# EUREF IE/UK 2009
# Final Report

**Final report on the processing and analysis of the EUREF IE/UK 2009 campaign.**

## Responsibility for this document

Mark Greaves, Ordnance Survey Geodetic Analyst is responsible for the content of this document.

## Change history

| Version | Date | Summary of change |
|---|---|---|
| 1.0 | Feb 2010 | First issue –DRAFT |
| 2.0 | Mar 2010 | Final version for presentation at Spring TWG meeting |
| 2.1 | Mar 2010 | Corrections to minor typos |
| 3.0 | May 2010 | Changes following presentation to TWG |
| 3.1 | May 2010 | Corrections to Table 9 and Figure 5 – replace SOLA with OS12 |

## Trademarks

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# Contents

# Summary

The internal quality of the solution, as indicated by the daily coordinate repeatabilities, is around 1 to 2 mm in N and E and around 3-5 mm in U.

The coordinate recoveries of the fiducial stations show that ITRF2005 is being realised to around 2 mm in N and E and around 6 mm in U although some stations at the outer edges of the network are at the 10 mm level in U with one (HOFN) at 17mm.

Comparison with the EUREF GB 2001 campaign (based on ITRF97) is at the 10 mm level when compared in ETRF97 but at the 25 mm level when compared in ETRF2000.

Comparison with an ITRF2000 solution for the stations in Northern Ireland is at the 10 mm level when compared in ETRF2000.

