Certificate "GNPCV Type Mean"

Harxon CGX611A HXCM
GNPCV Type Mean from Absolute Calibrations with a Robot

- GNSS Antenna Calibration Method
- Calibration Procedure
- Calibration Result
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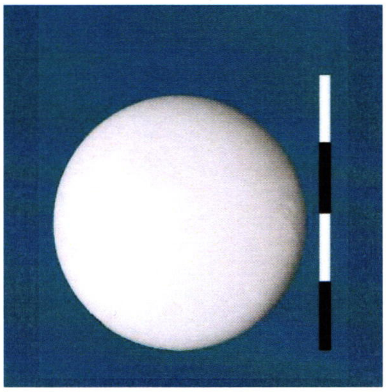
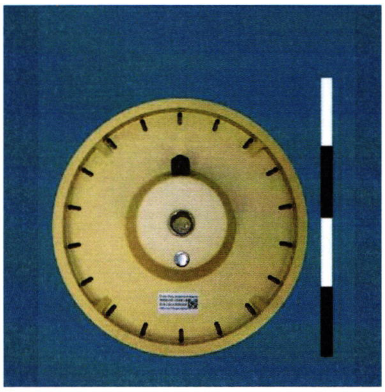
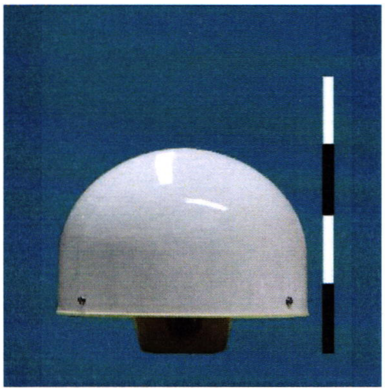
Calibration of GNSS Antenna
Harxon CGX611A HXCM
GNPCV Type Mean from Absolute Calibrations with a Robot

(IGS Name*: HXCCGX611A HXCM)







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 HXCCGX611A HXCM 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 HXCCGX611A HXCM antenna is derived from five individual antennas with serial numbers C20119000244, C20119000245, C20119000246, C201190002447 and C20119000248.

GNPCV Type Mean

The GNPCV Type Mean is the adjusted mean of the five individual HXCCGX611A HXCM GNSS antennas. The Antenna Reference Point (ARP) is the reference point used in the calibration. The reference direction to north is defined by the receiver connector (RXC). 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
HXCCGX611A      HXCM                                        TYPE / SERIAL NO
ROBOT                Geo++ GmbH              5    2021-01-28METH / BY / # / DATE
     5.0                                                    DAZI
     0.0  90.0   5.0                                        ZEN1 / ZEN2 / DZEN
    10                                                      # OF FREQUENCIES
                                                            COMMENT
   G01                                                      START OF FREQUENCY
     -0.58      0.19     96.44                              NORTH / EAST / UP
   NOAZI    0.00    0.01    0.02   -0.01   -0.13   -0.38   -0.70   -1.05   -1.32   -1.47   -1.47   -1.35   -1.16   -0.94   -0.65
-0.19    0.59    1.79    3.39
   G01                                                      END OF FREQUENCY
   G01                                                      START OF FREQ RMS
   NOAZI    0.00    0.00    0.01    0.02    0.03    0.03    0.04    0.04    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
     -0.88      0.15     97.14                              NORTH / EAST / UP
   NOAZI    0.00    0.05    0.19    0.31    0.33    0.20   -0.08   -0.44   -0.77   -0.98   -1.02   -0.94   -0.80   -0.64   -0.47
-0.18    0.41    1.43    2.90
```


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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    0.07    0.06
0.07    0.07    0.08    0.08
   R01                                                      END OF FREQ RMS
   C02                                                      START OF FREQUENCY
     -0.41      0.22     96.01                              NORTH / EAST / UP
   NOAZI    0.00   -0.01   -0.06   -0.17   -0.36   -0.65   -0.99   -1.32   -1.56   -1.68   -1.65   -1.50   -1.29   -1.02   -0.66
-0.10    0.78    2.08    3.77
   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    0.06    0.06    0.06    0.06    0.06    0.06    0.06
0.06    0.07    0.07    0.08
   C02                                                      END OF FREQ RMS
   E06                                                      START OF FREQUENCY
     -0.41     -0.18     94.88                              NORTH / EAST / UP
   NOAZI    0.00   -0.02   -0.05   -0.07   -0.06   -0.02   -0.01   -0.09   -0.29   -0.55   -0.77   -0.83   -0.66   -0.33    0.02
0.23    0.22    0.11    0.19
   E06                                                      END OF FREQUENCY
   E06                                                      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    0.07    0.07    0.07
0.07    0.07    0.08    0.08
   E06                                                      END OF FREQ RMS
   C06                                                      START OF FREQUENCY
     -0.35     -0.18     94.51                              NORTH / EAST / UP
   NOAZI    0.00   -0.02   -0.07   -0.10   -0.11   -0.11   -0.13   -0.24   -0.45   -0.70   -0.90   -0.93   -0.73   -0.38    0.00
0.25    0.32    0.34    0.59
   C06                                                      END OF FREQUENCY
   C06                                                      START OF FREQ RMS
   NOAZI    0.00    0.00    0.02    0.03    0.04    0.04    0.05    0.05    0.04    0.04    0.05    0.05    0.05    0.05    0.05
0.05    0.05    0.06    0.06
   C06                                                      END OF FREQ RMS
   R02                                                      START OF FREQUENCY
     -0.28     -0.18     94.10                              NORTH / EAST / UP
   NOAZI    0.00   -0.03   -0.10   -0.19   -0.26   -0.32   -0.42   -0.58   -0.80   -1.04   -1.20   -1.18   -0.94   -0.54   -0.10
0.26    0.50    0.76    1.29
   R02                                                      END OF FREQUENCY
   R02                                                      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    0.07    0.07    0.07
0.07    0.07    0.08    0.08
   R02                                                      END OF FREQ RMS
   G02                                                      START OF FREQUENCY
     -0.28     -0.19     94.21                              NORTH / EAST / UP
   NOAZI    0.00   -0.04   -0.14   -0.26   -0.38   -0.49   -0.62   -0.81   -1.04   -1.29   -1.44   -1.40   -1.14   -0.70   -0.19
0.27    0.65    1.05    1.71
   G02                                                      END OF FREQUENCY
   G02                                                      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    0.04    0.04    0.04    0.04
0.04    0.04    0.04    0.05
   G02                                                      END OF FREQ RMS
   E07                                                      START OF FREQUENCY
     -0.33     -0.21     94.85                              NORTH / EAST / UP
   NOAZI    0.00   -0.05   -0.18   -0.35   -0.51   -0.66   -0.81   -1.01   -1.26   -1.52   -1.69   -1.66   -1.39   -0.90   -0.30
0.28    0.79    1.30    2.02
   E07                                                      END OF FREQUENCY
   E07                                                      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    0.03    0.03    0.03
0.03    0.04    0.04    0.04
   E07                                                      END OF FREQ RMS
   E08                                                      START OF FREQUENCY
     -0.42     -0.23     95.69                              NORTH / EAST / UP
   NOAZI    0.00   -0.06   -0.22   -0.42   -0.61   -0.77   -0.93   -1.12   -1.38   -1.66   -1.86   -1.86   -1.58   -1.05   -0.37
0.30    0.89    1.44    2.14
   E08                                                      END OF FREQUENCY
   E08                                                      START OF FREQ RMS
   NOAZI    0.00    0.00    0.01    0.02    0.02    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03    0.03
0.03    0.03    0.03    0.04
   E08                                                      END OF FREQ RMS
   G05                                                      START OF FREQUENCY
     -0.55     -0.26     96.84                              NORTH / EAST / UP
   NOAZI    0.00   -0.07   -0.26   -0.49   -0.70   -0.86   -1.00   -1.18   -1.44   -1.75   -1.99   -2.03   -1.76   -1.19   -0.42
0.36    1.02    1.58    2.20
   G05                                                      END OF FREQUENCY
   G05                                                      START OF FREQ RMS
   NOAZI    0.00    0.00    0.01    0.02    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
   G05                                                      END OF FREQ RMS
                                                            END OF ANTENNA
```

