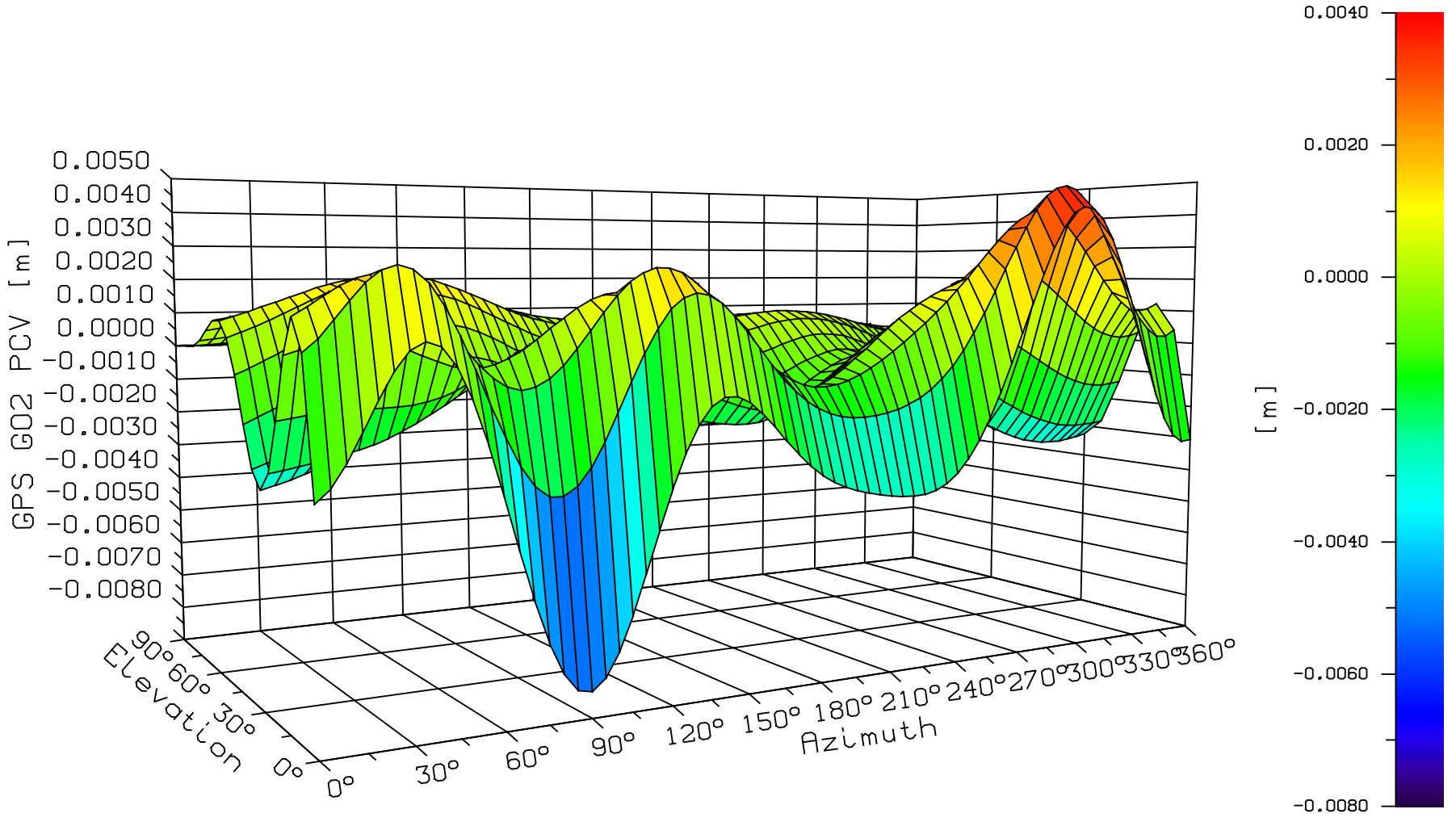
TOKT5_____NONE, SN:TYPE
GPS G02 PCV [m]

mean: -0.00016 [m]
StdDev:+0.00143 [m]
RMS: +0.00144 [m]



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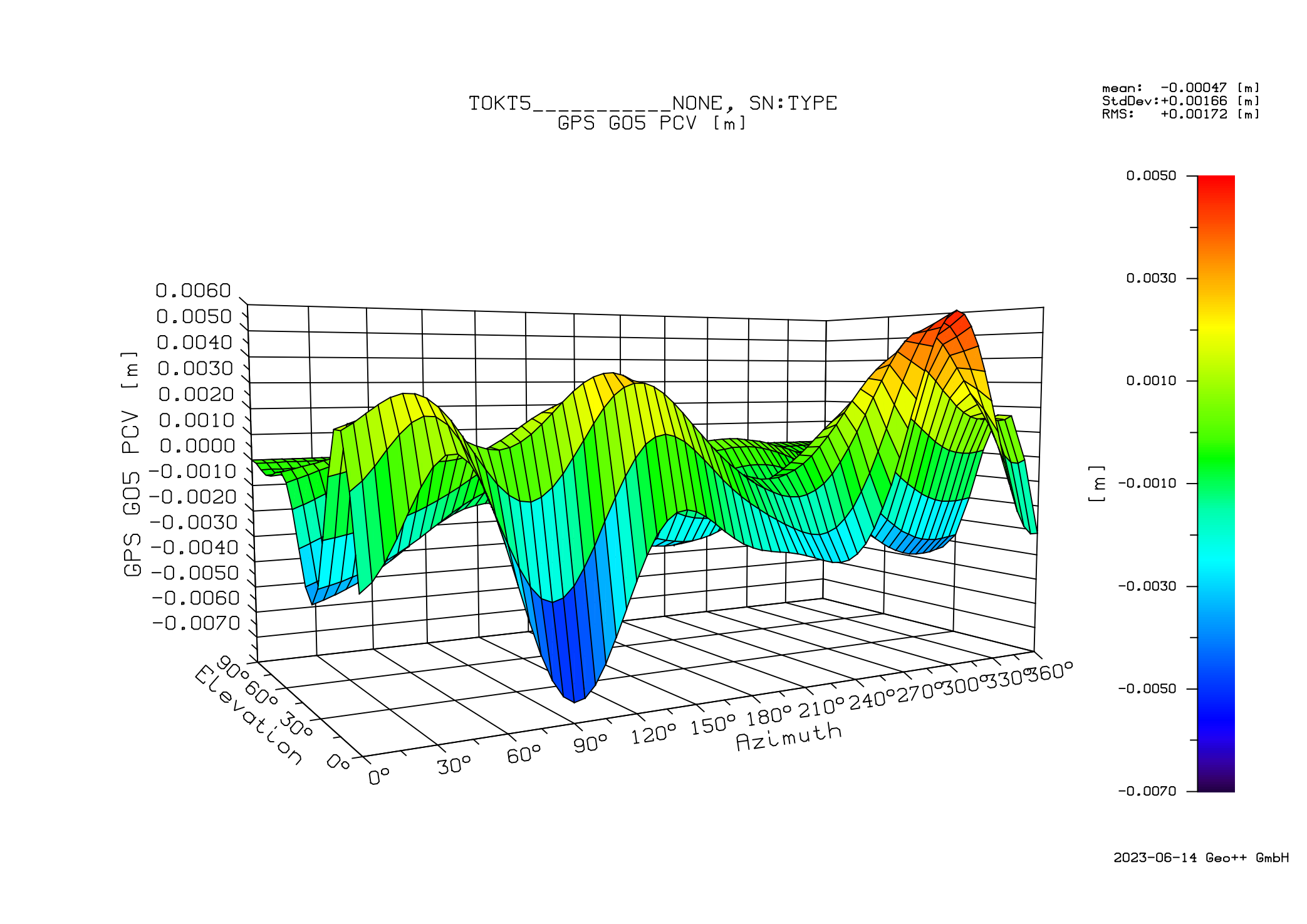
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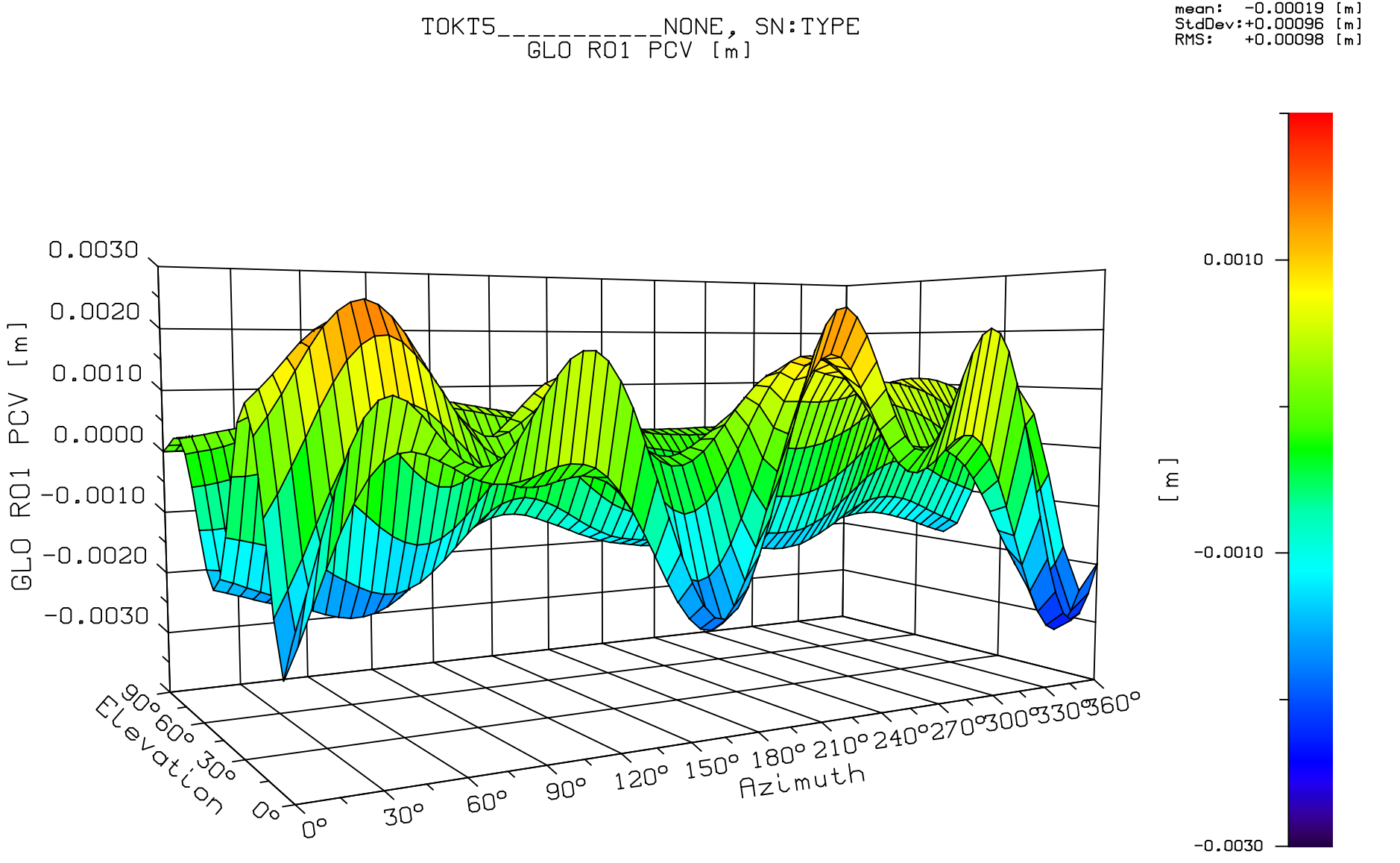