# ITRF2005 epoch 2009.756 coordinates

| Station | X | Y | Z | Latitude | Longitude | Height |
|---|---|---|---|---|---|---|
| ADAR 19161M001 | 3852249.3801 | -319510.6541 | 5056510.5778 | N 52 47 21.179407 | W 004 44 28.806871 | 148.428 |
| ARIS 19190M001 | 3472288.4103 | -355730.4562 | 5320461.2814 | N 56 54 34.514570 | W 005 50 58.035475 | 61.364 |
| ARKL 13612M001 | 3842455.7909 | -414558.9955 | 5056988.1096 | N 52 47 49.141202 | W 006 09 27.972105 | 91.746 |
| BELF 13240M001 | 3685257.9450 | -382908.9947 | 5174311.0520 | N 54 34 37.842466 | W 005 55 54.884142 | 82.017 |
| BNTY 13614M001 | 3909582.1206 | -650714.5555 | 4980627.5344 | N 51 40 34.060859 | W 009 26 59.058848 | 114.622 |
| BOR1 12205M002 | 3738358.3762 | 1148173.7839 | 5021815.8215 | N 52 16 37.046736 | E 017 04 24.448063 | 124.370 |
| BRUS 13101M004 | 4027893.6903 | 307045.9027 | 4919475.1767 | N 50 47 52.147342 | E 004 21 33.193255 | 149.689 |
| BUXT 19191M001 | 3824391.3961 | -128197.0980 | 5086209.6182 | N 53 13 45.244560 | W 001 55 11.597021 | 441.822 |
| CAGL 12725M003 | 4893378.7562 | 772649.8795 | 4004182.2210 | N 39 08 09.285336 | E 008 58 21.913491 | 238.360 |
| CAMO 19187M002 | 4071656.9822 | -379671.4716 | 4878472.7210 | N 50 13 06.021026 | W 005 19 38.202109 | 140.993 |
| CARL 13205S001 | 3671344.3164 | -188441.0836 | 5194774.1899 | N 54 53 43.537717 | W 002 56 17.783132 | 93.572 |
| CAVN 13615M001 | 3726882.1558 | -481707.5760 | 5136439.3876 | N 53 59 36.707083 | W 007 21 53.180064 | 146.975 |
| CHIO 19194M001 | 4007952.6627 | -100633.9489 | 4944059.2451 | N 51 08 56.384664 | W 001 26 17.925814 | 128.329 |
| CLNM 13617M001 | 3868650.7166 | -522748.3944 | 5027091.5960 | N 52 21 17.990596 | W 007 41 43.574320 | 82.982 |
| CSTB 13619M001 | 3721279.8207 | -608536.4469 | 5127051.2331 | N 53 51 02.668440 | W 009 17 14.303850 | 111.206 |
| DARE 13208S001 | 3811965.3084 | -175799.7610 | 5093615.7687 | N 53 20 41.303500 | W 002 38 25.760390 | 88.454 |
| DNGL 13620M001 | 3660877.6809 | -520221.1823 | 5179609.7392 | N 54 39 33.281270 | W 008 05 15.881687 | 93.122 |
| DVTG 13283M002 | 4011083.6364 | 92599.1488 | 4941591.9789 | N 51 06 52.300530 | E 001 19 20.946209 | 50.088 |
| EDIN 13217S001 | 3575928.1636 | -205860.3437 | 5259853.4261 | N 55 55 29.231101 | W 003 17 41.236382 | 119.077 |
| ENIS 13246M001 | 3688503.8315 | -495090.5021 | 5162577.5148 | N 54 23 43.449733 | W 007 38 41.460928 | 107.362 |
| ESMA 19102M001 | 3632179.4116 | -203514.7391 | 5221768.3477 | N 55 18 58.734610 | W 003 12 25.156909 | 324.081 |
| FOYL 13241M001 | 3638083.2113 | -468414.5794 | 5200402.5739 | N 54 59 01.523338 | W 007 20 11.931084 | 68.926 |
| GLAS 13219S001 | 3578263.1784 | -268830.2633 | 5255394.5151 | N 55 51 14.411873 | W 004 17 47.349664 | 71.668 |
| GLSV 12356M001 | 3512888.8650 | 2068979.9530 | 4888903.2440 | N 50 21 51.059873 | E 030 29 48.241845 | 226.320 |
| GLWY 13627M001 | 3774050.6835 | -601852.3838 | 5089350.6126 | N 53 16 50.464639 | W 009 03 38.637485 | 86.509 |
| GRAS 10002M006 | 4581690.8447 | 556114.9240 | 4389360.8541 | N 43 45 17.058509 | E 006 55 14.067847 | 1319.320 |
| HERO 19168M001 | 4033452.5399 | 23629.6851 | 4924309.5839 | N 50 52 02.945881 | E 000 20 08.373375 | 71.656 |
| HERS 13212M007 | 4033470.0537 | 23672.9653 | 4924301.3658 | N 50 52 02.332054 | E 000 20 10.581328 | 76.495 |
| HERT 13212M010 | 4033460.8653 | 23537.8753 | 4924318.3111 | N 50 52 02.928615 | E 000 20 03.676034 | 83.341 |
| HOE2 14284M002 | 3650022.6141 | 532050.6275 | 5185984.5439 | N 54 45 31.509897 | E 008 17 36.201676 | 62.731 |
| HOFN 10204M002 | 2679689.9613 | -727951.1531 | 5722789.3916 | N 64 16 02.253349 | W 015 11 52.509468 | 82.765 |
| IESG 13220M001 | 3851174.1855 | -80151.5505 | 5066647.2735 | N 52 56 26.489537 | W 001 11 32.212414 | 98.480 |