Garbsen, June 30, 2021 Dr. Temmo Wübbena

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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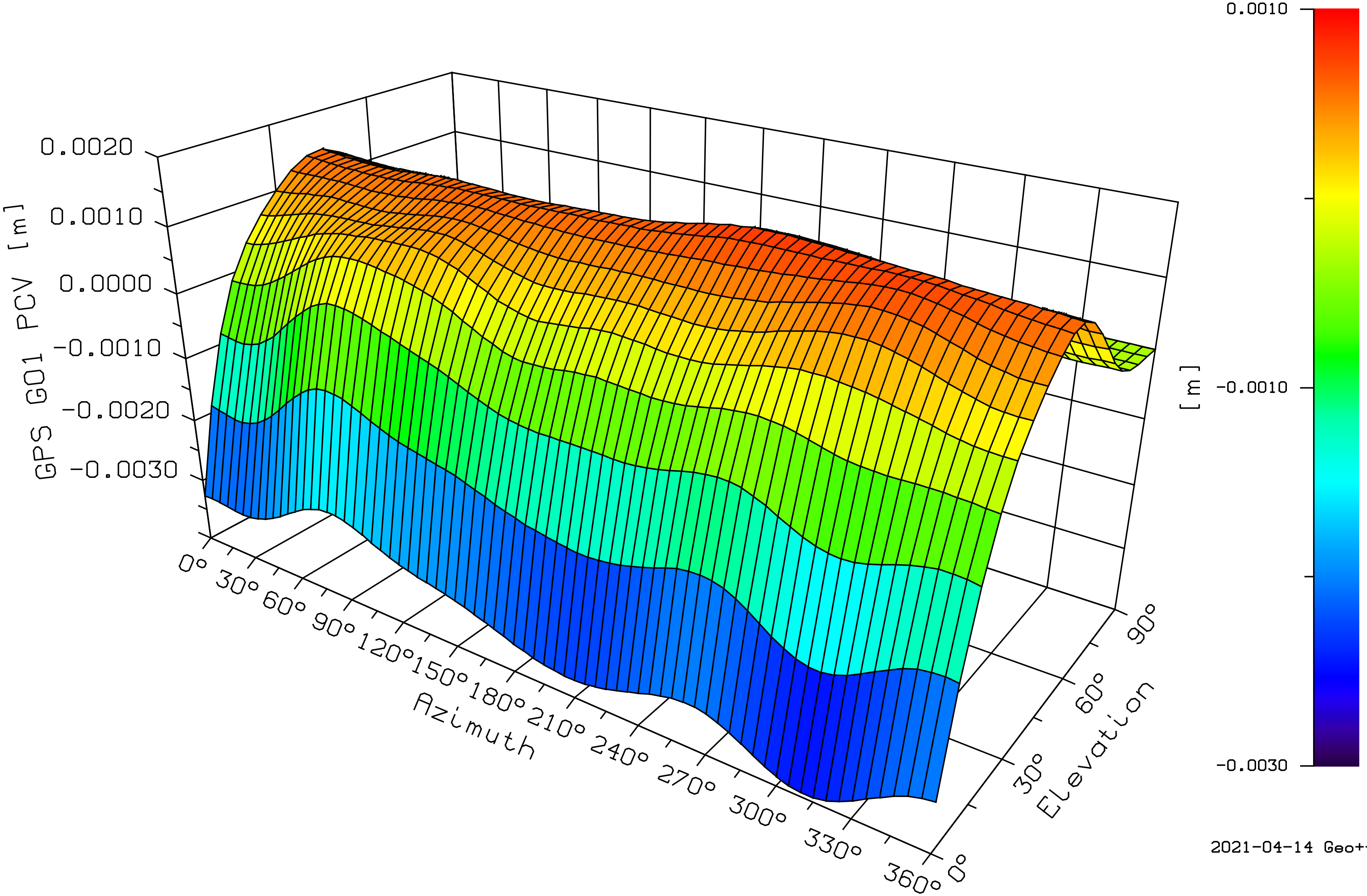
GPS G01 PCV [m]