GPS G05 PCV [m]
mean: -0.00047 [m]
StdDev:+0.00166 [m]
RMS: +0.00172 [m]
GPS G05 PCV [m]
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
-0.0010
-0.0020
-0.0030
-0.0040
-0.0050
-0.0060
-0.0070
Elevation
90°
60°
30°
0°
Azimuth
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
360°
[m]
0.0050
0.0030
0.0010
-0.0010
-0.0030
-0.0050
-0.0070
2023-06-14 Geo++ GmbH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GLO R01 PCV [m]
mean: -0.00019 [m]
StdDev:+0.00096 [m]
RMS: +0.00098 [m]
GLO R01 PCV [m]
0.0030
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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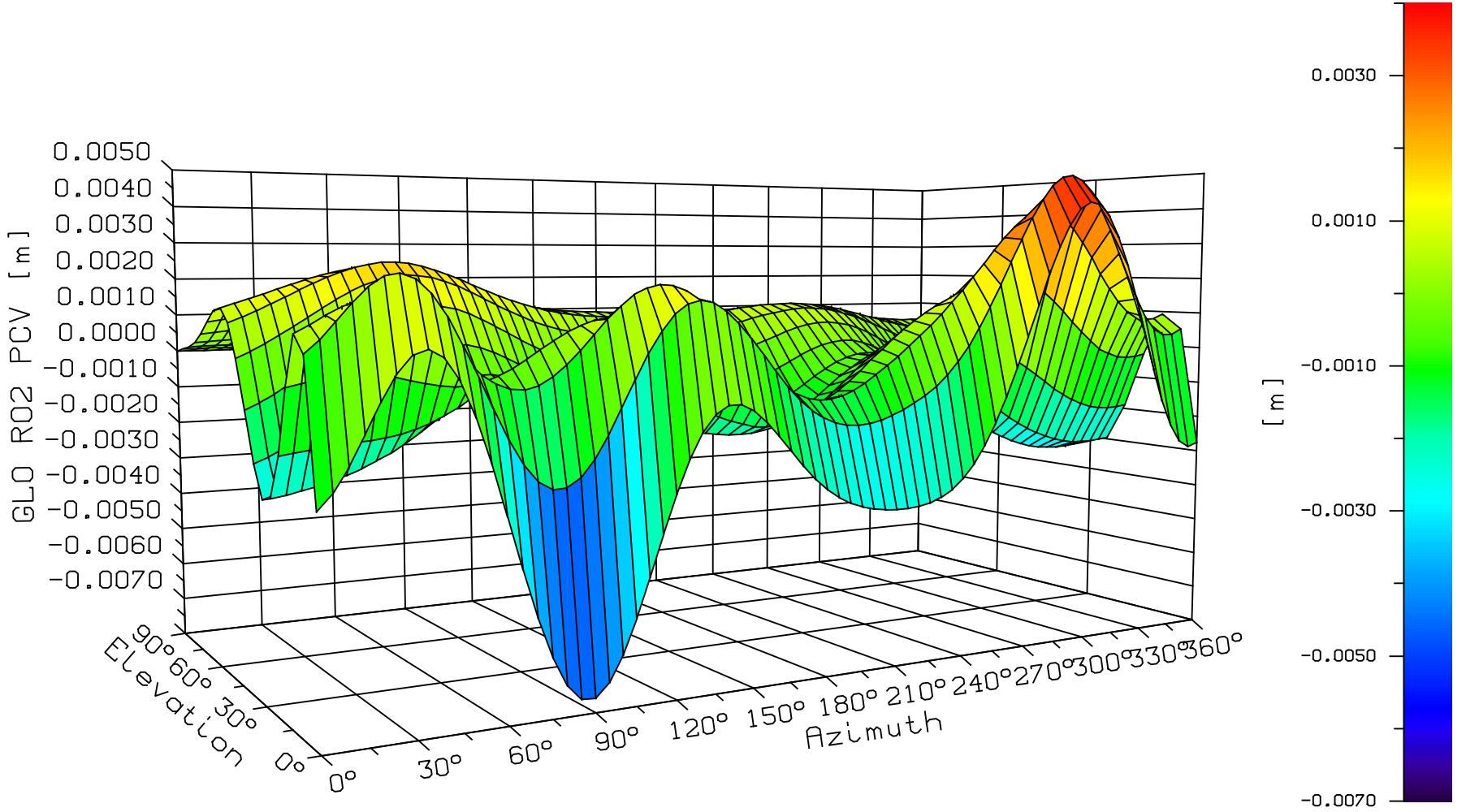