| INVR 13221M001 | 3427172.0993 | -252834.0613 | 5355255.7610 | N 57 29 10.512975 | W 004 13 09.335269 | 66.223 |
| JOZE 12204M001 | 3664940.0841 | 1409153.9393 | 5009571.4402 | N 52 05 50.192071 | E 021 01 53.544966 | 141.450 |
| KING 13225S001 | 3868685.7629 | 27112.9415 | 5053897.2167 | N 52 45 04.934045 | E 000 24 05.543632 | 66.455 |
| KINT 19192M001 | 3456261.0077 | -140550.5943 | 5340852.1119 | N 57 14 43.338172 | W 002 19 43.243172 | 141.275 |
| KLRE 13245M001 | 3645420.8868 | -422952.1566 | 5199265.0242 | N 54 57 53.783771 | W 006 37 04.908995 | 147.957 |
| LEED 13215S001 | 3773717.4896 | -109614.1612 | 5123816.3611 | N 53 48 00.788155 | W 001 39 49.634452 | 215.639 |
| LERI 19159M003 | 3183134.6277 | -65772.4714 | 5508281.4877 | N 60 08 17.986971 | W 001 11 01.401857 | 132.119 |
| MATE 12734M008 | 4641949.4725 | 1393045.5114 | 4133287.5351 | N 40 38 56.876962 | E 016 42 16.058394 | 535.654 |
| MCHA 19101M001 | 3929946.8701 | -205930.6738 | 5002873.5991 | N 51 59 51.759184 | W 002 59 58.476106 | 288.164 |
| METS 10503S011 | 2892570.7136 | 1311843.5133 | 5512634.1904 | N 60 13 02.901763 | E 024 23 43.159127 | 94.642 |
| MORO 13299M002 | 3645662.6925 | -107277.3543 | 5215058.0086 | N 55 12 46.264271 | W 001 41 07.801989 | 145.189 |
| MORP 13299S001 | 3645667.7845 | -107277.1625 | 5215053.5822 | N 55 12 46.047589 | W 001 41 07.782677 | 144.455 |
| MRKT 13242M001 | 3711921.6716 | -423146.7581 | 5152394.6149 | N 54 14 13.599282 | W 006 30 12.436037 | 224.403 |
| NEWL 13273M103 | 4079953.8989 | -395930.1693 | 4870197.0075 | N 50 06 10.907850 | W 005 32 34.034086 | 64.524 |
| NICO 14302M001 | 4359415.6338 | 2874117.1252 | 3650777.8895 | N 35 08 27.553267 | E 033 23 47.209022 | 190.026 |
| NOT1 12717M004 | 4934546.1412 | 1321265.0925 | 3806456.1954 | N 36 52 33.043044 | E 014 59 23.238291 | 126.336 |
| OMGH 13244M001 | 3671990.2915 | -467517.2496 | 5176939.5536 | N 54 36 58.410633 | W 007 15 21.065181 | 217.434 |
| OS12 | 4033458.9007 | 23626.6259 | 4924303.3529 | N 50 52 02.659410 | E 000 20 08.215032 | 70.826 |
| OSLS 10307M001 | 3169981.8100 | 579956.8324 | 5485936.7376 | N 59 44 11.715364 | E 010 22 03.931169 | 221.562 |
| PDEL 31906M004 | 4551595.9385 | -2186893.0449 | 3883410.8991 | N 37 44 51.900447 | W 025 39 45.946305 | 110.624 |
| POLV 12336M001 | 3411557.2549 | 2348464.0563 | 4834396.9354 | N 49 36 09.412027 | E 034 32 34.555210 | 178.378 |
| PRTL 13622M001 | 3812787.2786 | -488495.3933 | 5072816.7125 | N 53 01 54.697148 | W 007 18 03.516987 | 175.458 |
| RABT 35001M002 | 5255617.6416 | -631745.6080 | 3546322.6133 | N 33 59 53.175579 | W 006 51 15.438642 | 90.090 |
| RAMO 20703S001 | 4514721.7510 | 3133507.9039 | 3228024.7879 | N 30 35 51.382810 | E 034 45 47.305972 | 886.829 |
| SFER 13402M004 | 5105518.9707 | -555145.7959 | 3769803.4418 | N 36 27 51.646440 | W 006 12 20.321541 | 84.174 |
| SHAM 13274S002 | 4026741.2976 | -101963.4738 | 4928808.1323 | N 50 55 52.619279 | W 001 27 01.836055 | 100.425 |
| SNEO 19135M002 | 3918752.6780 | -7694.0222 | 5015570.3689 | N 52 11 07.326061 | W 000 06 44.976810 | 120.057 |
| STRN 19176M001 | 3666407.3066 | -302232.9699 | 5192985.5370 | N 54 51 59.744696 | W 004 42 44.670967 | 164.190 |
| SWAS 19193M001 | 3963403.5133 | -275880.6219 | 4972970.3061 | N 51 33 56.012873 | W 003 58 54.353247 | 89.988 |
| SWRD 13624M001 | 3783414.8925 | -412281.7783 | 5101201.8056 | N 53 27 32.610436 | W 006 13 08.503059 | 94.628 |
| TRLE 13625M001 | 3854260.6446 | -656960.8716 | 5022495.0236 | N 52 17 12.426599 | W 009 40 23.279997 | 137.231 |
| VILL 13406M001 | 4849833.6497 | -335048.9351 | 4116014.9942 | N 40 26 36.938471 | W 003 57 07.121501 | 647.345 |
| WTZR 14201M010 | 4075580.4847 | 931853.8805 | 4801568.1920 | N 49 08 39.116823 | E 012 52 44.079896 | 666.039 |
| ZIMM 14001M004 | 4331297.0079 | 567555.9669 | 4633133.9994 | N 46 52 37.553555 | E 007 27 55.000941 | 956.349 |