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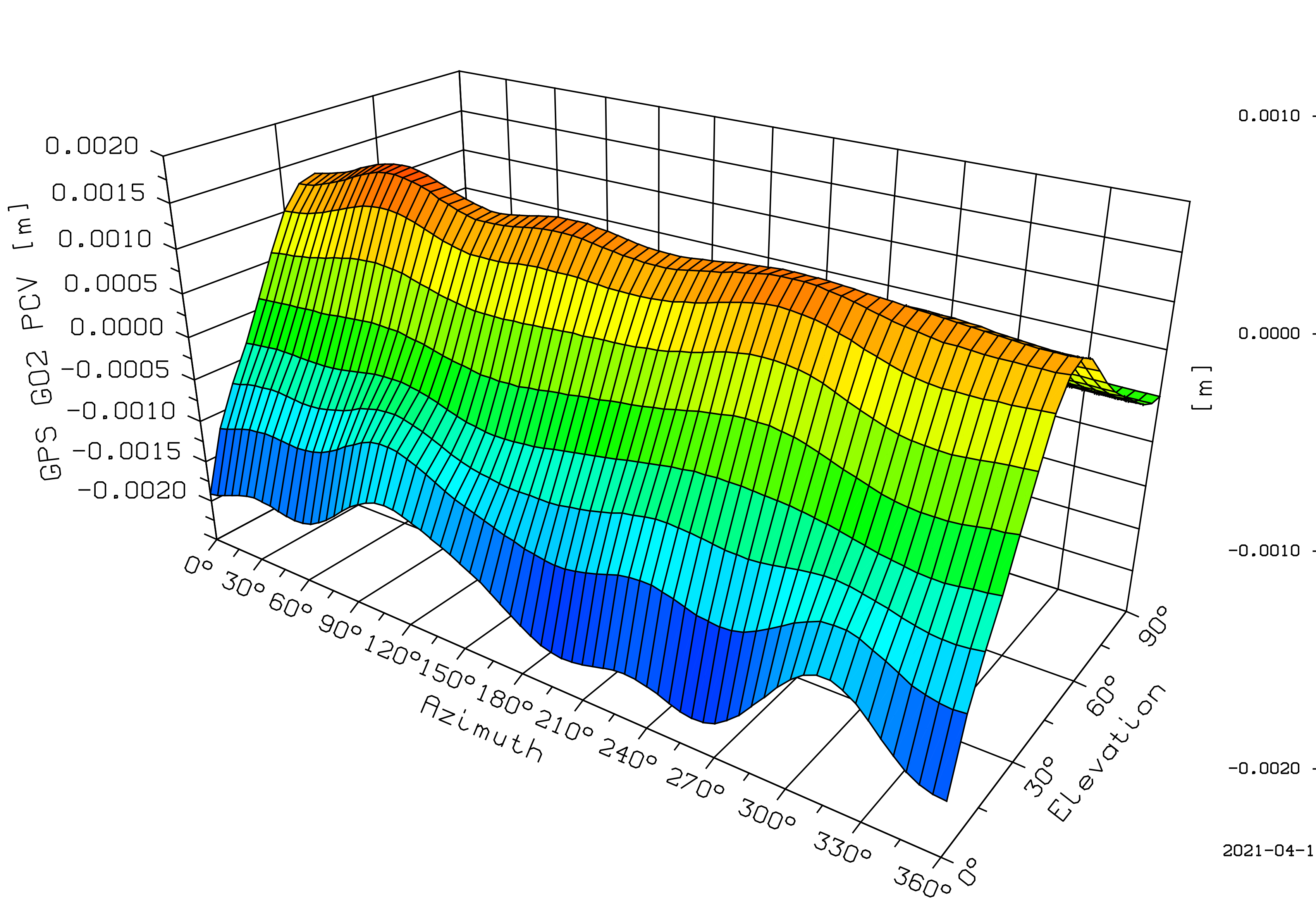
GPS G02 PCV [m]



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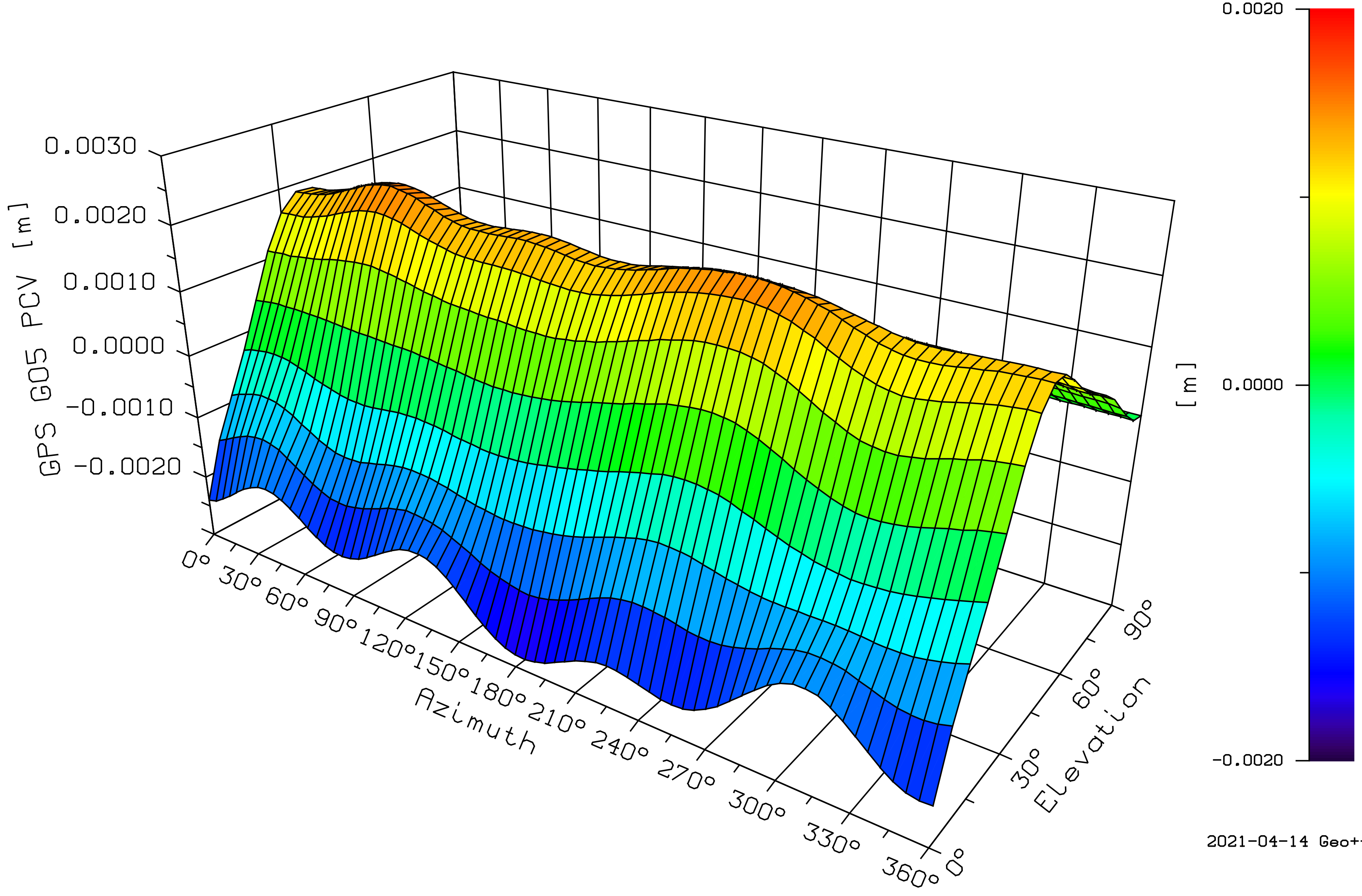