TOKT5_____NONE, SN:TYPE
GLO R02 PCV [m]

mean: -0.00000 [m]
StdDev:+0.00140 [m]
RMS: +0.00140 [m]



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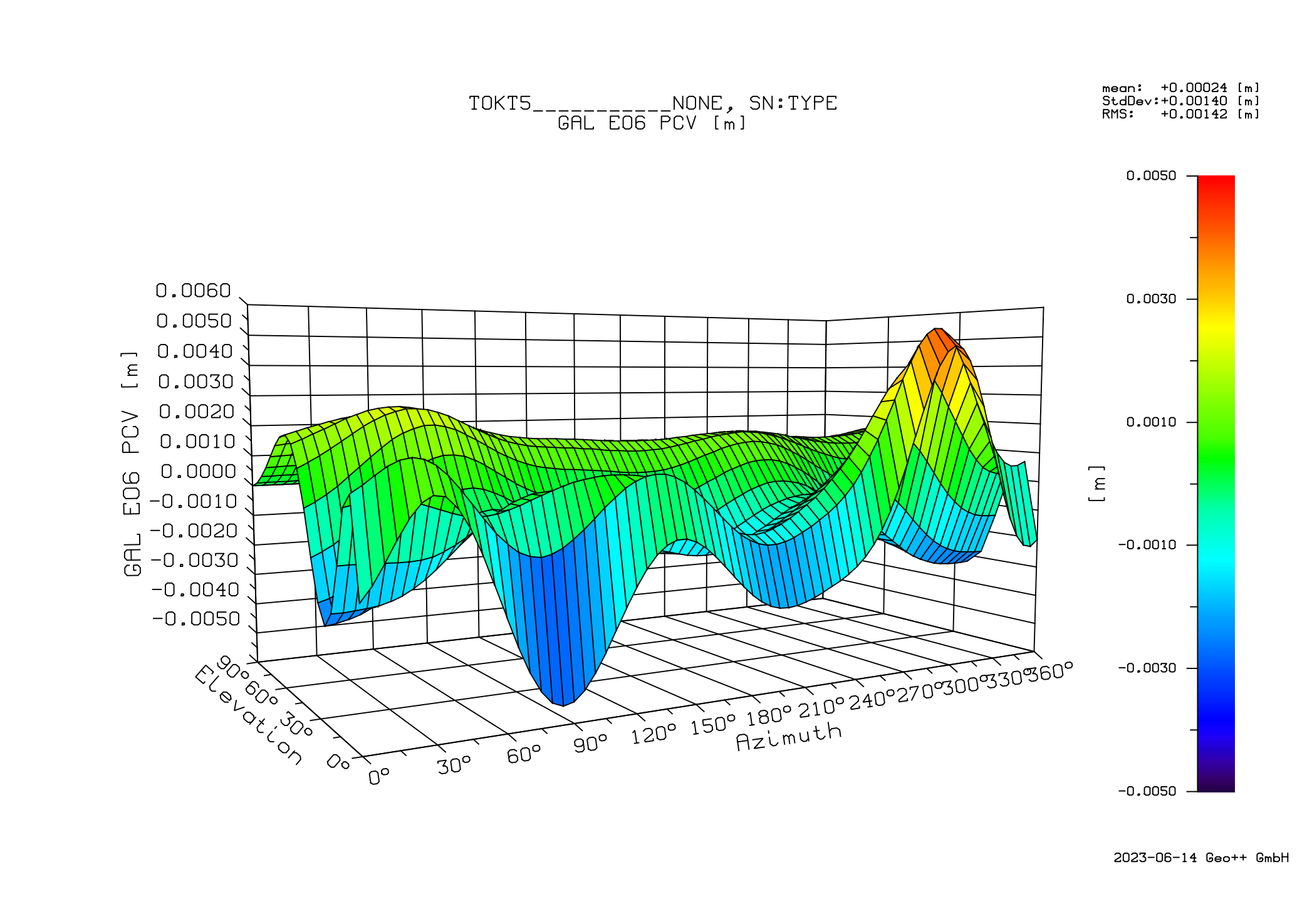
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GAL E06 PCV [m]
mean: +0.00024 [m]
StdDev:+0.00140 [m]
RMS: +0.00142 [m]
GAL E06 PCV [m]