# ETRF2000 coordinates

| Station | X | Y | Z | Latitude | Longitude | Height |
|---|---|---|---|---|---|---|
| ADAR 19161M001 | 3852249.6607 | -319510.9515 | 5056510.3199 | N 52 47 21.166524 | W 004 44 28.821449 | 148.407 |
| ARIS 19190M001 | 3472288.7005 | -355730.7255 | 5320461.0422 | N 56 54 34.501785 | W 005 50 58.049558 | 61.337 |
| ARKL 13612M001 | 3842456.0639 | -414559.2923 | 5056987.8514 | N 52 47 49.128338 | W 006 09 27.986291 | 91.723 |
| BELF 13240M001 | 3685258.2261 | -382909.2799 | 5174310.8019 | N 54 34 37.829633 | W 005 55 54.898317 | 81.993 |
| BNTY 13614M001 | 3909582.3711 | -650714.8573 | 4980627.2708 | N 51 40 34.048040 | W 009 26 59.072201 | 114.599 |
| BOR1 12205M002 | 3738358.7719 | 1148173.4976 | 5021815.5811 | N 52 16 37.034449 | E 017 04 24.427500 | 124.360 |
| BRUS 13101M004 | 4027894.0142 | 307045.5931 | 4919474.9150 | N 50 47 52.134480 | E 004 21 33.176235 | 149.675 |
| BUXT 19191M001 | 3824391.6933 | -128197.3932 | 5086209.3632 | N 53 13 45.231670 | W 001 55 11.612388 | 441.801 |
| CAGL 12725M003 | 4893379.0731 | 772649.5090 | 4004181.9194 | N 39 08 09.272526 | E 008 58 21.896195 | 238.368 |
| CAMO 19187M002 | 4071657.2494 | -379671.7851 | 4878472.4515 | N 50 13 06.008104 | W 005 19 38.216602 | 140.975 |
| CARL 13205S001 | 3671344.6140 | -188441.3676 | 5194773.9421 | N 54 53 43.524860 | W 002 56 17.798190 | 93.548 |
| CAVN 13615M001 | 3726882.4272 | -481707.8643 | 5136439.1346 | N 53 59 36.694264 | W 007 21 53.193848 | 146.950 |
| CHIO 19194M001 | 4007952.9553 | -100634.2576 | 4944058.9811 | N 51 08 56.371739 | W 001 26 17.941313 | 128.312 |
| CLNM 13617M001 | 3868650.9795 | -522748.6931 | 5027091.3356 | N 52 21 17.977752 | W 007 41 43.588100 | 82.959 |
| CSTB 13619M001 | 3721280.0815 | -608536.7348 | 5127050.9793 | N 53 51 02.655662 | W 009 17 14.317090 | 111.180 |
| DARE 13208S001 | 3811965.6022 | -175800.0554 | 5093615.5140 | N 53 20 41.290614 | W 002 38 25.775555 | 88.433 |
| DNGL 13620M001 | 3660877.9513 | -520221.4657 | 5179609.4892 | N 54 39 33.268479 | W 008 05 15.895216 | 93.096 |
| DVTG 13283M002 | 4011083.9443 | 92598.8401 | 4941591.7163 | N 51 06 52.287622 | E 001 19 20.929978 | 50.073 |
| EDIN 13217S001 | 3575928.4629 | -205860.6206 | 5259853.1829 | N 55 55 29.218267 | W 003 17 41.251311 | 119.052 |
| ENIS 13246M001 | 3688504.1031 | -495090.7876 | 5162577.2636 | N 54 23 43.436927 | W 007 38 41.474609 | 107.336 |
| ESMA 19102M001 | 3632179.7093 | -203515.0202 | 5221768.1017 | N 55 18 58.721762 | W 003 12 25.171878 | 324.057 |
| FOYL 13241M001 | 3638083.4868 | -468414.8611 | 5200402.3255 | N 54 59 01.510540 | W 007 20 11.944816 | 68.900 |
| GLAS 13219S001 | 3578263.4725 | -268830.5405 | 5255394.2713 | N 55 51 14.399045 | W 004 17 47.364286 | 71.642 |
| GLSV 12356M001 | 3512889.3273 | 2068979.6868 | 4888903.0221 | N 50 21 51.048731 | E 030 29 48.218371 | 226.317 |
| GLWY 13627M001 | 3774050.9431 | -601852.6756 | 5089350.3563 | N 53 16 50.451844 | W 009 03 38.650830 | 86.485 |
| GRAS 10002M006 | 4581691.1630 | 556114.5749 | 4389360.5665 | N 43 45 17.045643 | E 006 55 14.050645 | 1319.319 |
| HERO 19168M001 | 4033452.8415 | 23629.3747 | 4924309.3197 | N 50 52 02.932960 | E 000 20 08.357412 | 71.641 |
| HERS 13212M007 | 4033470.3553 | 23672.6549 | 4924301.1016 | N 50 52 02.319134 | E 000 20 10.565365 | 76.479 |
| HERT 13212M010 | 4033461.1669 | 23537.5649 | 4924318.0469 | N 50 52 02.915695 | E 000 20 03.660071 | 83.326 |
| HOE2 14284M002 | 3650022.9687 | 532050.3461 | 5185984.3030 | N 54 45 31.497206 | E 008 17 36.183245 | 62.714 |
| HOFN 10204M002 | 2679690.2408 | -727951.3630 | 5722789.1889 | N 64 16 02.241061 | W 015 11 52.519071 | 82.724 |
| IESG 13220M001 | 3851174.4856 | -80151.8476 | 5066647.0176 | N 52 56 26.476643 | W 001 11 32.227986 | 98.460 |
| INVR 13221M001 | 3427172.3994 | -252834.3272 | 5355255.5249 | N 57 29 10.500182 | W 004 13 09.349860 | 66.195 |