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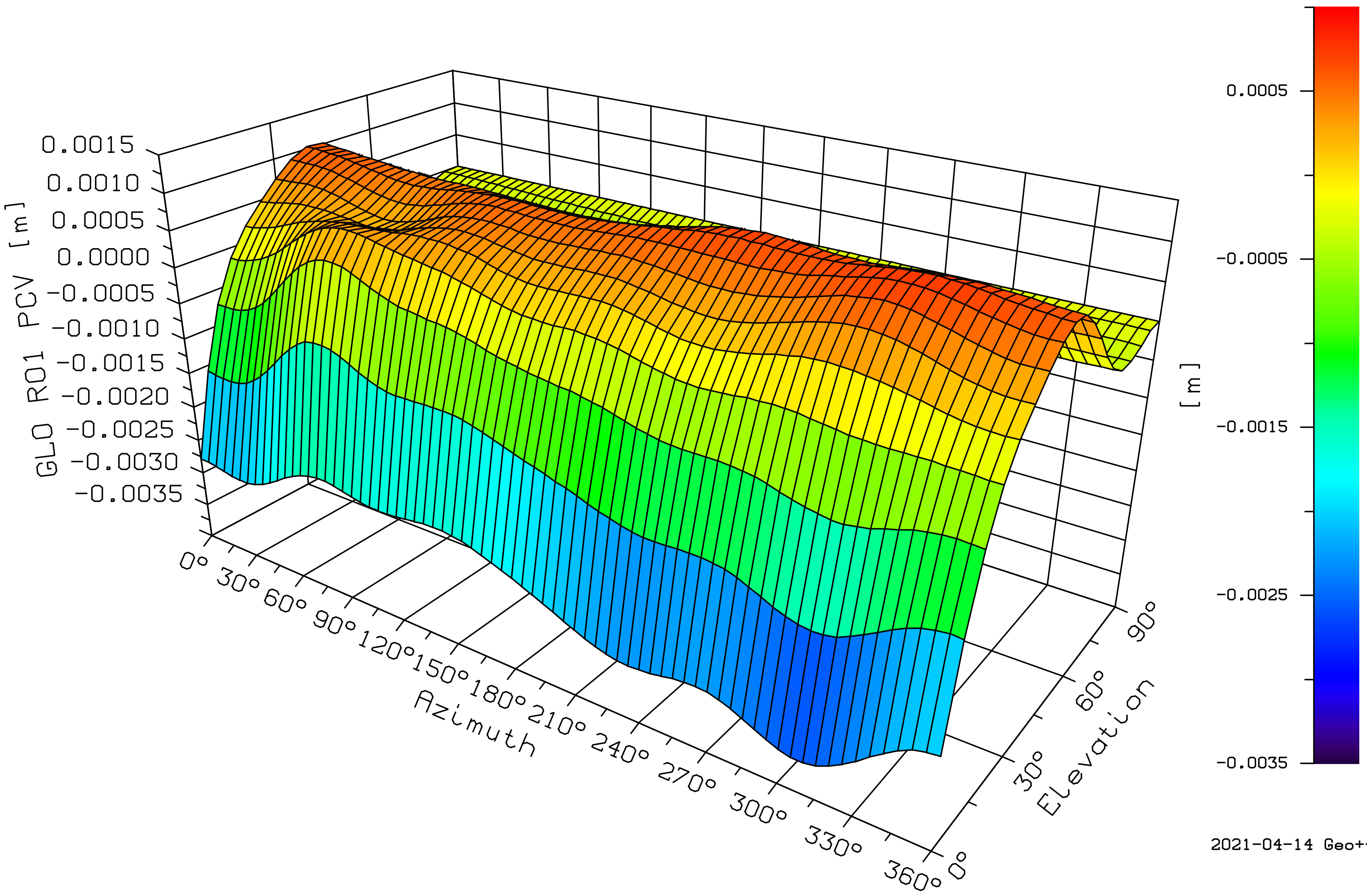