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
-0.0010
-0.0020
-0.0030
-0.0040
-0.0050
Elevation
90°
60°
30°
0°
Azimuth
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
360°
[m]
0.0050
0.0030
0.0010
-0.0010
-0.0030
-0.0050
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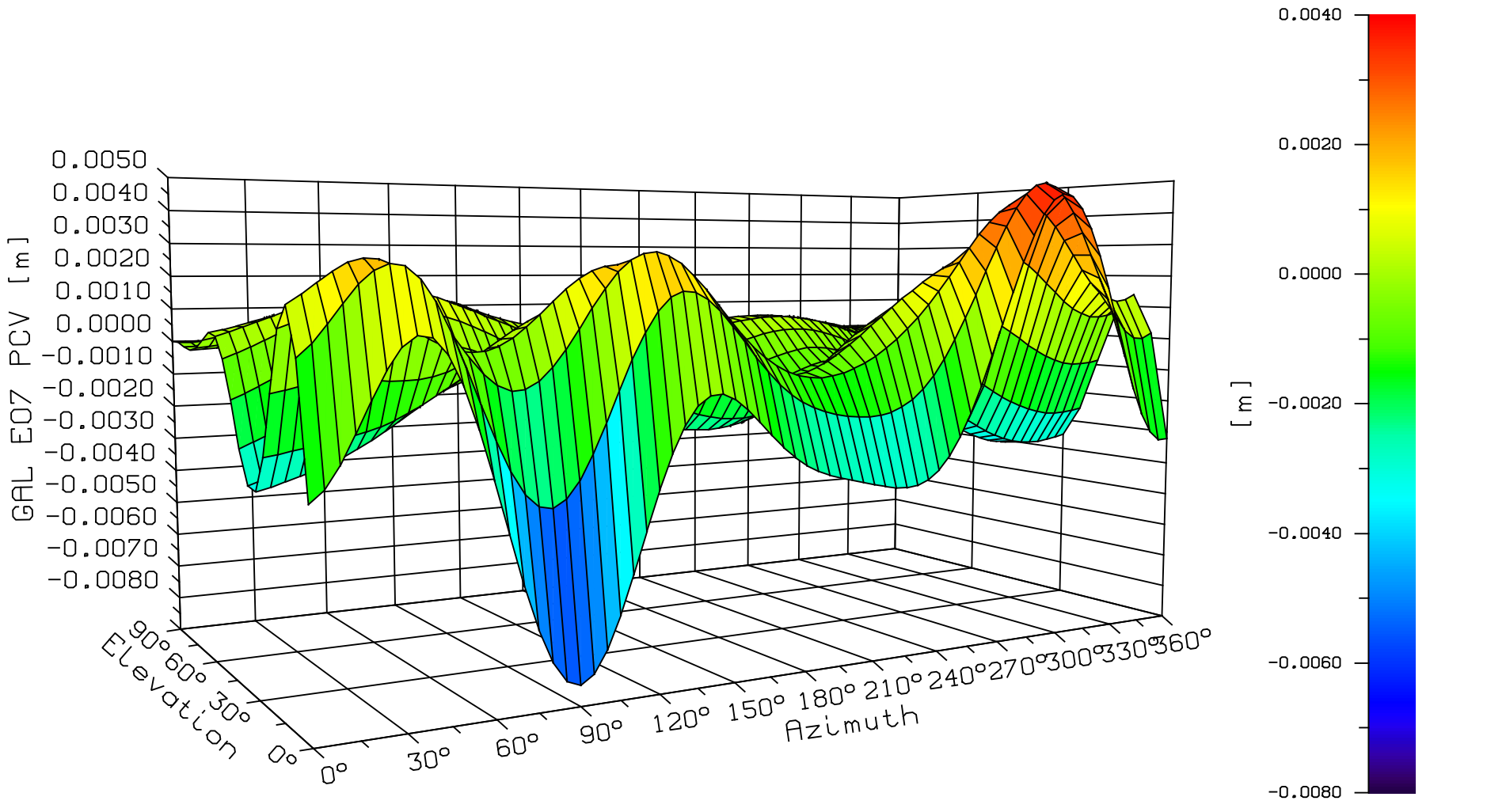
TOKI5_____NONE, SN:TYPE