| JOZE 12204M001 | 3664940.4999 | 1409153.6592 | 5009571.2055 | N 52 05 50.180065 | E 021 01 53.523393 | 141.442 |
| KING 13225S001 | 3868686.0710 | 27112.6432 | 5053896.9608 | N 52 45 04.921154 | E 000 24 05.527613 | 66.437 |
| KINT 19192M001 | 3456261.3161 | -140550.8623 | 5340851.8753 | N 57 14 43.325361 | W 002 19 43.258392 | 141.249 |
| KLRE 13245M001 | 3645421.1659 | -422952.4388 | 5199264.7758 | N 54 57 53.770957 | W 006 37 04.922943 | 147.931 |
| LEED 13215S001 | 3773717.7901 | -109614.4527 | 5123816.1088 | N 53 48 00.775275 | W 001 39 49.649894 | 215.617 |
| LERI 19159M003 | 3183134.9500 | -65772.7189 | 5508281.2654 | N 60 08 17.974222 | W 001 11 01.417456 | 132.089 |
| MATE 12734M008 | 4641949.8450 | 1393045.1606 | 4133287.2511 | N 40 38 56.864572 | E 016 42 16.039537 | 535.663 |
| MCHA 19101M001 | 3929947.1572 | -205930.9769 | 5002873.3382 | N 51 59 51.746274 | W 002 59 58.491183 | 288.145 |
| METS 10503S011 | 2892571.1455 | 1311843.2906 | 5512633.9936 | N 60 13 02.890154 | E 024 23 43.134371 | 94.621 |
| MORO 13299M002 | 3645662.9975 | -107277.6363 | 5215057.7628 | N 55 12 46.251420 | W 001 41 07.817423 | 145.166 |
| MORP 13299S001 | 3645668.0895 | -107277.4445 | 5215053.3364 | N 55 12 46.034738 | W 001 41 07.798110 | 144.431 |
| MRKT 13242M001 | 3711921.9485 | -423147.0453 | 5152394.3631 | N 54 14 13.586449 | W 006 30 12.450060 | 224.378 |
| NEWL 13273M103 | 4079954.1645 | -395930.4835 | 4870196.7375 | N 50 06 10.894927 | W 005 32 34.048532 | 64.506 |
| NICO 14302M001 | 4359416.1002 | 2874116.8026 | 3650777.6309 | N 35 08 27.542450 | E 033 23 47.188242 | 190.050 |
| NOT1 12717M004 | 4934546.4922 | 1321264.7209 | 3806455.8960 | N 36 52 33.030546 | E 014 59 23.220131 | 126.351 |
| OMGH 13244M001 | 3671990.5660 | -467517.5338 | 5176939.3035 | N 54 36 58.397823 | W 007 15 21.078959 | 217.408 |
| OS12 | 4033459.2023 | 23626.3155 | 4924303.0887 | N 50 52 02.646489 | E 000 20 08.199069 | 70.810 |
| OSLS 10307M001 | 3169982.1826 | 579956.5869 | 5485936.5211 | N 59 44 11.702842 | E 010 22 03.911420 | 221.538 |
| PDEL 31906M004 | 4551596.0132 | -2186893.3907 | 3883410.5901 | N 37 44 51.888212 | W 025 39 45.957715 | 110.607 |
| POLV 12336M001 | 3411557.7366 | 2348463.7989 | 4834396.7207 | N 49 36 09.401341 | E 034 32 34.531049 | 178.377 |
| PRTL 13622M001 | 3812787.5464 | -488495.6879 | 5072816.4551 | N 53 01 54.684308 | W 007 18 03.530841 | 175.435 |
| RABT 35001M002 | 5255617.8245 | -631746.0053 | 3546322.2818 | N 33 59 53.162503 | W 006 51 15.453162 | 90.095 |
| RAMO 20703S001 | 4514722.2174 | 3133507.5726 | 3228024.5233 | N 30 35 51.372205 | E 034 45 47.285775 | 886.861 |
| SFER 13402M004 | 5105519.1705 | -555146.1830 | 3769803.1186 | N 36 27 51.633371 | W 006 12 20.336129 | 84.175 |
| SHAM 13274S002 | 4026741.5894 | -101963.7838 | 4928807.8674 | N 50 55 52.606350 | W 001 27 01.851545 | 100.408 |
| SNEO 19135M002 | 3918752.9815 | -7694.3242 | 5015570.1102 | N 52 11 07.313157 | W 000 06 44.992675 | 120.039 |
| STRN 19176M001 | 3666407.5950 | -302233.2536 | 5192985.2885 | N 54 51 59.731853 | W 004 42 44.685491 | 164.165 |
| SWAS 19193M001 | 3963403.7933 | -275880.9275 | 4972970.0429 | N 51 33 55.999961 | W 003 58 54.368065 | 89.968 |
| SWRD 13624M001 | 3783415.1678 | -412282.0707 | 5101201.5503 | N 53 27 32.597584 | W 006 13 08.517197 | 94.604 |
| TRLE 13625M001 | 3854260.8966 | -656961.1693 | 5022494.7628 | N 52 17 12.413799 | W 009 40 23.293245 | 137.207 |
| VILL 13406M001 | 4849833.8838 | -335049.3044 | 4116014.6858 | N 40 26 36.925416 | W 003 57 07.136448 | 647.342 |
| WTZR 14201M010 | 4075580.8527 | 931853.5688 | 4801567.9329 | N 49 08 39.104256 | E 012 52 44.060858 | 666.032 |
| ZIMM 14001M004 | 4331297.3388 | 567555.6358 | 4633133.7246 | N 46 52 37.540735 | E 007 27 54.983409 | 956.344 |