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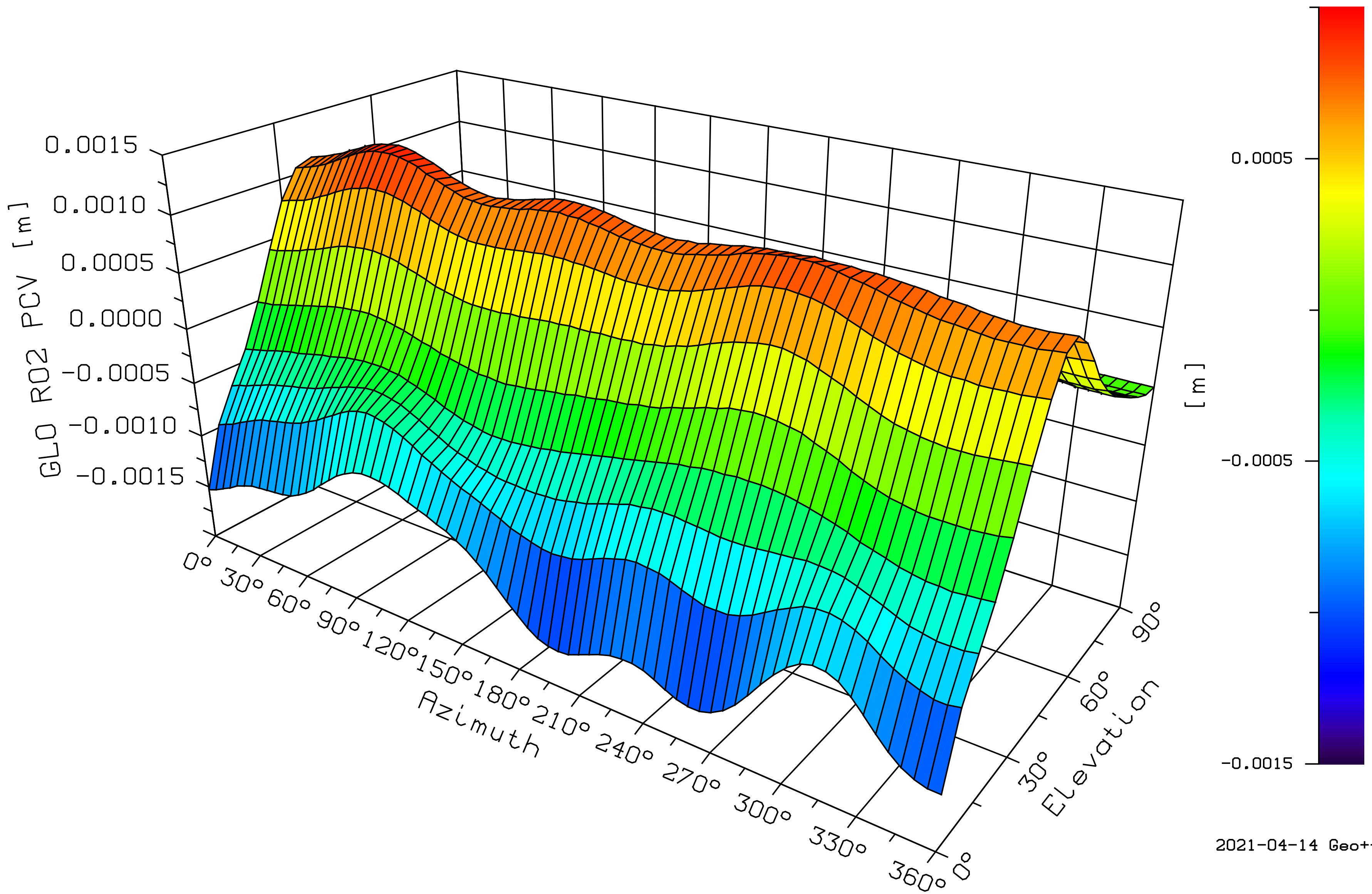
GLO R02 PCV [m]



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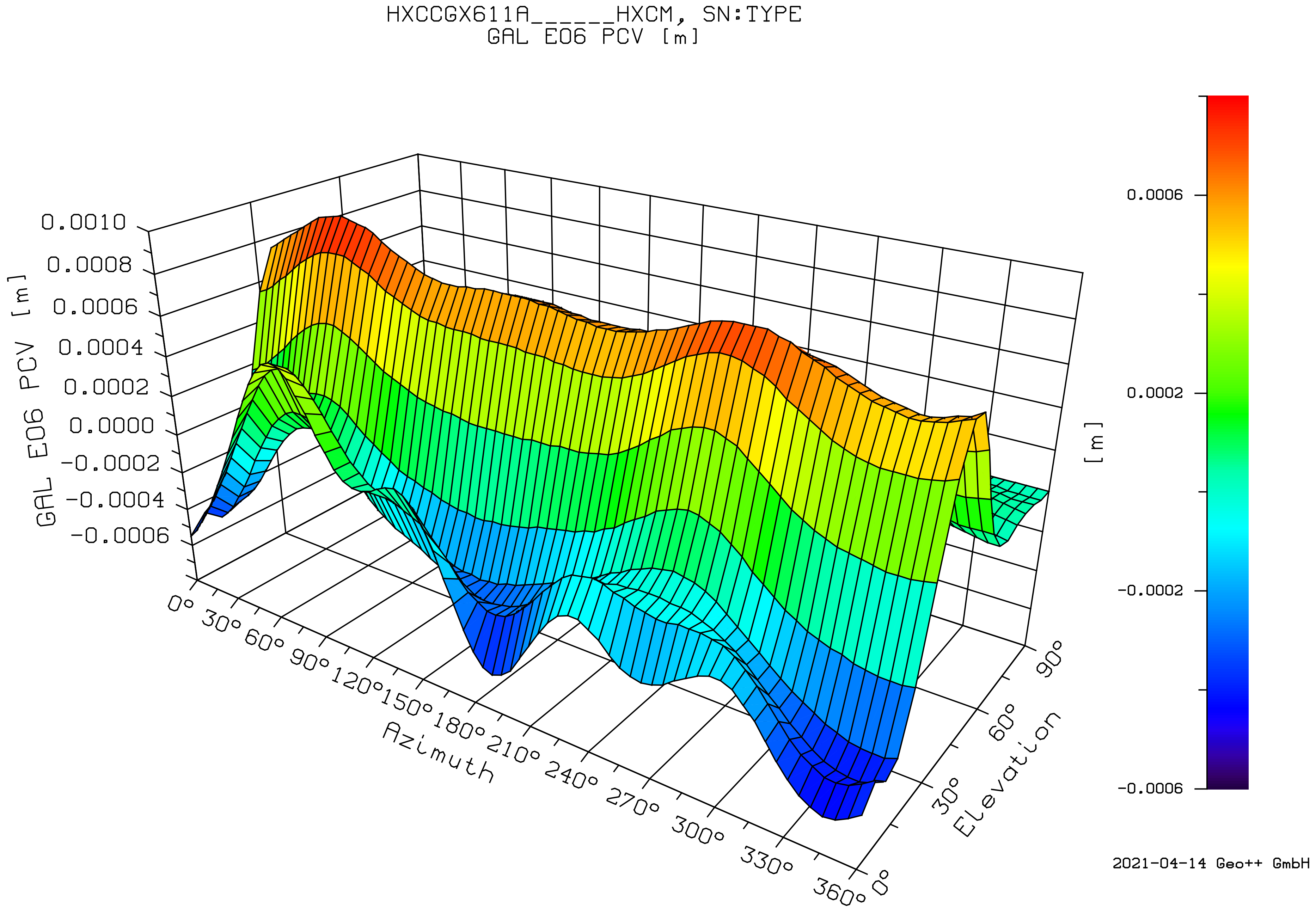