GAL E07 PCV [m]

mean: -0.00032 [m]
StdDev:+0.00148 [m]
RMS: +0.00152 [m]



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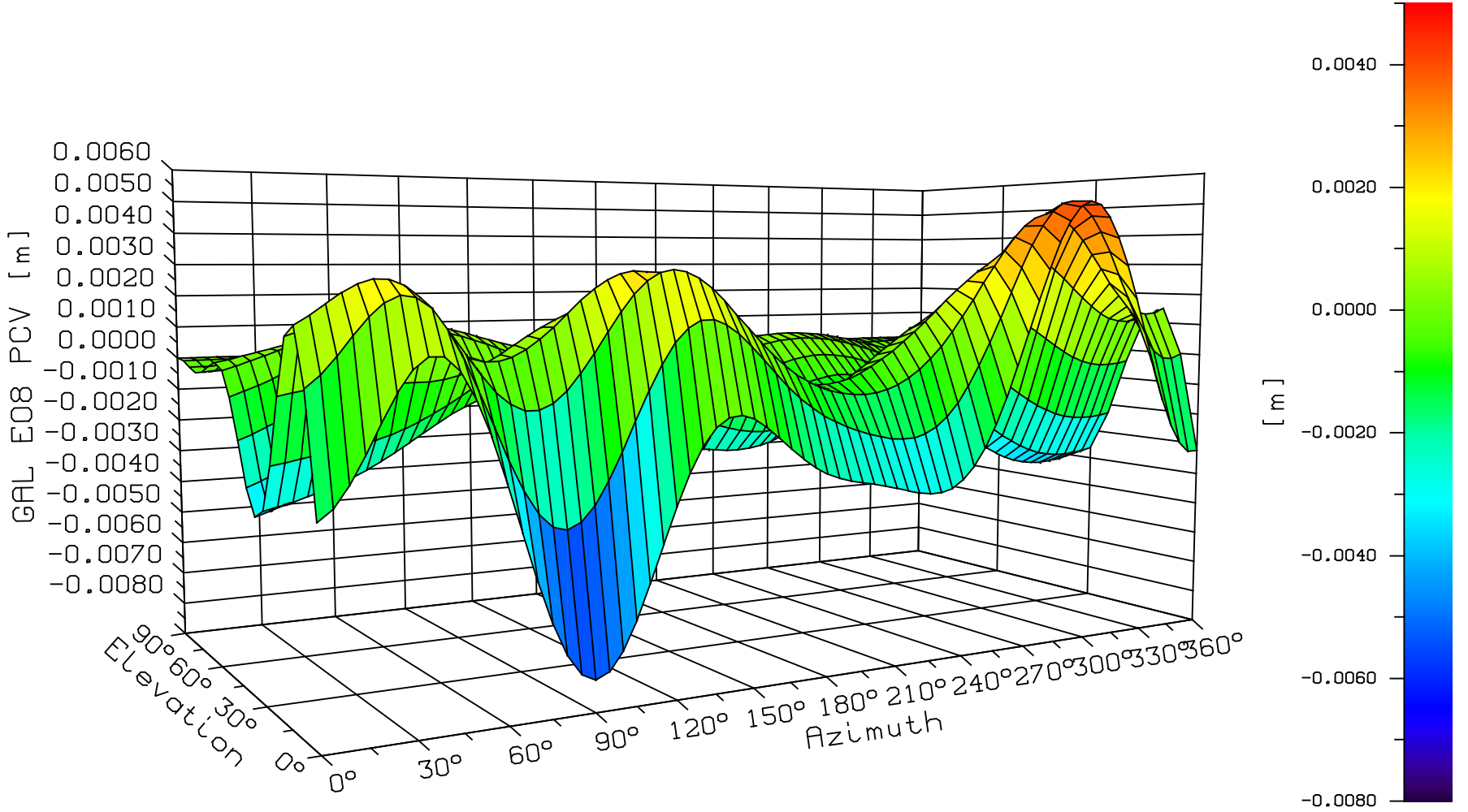
TOKI5_____NONE, SN:TYPE
GAL E08 PCV [m]

mean: -0.00042 [m]
StdDev:+0.00155 [m]
RMS: +0.00161 [m]



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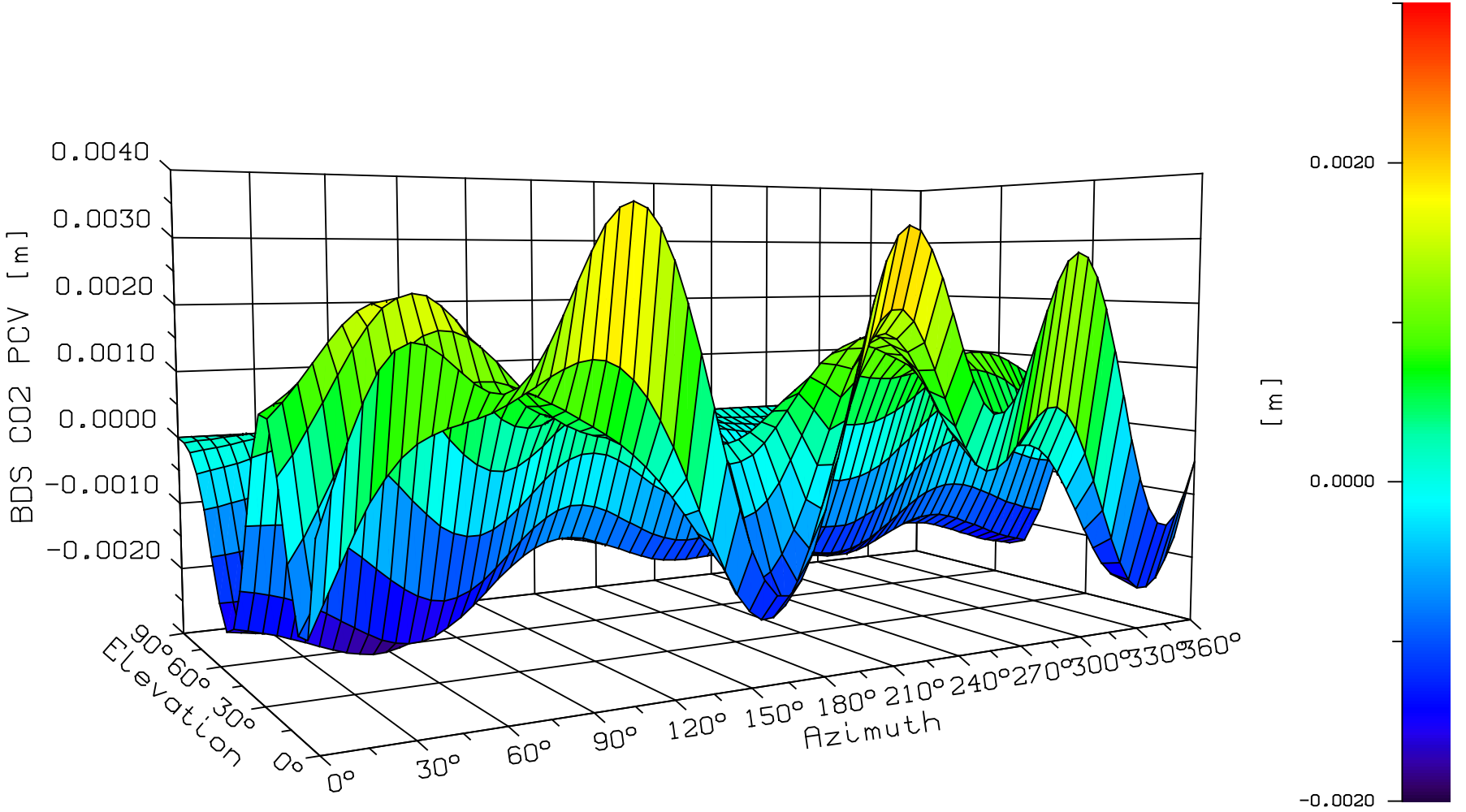