# ETRF97 coordinates

| Station | X | Y | Z | Latitude | Longitude | Height |
|---|---|---|---|---|---|---|
| ADAR 19161M001 | 3852249.6709 | -319510.9644 | 5056510.2833 | N 52 47 21.165518 | W 004 44 28.822090 | 148.385 |
| ARIS 19190M001 | 3472288.7109 | -355730.7475 | 5320461.0060 | N 56 54 34.500806 | W 005 50 58.050789 | 61.313 |
| ARKL 13612M001 | 3842456.0756 | -414559.3054 | 5056987.8137 | N 52 47 49.127264 | W 006 09 27.986919 | 91.701 |
| BELF 13240M001 | 3685258.2372 | -382909.2968 | 5174310.7649 | N 54 34 37.828602 | W 005 55 54.899188 | 81.970 |
| BNTY 13614M001 | 3909582.3865 | -650714.8689 | 4980627.2301 | N 51 40 34.046789 | W 009 26 59.072665 | 114.577 |
| BOR1 12205M002 | 3738358.7591 | 1148173.4858 | 5021815.5621 | N 52 16 37.034475 | E 017 04 24.427103 | 124.335 |
| BRUS 13101M004 | 4027894.0149 | 307045.5857 | 4919474.8856 | N 50 47 52.133875 | E 004 21 33.175856 | 149.652 |
| BUXT 19191M001 | 3824391.7006 | -128197.4065 | 5086209.3290 | N 53 13 45.230808 | W 001 55 11.613091 | 441.778 |
| CAGL 12725M003 | 4893379.0671 | 772649.5267 | 4004181.8931 | N 39 08 09.271930 | E 008 58 21.896962 | 238.349 |
| CAMO 19187M002 | 4071657.2608 | -379671.7925 | 4878472.4137 | N 50 13 06.007022 | W 005 19 38.216920 | 140.954 |
| CARL 13205S001 | 3671344.6220 | -188441.3847 | 5194773.9075 | N 54 53 43.523982 | W 002 56 17.799125 | 93.525 |
| CAVN 13615M001 | 3726882.4398 | -481707.8803 | 5136439.0964 | N 53 59 36.693157 | W 007 21 53.194631 | 146.928 |
| CHIO 19194M001 | 4007952.9623 | -100634.2663 | 4944058.9468 | N 51 08 56.370861 | W 001 26 17.941752 | 128.290 |
| CLNM 13617M001 | 3868650.9929 | -522748.7057 | 5027091.2965 | N 52 21 17.976596 | W 007 41 43.588665 | 82.938 |
| CSTB 13619M001 | 3721280.0961 | -608536.7510 | 5127050.9396 | N 53 51 02.654460 | W 009 17 14.317836 | 111.158 |
| DARE 13208S001 | 3811965.6101 | -175800.0690 | 5093615.4792 | N 53 20 41.289721 | W 002 38 25.776270 | 88.410 |
| DNGL 13620M001 | 3660877.9644 | -520221.4833 | 5179609.4506 | N 54 39 33.267350 | W 008 05 15.896086 | 93.074 |
| DVTG 13283M002 | 4011083.9483 | 92598.8318 | 4941591.6844 | N 51 06 52.286878 | E 001 19 20.929546 | 50.050 |
| EDIN 13217S001 | 3575928.4711 | -205860.6400 | 5259853.1483 | N 55 55 29.217391 | W 003 17 41.252399 | 119.029 |
| ENIS 13246M001 | 3688504.1159 | -495090.8045 | 5162577.2253 | N 54 23 43.435813 | W 007 38 41.475443 | 107.314 |
| ESMA 19102M001 | 3632179.7175 | -203515.0382 | 5221768.0671 | N 55 18 58.720881 | W 003 12 25.172871 | 324.034 |
| FOYL 13241M001 | 3638083.4991 | -468414.8792 | 5200402.2876 | N 54 59 01.509452 | W 007 20 11.945738 | 68.877 |
| GLAS 13219S001 | 3578263.4816 | -268830.5598 | 5255394.2360 | N 55 51 14.398123 | W 004 17 47.365353 | 71.619 |
| GLSV 12356M001 | 3512889.2996 | 2068979.6747 | 4888903.0141 | N 50 21 51.049314 | E 030 29 48.218554 | 226.292 |
| GLWY 13627M001 | 3774050.9576 | -601852.6905 | 5089350.3164 | N 53 16 50.450640 | W 009 03 38.651501 | 86.463 |
| GRAS 10002M006 | 4581691.1602 | 556114.5829 | 4389360.5386 | N 43 45 17.045030 | E 006 55 14.051015 | 1319.298 |
| HERO 19168M001 | 4033452.8466 | 23629.3669 | 4924309.2868 | N 50 52 02.932161 | E 000 20 08.357012 | 71.618 |
| HERS 13212M007 | 4033470.3604 | 23672.6470 | 4924301.0687 | N 50 52 02.318335 | E 000 20 10.564960 | 76.457 |
| HERT 13212M010 | 4033461.1720 | 23537.5570 | 4924318.0140 | N 50 52 02.914896 | E 000 20 03.659665 | 83.303 |
| HOE2 14284M002 | 3650022.9655 | 532050.3300 | 5185984.2771 | N 54 45 31.496868 | E 008 17 36.182379 | 62.689 |
| HOFN 10204M002 | 2679690.2560 | -727951.4027 | 5722789.1498 | N 64 16 02.239783 | W 015 11 52.521621 | 82.700 |
| IESG 13220M001 | 3851174.4921 | -80151.8602 | 5066646.9839 | N 52 56 26.475812 | W 001 11 32.228653 | 98.437 |
| INVR 13221M001 | 3427172.4082 | -252834.3501 | 5355255.4901 | N 57 29 10.499292 | W 004 13 09.351192 | 66.171 |
| JOZE 12204M001 | 3664940.4829 | 1409153.6469 | 5009571.1898 | N 52 05 50.180271 | E 021 01 53.523110 | 141.417 |
| KING 13225S001 | 3868686.0758 | 27112.6312 | 5053896.9283 | N 52 45 04.920396 | E 000 24 05.526972 | 66.414 |
| KINT 19192M001 | 3456261.3231 | -140550.8844 | 5340851.8417 | N 57 14 43.324559 | W 002 19 43.259692 | 141.225 |
| KLRE 13245M001 | 3645421.1775 | -422952.4568 | 5199264.7384 | N 54 57 53.769903 | W 006 37 04.923873 | 147.909 |
| LEED 13215S001 | 3773717.7970 | -109614.4672 | 5123816.0749 | N 53 48 00.774436 | W 001 39 49.650675 | 215.594 |
| LERI 19159M003 | 3183134.9556 | -65772.7471 | 5508281.2332 | N 60 08 17.973531 | W 001 11 01.419275 | 132.064 |
| MATE 12734M008 | 4641949.8290 | 1393045.1739 | 4133287.2327 | N 40 38 56.864363 | E 016 42 16.040275 | 535.643 |
| MCHA 19101M001 | 3929947.1657 | -205930.9876 | 5002873.3028 | N 51 59 51.745338 | W 002 59 58.491720 | 288.122 |
| METS 10503S011 | 2892571.1293 | 1311843.2601 | 5512633.9783 | N 60 13 02.890675 | E 024 23 43.133002 | 94.594 |
| MORO 13299M002 | 3645663.0043 | -107277.6539 | 5215057.7292 | N 55 12 46.250606 | W 001 41 07.818406 | 145.143 |
| MORP 13299S001 | 3645668.0963 | -107277.4621 | 5215053.3028 | N 55 12 46.033924 | W 001 41 07.799094 | 144.408 |
| MRKT 13242M001 | 3711921.9601 | -423147.0616 | 5152394.3256 | N 54 14 13.585389 | W 006 30 12.450882 | 224.355 |
| NEWL 13273M103 | 4079954.1760 | -395930.4906 | 4870196.6995 | N 50 06 10.893837 | W 005 32 34.048831 | 64.485 |
| NICO 14302M001 | 4359416.0602 | 2874116.8198 | 3650777.6297 | N 35 08 27.542865 | E 033 23 47.189679 | 190.030 |
| NOT1 12717M004 | 4934546.4775 | 1321264.7426 | 3806455.8759 | N 36 52 33.030192 | E 014 59 23.221131 | 126.332 |
| OMGH 13244M001 | 3671990.5783 | -467517.5511 | 5176939.2655 | N 54 36 58.396732 | W 007 15 21.079828 | 217.386 |
| OS12 | 4033459.2074 | 23626.3076 | 4924303.0558 | N 50 52 02.645691 | E 000 20 08.198664 | 70.788 |
| OSLS 10307M001 | 3169982.1781 | 579956.5598 | 5485936.4967 | N 59 44 11.702705 | E 010 22 03.909765 | 221.512 |
| PDEL 31906M004 | 4551596.0524 | -2186893.3818 | 3883410.5285 | N 37 44 51.886007 | W 025 39 45.956694 | 110.594 |
| POLV 12336M001 | 3411557.7044 | 2348463.7864 | 4834396.7161 | N 49 36 09.402073 | E 034 32 34.531445 | 178.352 |
| PRTL 13622M001 | 3812787.5592 | -488495.7018 | 5072816.4166 | N 53 01 54.683185 | W 007 18 03.531494 | 175.413 |
| RABT 35001M002 | 5255617.8404 | -631745.9788 | 3546322.2376 | N 33 59 53.161085 | W 006 51 15.452063 | 90.081 |
| RAMO 20703S001 | 4514722.1733 | 3133507.5978 | 3228024.5243 | N 30 35 51.372594 | E 034 45 47.287496 | 886.843 |
| SFER 13402M004 | 5105519.1852 | -555146.1614 | 3769803.0758 | N 36 27 51.632018 | W 006 12 20.335203 | 84.159 |
| SHAM 13274S002 | 4026741.5964 | -101963.7921 | 4928807.8330 | N 50 55 52.605467 | W 001 27 01.851961 | 100.386 |
| SNEO 19135M002 | 3918752.9869 | -7694.3350 | 5015570.0772 | N 52 11 07.312364 | W 000 06 44.993242 | 120.016 |
| STRN 19176M001 | 3666407.6048 | -302233.2709 | 5192985.2526 | N 54 51 59.730889 | W 004 42 44.686413 | 164.142 |
| SWAS 19193M001 | 3963403.8030 | -275880.9375 | 4972970.0066 | N 51 33 55.998968 | W 003 58 54.368548 | 89.946 |
| SWRD 13624M001 | 3783415.1794 | -412282.0853 | 5101201.5128 | N 53 27 32.596521 | W 006 13 08.517916 | 94.582 |
| TRLE 13625M001 | 3854260.9120 | -656961.1823 | 5022494.7221 | N 52 17 12.412549 | W 009 40 23.293785 | 137.186 |
| VILL 13406M001 | 4849833.8950 | -335049.2905 | 4116014.6465 | N 40 26 36.924232 | W 003 57 07.135827 | 647.324 |
| WTZR 14201M010 | 4075580.8436 | 931853.5646 | 4801567.9107 | N 49 08 39.104026 | E 012 52 44.060756 | 666.009 |
| ZIMM 14001M004 | 4331297.3357 | 567555.6370 | 4633133.6974 | N 46 52 37.540202 | E 007 27 54.983485 | 956.322 |