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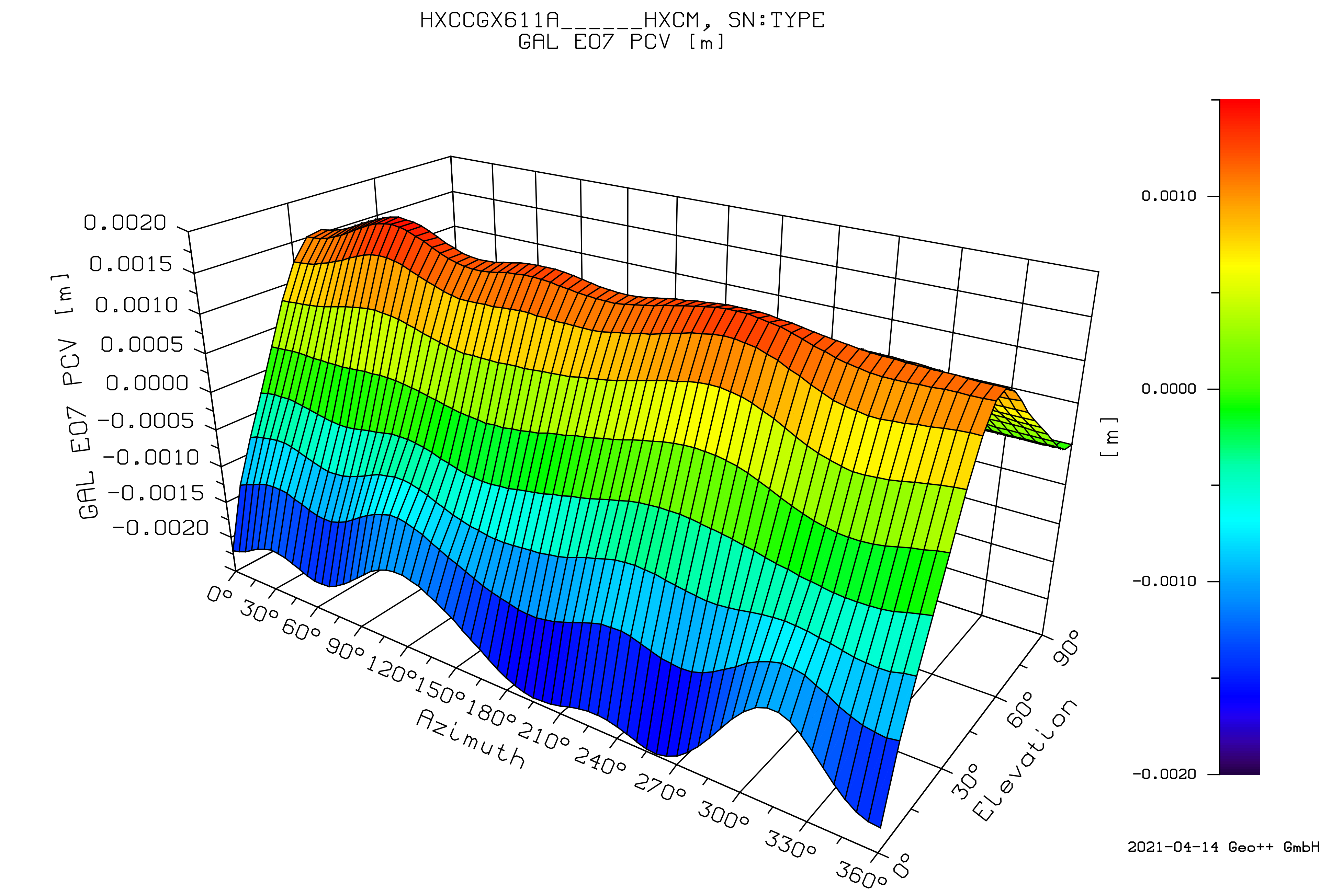
GAL E06 PCV [m]
GAL E06 PCV [m]
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
-0.0002
-0.0004
-0.0006
Azimuth
0° 30° 60° 90° 120° 150° 180° 210° 240° 270° 300° 330° 360°
Elevation
0° 30° 60° 90°
[m]
0.0006
0.0002
-0.0002
-0.0006
2021-04-14 Geo++ GmbH