TOKT5_____NONE, SN:TYPE
BDS CO2 PCV [m]

mean: -0.00036 [m]
StdDev:+0.00114 [m]
RMS: +0.00119 [m]



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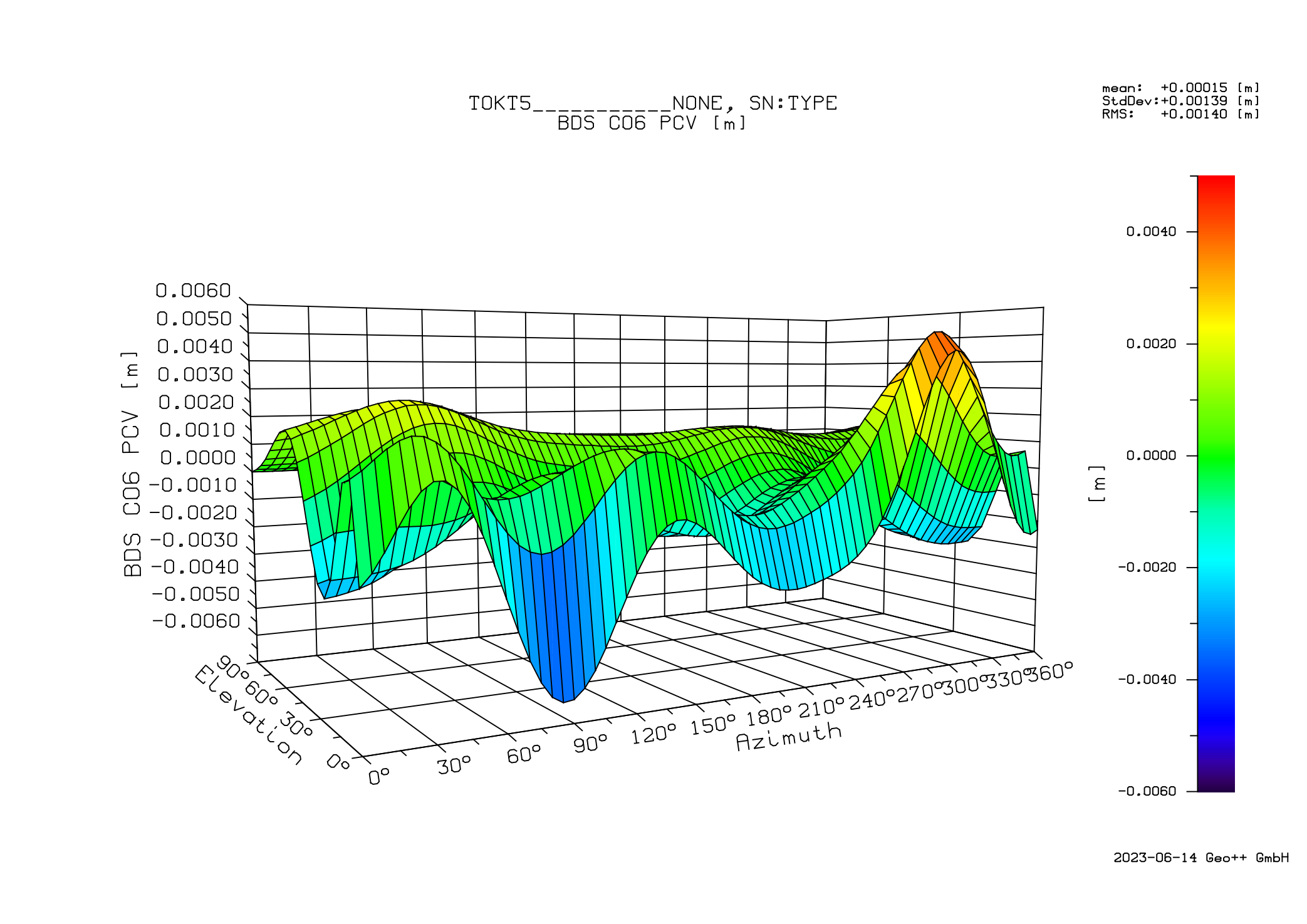
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BDS C06 PCV [m]
mean: +0.00015 [m]
StdDev:+0.00139 [m]
RMS: +0.00140 [m]
BDS C06 PCV [m]
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
-0.0010
-0.0020
-0.0030
-0.0040
-0.0050
-0.0060
Elevation
90°
60°
30°
0°
Azimuth
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
360°
[m]
0.0040
0.0020
0.0000
-0.0020
-0.0040
-0.0060
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