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# 1 Introduction

This report details the processing and analysis of data from the EUREF IE/UK 2009 GNSS (GPS and GLONASS) campaign. The campaign was carried out as a EUREF densification campaign.

The campaign covered the territories of Great Britain, Ireland and Northern Ireland. These areas have some legacy EUREF campaigns:

- EUREF GB 2001 and EUREF GB 92 in Great Britain.
- EUREF EIR/GB 95 in Ireland and Northern Ireland with some points in Great Britain.

In Great Britain EUREF GB 2001 was predominantly based on stations with permanent receivers and over half of these have been destroyed. A new sub network of Ordnance Survey's permanent OS Net network was recently completed. This new sub network is known as GeoNet and the stations have been designed and built to have a much longer lifespan than the previous stations.

Similarly in Ireland and Northern Ireland the EUREF EIR/GB 95 network has been superseded by networks of permanent stations - the Ordnance Survey (Northern Ireland) Active stations and the OSi GeoNet stations. These networks have been coordinated in ETRF2000 but not in an official EUREF densification campaign.

The main motivation behind EUREF IE/UK 2009 was to take advantage of the new permanent GNSS stations that have been installed since the previous campaigns were carried out and also to take the opportunity to produce a combined "official" EUREF solution for the entire region.


# 2 Acknowledgments

The campaign and this report would not have been possible without the efforts and assistance of other colleagues and facilities. Their cooperation and hard work is gratefully acknowledged:

- Geoff Bell, Peter Downie and Ken Stewart of Land and Property Services (LPS), Northern Ireland – formerly Ordnance Survey Northern Ireland.
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- The services of the Natural Environment Research Council (NERC) British Isles continuous GNSS Facility (BIGF), www.bigf.ac.uk, in providing archived GNSS data and parallel processing of data for this project.
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- Robert Sherwood of the NERC satellite laser ranging station at Herstmonceux.
- Carine Bruyninx, Heinz Habrich, Ambrus Kenyeres and Gunter Stangl of the EUREF Technical Working Group (TWG).

# 3 Campaign configuration and fiducial selection

The campaign contained a total of 67 stations as shown in Table 1 (page 10), Figure 1 (page 11) and Figure 2 (page 13). 54 stations were from processed GNSS data and 13 were from EPN weekly SINEX solutions (see Figure 2). Initially station IOMS 13224S001 on the Isle of Man was included since it was used in the previous EUREF GB 2001 campaign. However it was removed after it was discovered that the RINEX data was corrupted resulting in a large height offset.

The observation period was for 2 weeks from 00:00:00 GMT, Sunday 27th September 2009 (DoY 270, GPS week/day 15510) to 23:59:30 GMT, Saturday 10th October 2009 (DoY 283, GPS week/day 15526).

Data was available for all stations on all days except for:

- KLRE incomplete data on day 281 and missing data for days 282 and 283;
- HOE2 incomplete data for day 275.

All stations are permanent receivers expect for OS12 which is a survey pillar with forced centring. Station equipment and monument types are listed in Table 2 (page 12).

The EPN A stations used as fiducial stations are shown in Figure 2 (page 13) and highlighted in bold in Table 1 (page 10).

The “Guidelines for EUREF Densifications” [Bruyninx et al 2009] state that EPN A stations within the densification region must be selected as fiducials. However station MORP (Morpeth) in the north of England was deselected as a fiducial due to antenna problems and a coordinate jump close to the start of the campaign.

The aim when selecting the fiducial stations external to the campaign region was to try use as many of the combined EPN solution reference stations as possible (see table at *http://www.epncb.oma.be/_dataproducts/products/combinedeurefsolution.php*). The reference stations immediately surrounding the campaign area were processed with the remainder coming from the EPN weekly SINEX solutions. The EPN raw station coordinate time series for each chosen fiducial station was checked to make sure none of the stations had a noisy time series or recent coordinate jumps.

The following combined EPN solution reference stations were rejected for use as fiducials:

- ONSA and WSRT due to not having absolute antenna calibrations.
- POTS because of recent antenna change.
- NYA1 and REYK due being rejected a high number of times from the weekly EPN solution as outliers.
- NYAL and TRAB because they are no longer active.
- TRO1 due to a noisy up component in the time series.

The set of combined EPN solution reference stations chosen for fiducials was then supplemented by 5 more EPN A stations to give an even spread of fiducial stations surrounding the campaign region. See Figure 2 (page 13).