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GAL E07 PCV [m]
GAL E07 PCV [m]
0.0020
0.0015
0.0010
0.0005
0.0000
-0.0005
-0.0010
-0.0015
-0.0020
0° 30° 60° 90° 120° 150° 180° 210° 240° 270° 300° 330° 360°
Azimuth
0° 30° 60° 90°
Elevation
[m]
0.0010
0.0000
-0.0010
-0.0020
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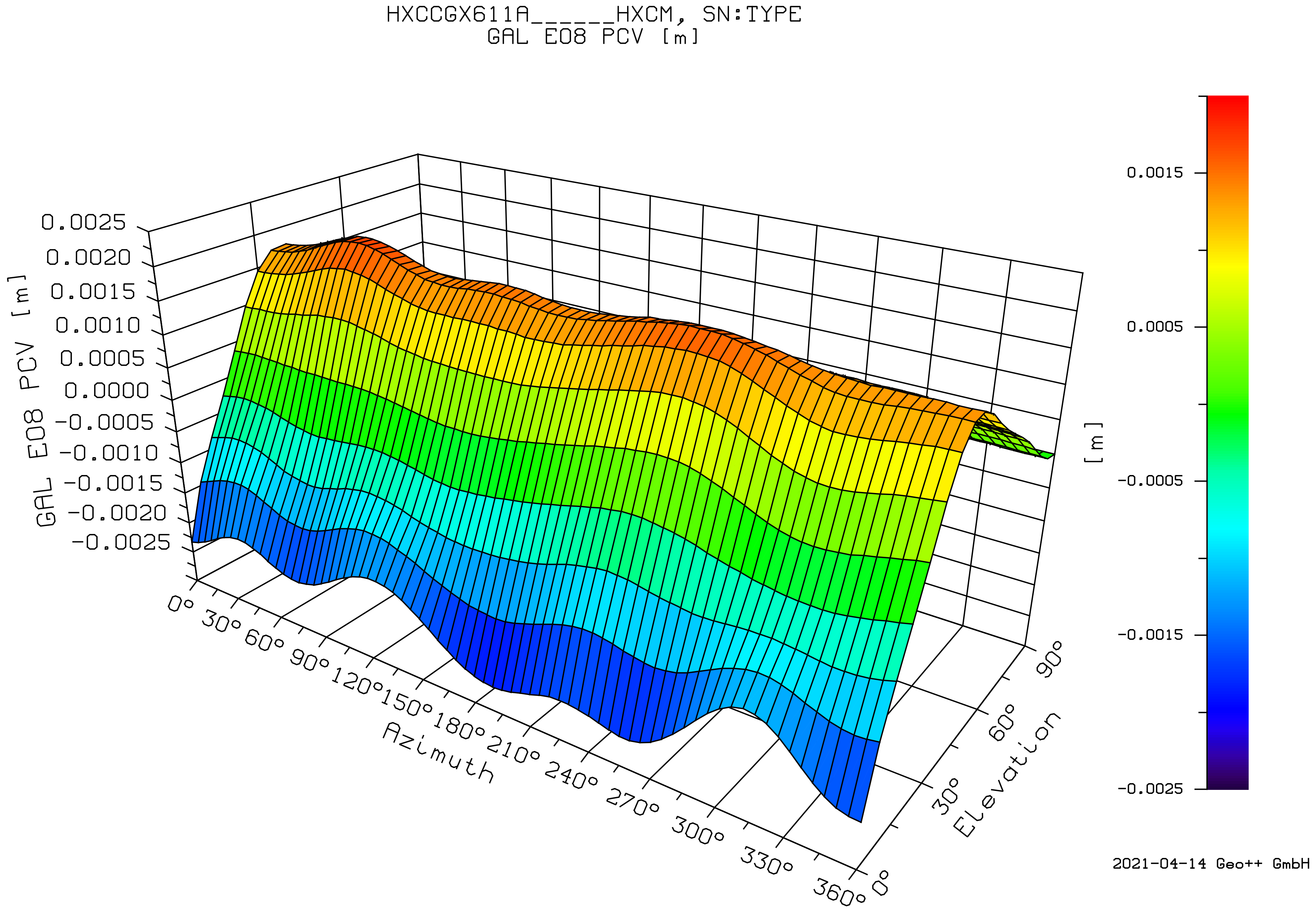

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GAL E08 PCV [m]
GAL E08 PCV [m]
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0.0020
0.0015
0.0010
0.0005
0.0000
-0.0005
-0.0010
-0.0015
-0.0020
-0.0025
Azimuth
0° 30° 60° 90° 120° 150° 180° 210° 240° 270° 300° 330° 360°
Elevation
0° 30° 60° 90°
[m]
0.0015
0.0005
-0.0005
-0.0015
-0.0025
2021-04-14 Geo++ GmbH

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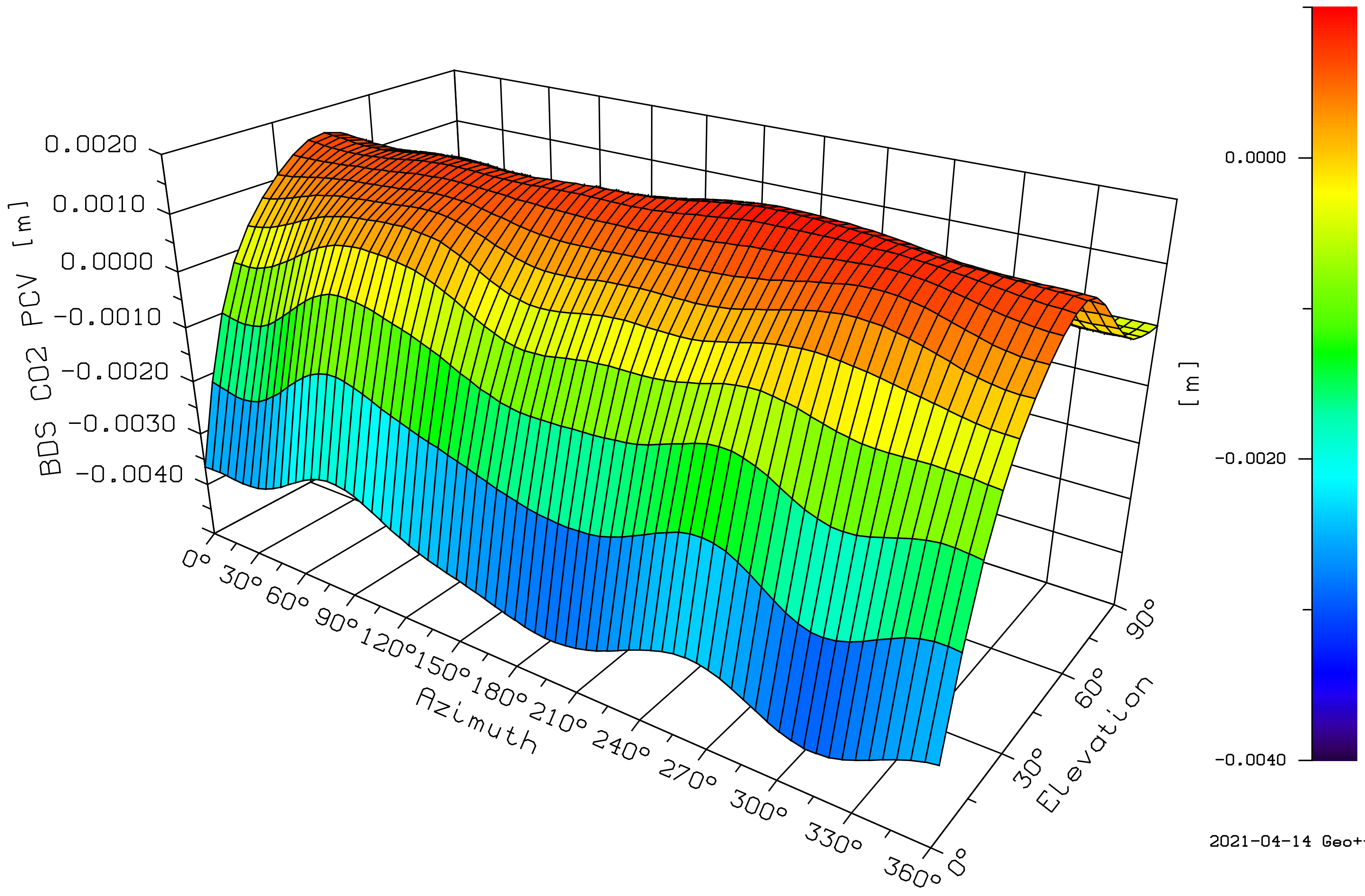
BDS C02 PCV [m]



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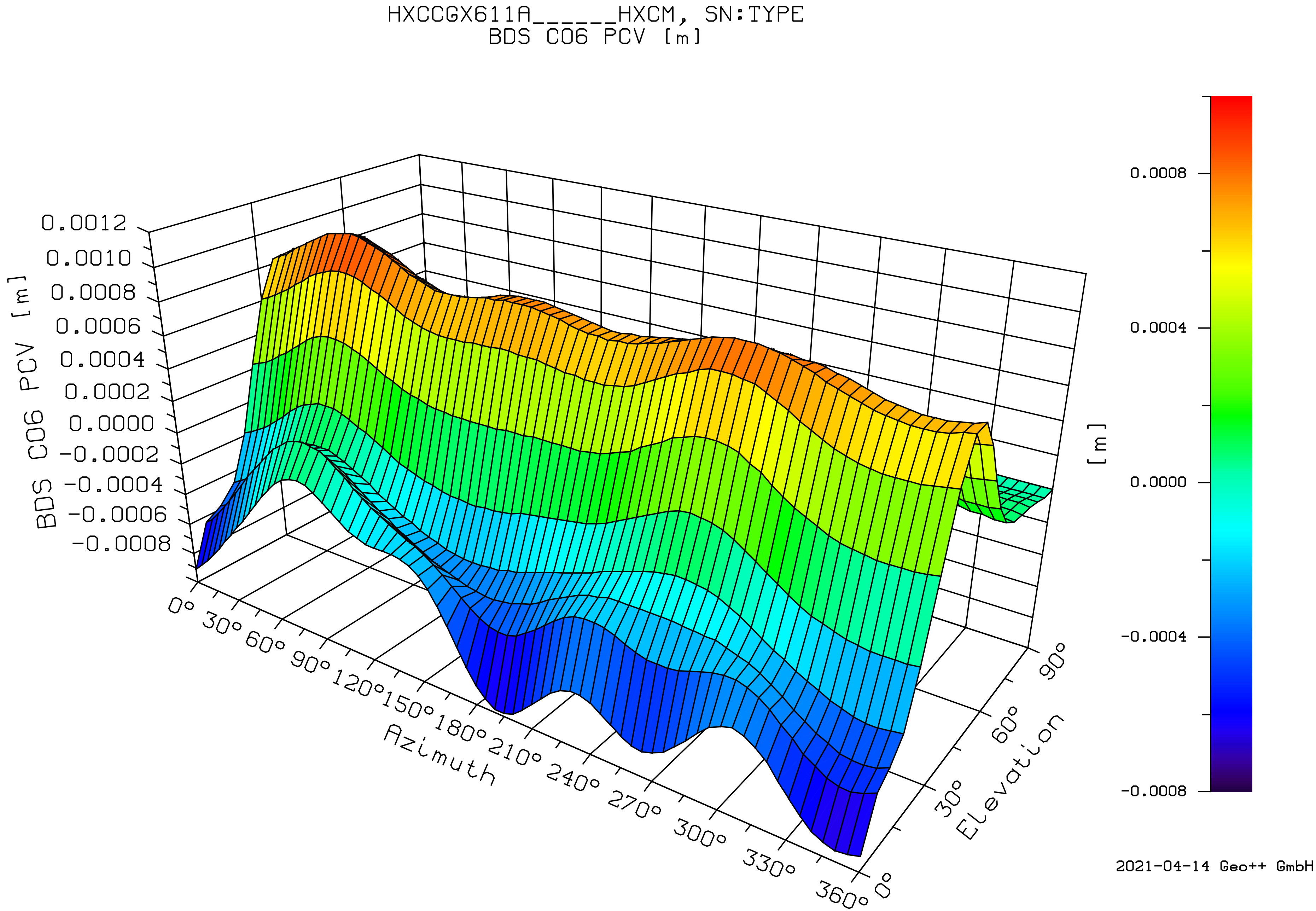
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BDS C06 PCV [m]
BDS C06 PCV [m]
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0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
-0.0002
-0.0004
-0.0006
-0.0008
0° 30° 60° 90° 120° 150° 180° 210° 240° 270° 300° 330° 360°
Azimuth
0° 30° 60° 90°
Elevation
[m]
0.0008
0.0004
0.0000
-0.0004
-0.0008
2021-04-14 Geo++ GmbH