**Table 1. List of EUREF IE/UK 2009 stations** (fiducial stations in bold).

| Stn ID | DOMES No. | Name | Type |
|---|---|---|---|
| ADAR | 19161M001 | Aberdaron | OS GeoNet and OS Net. |
| ARIS | 19190M001 | Arisaig | OS GeoNet and OS Net. |
| BUXT | 19191M001 | Buxton | OS GeoNet and OS Net. |
| CAMO | 19187M002 | Camborne | OS GeoNet and OS Net. |
| CHIO | 19194M001 | Chilbolton | OS GeoNet and OS Net. |
| HERO | 19168M001 | Herstmonceux | OS GeoNet and OS Net. |
| KINT | 19192M001 | Kintore | OS GeoNet and OS Net. |
| LERI | 19159M003 | Lerwick | OS GeoNet and OS Net. |
| MORO | 13299M002 | Morpeth | OS GeoNet and OS Net. |
| SNEO | 19135M002 | St. Neots | OS GeoNet and OS Net. |
| STRN | 19176M001 | Stranraer | OS GeoNet and OS Net. |
| SWAS | 19193M001 | Swansea | OS GeoNet and OS Net. |
| DVTG | 13283M002 | Dover Tide Gauge | IESSG Tide gauge. |
| ESMA | 19102M001 | Eskdalemuir | IESSG geodetic. |
| MCHA | 19101M001 | Michaelchurch Escley | IESSG geodetic. |
| BELF | 13240M001 | Belfast | LPS OSNI Active and EPN B. |
| ENIS | 13246M001 | Enniskillen | LPS OSNI Active. |
| FOYL | 13241M001 | Foyle | LPS OSNI Active. |
| KLRE | 13245M001 | Kilrea | LPS OSNI Active. |
| MRKT | 13242M001 | Markethill | LPS OSNI Active. |
| OMGH | 13244M001 | Omagh | LPS OSNI Active. |
| ARKL | 13612M001 | Arklow | OSi GeoNet. |
| BNTY | 13614M001 | Bantry | OSi GeoNet. |
| CAVN | 13615M001 | Cavan | OSi GeoNet. |
| CLNM | 13617M001 | Clonmel | OSi GeoNet. |
| CSTB | 13619M001 | Castlebar | OSi GeoNet. |
| DNGL | 13620M001 | Donegal | OSi GeoNet. |
| GLWY | 13627M001 | Galway | OSi GeoNet. |
| PRTL | 13622M001 | Portlaoise | OSi GeoNet. |
| SWRD | 13624M001 | Swords | OSi GeoNet. |
| TRLE | 13625M001 | Tralee | OSi GeoNet. |
| CARL | 13205S001 | Carlisle | OS *OS Net* and EUREF GB 2001. |
| **DARE** | **13208S001** | **Daresbury** | **OS *OS Net*, EUREF GB 2001 & EPN A fiducial.** |
| EDIN | 13217S001 | Edinburgh | OS *OS Net* and EUREF GB 2001. |
| GLAS | 13219S001 | Glasgow | OS *OS Net* and EUREF GB 2001. |
| IESG | 13220M001 | IESSG, Nottingham | OS *OS Net* and EUREF GB 2001. |
| KING | 13225S001 | King’s Lynn | OS *OS Net* and EUREF GB 2001. |
| LEED | 13215S001 | Leeds | OS *OS Net* and EUREF GB 2001. |
| OS12 | | Solar Pillar, Herstmonceux | EUREF GB 2001 (NOT permanent receiver). |
| SHAM | 13274S002 | Southampton | OS *OS Net* and EUREF GB 2001. |
| INVR | 13221M001 | Inverness | OS *OS Net* and EPN B. |
| **HERS** | **13212M007** | **Herstmonceux** | **EPN A fiducial. Processed data.** |
| **HERT** | **13212M010** | **Herstmonceux** | **EPN A fiducial. Processed data.** |
| MORP | 13299S001 | Morpeth | EPN A. Processed data. |
| **NEWL** | **13273M103** | **Newlyn** | **EPN A fiducial. Processed data.** |
| **BRUS** | **13101M004** | **Brussels** | **EPN A fiducial. Processed data.** |
| **GRAS** | **10002M006** | **Caussols** | **EPN A fiducial. Processed data.** |
| **HOE2** | **14284M002** | **Hoernum** | **EPN A fiducial. Processed data.** |
| **HOFN** | **10204M002** | **Hoefn** | **EPN A fiducial. Processed data.** |
| **OSLS** | **10307M001** | **Oslo** | **EPN A fiducial. Processed data.** |
| **PDEL** | **31906M004** | **Ponta Delgada** | **EPN A fiducial. Processed data.** |
| **TRDS** | **10331M001** | **Trondheim** | **EPN A fiducial. Processed data.** |
| **VILL** | **13406M001** | **Villafranca** | **EPN A fiducial. Processed data.** |
| **ZIMM** | **14001M004** | **Zimmerwald** | **EPN A fiducial. Processed data.** |
| **BOR1** | **12205M002** | **Borowiec** | **EPN A fiducial. SINEX data.** |
| **CAGL** | **12725M003** | **Cagliari - Astronomi** | **EPN A fiducial. SINEX data.** |
| **GLSV** | **12356M001** | **Kiev/Golosiiv** | **EPN A fiducial. SINEX data.** |
| **JOZE** | **12204M001** | **Jozefoslaw** | **EPN A fiducial. SINEX data.** |
| **MATE** | **12734M008** | **Matera** | **EPN A fiducial. SINEX data.** |
| **METS** | **10503S011** | **Metsahovi** | **EPN A fiducial. SINEX data.** |
| **NICO** | **14302M001** | **Nicosia-Athalassa** | **EPN A fiducial. SINEX data.** |
| **NOT1** | **12717M004** | **Noto-Radioastronomy** | **EPN A fiducial. SINEX data.** |
| **POLV** | **12336M001** | **Poltava** | **EPN A fiducial. SINEX data.** |
| **RABT** | **35001M002** | **Rabat, EMI** | **EPN A fiducial. SINEX data.** |
| **RAMO** | **20703S001** | **Mitzpe Ramon** | **EPN A fiducial. SINEX data.** |
| **SFER** | **13402M004** | **San Fernando** | **EPN A fiducial. SINEX data.** |
| **WTZR** | **14201M010** | **Wettzell** | **EPN A fiducial. SINEX data.** |

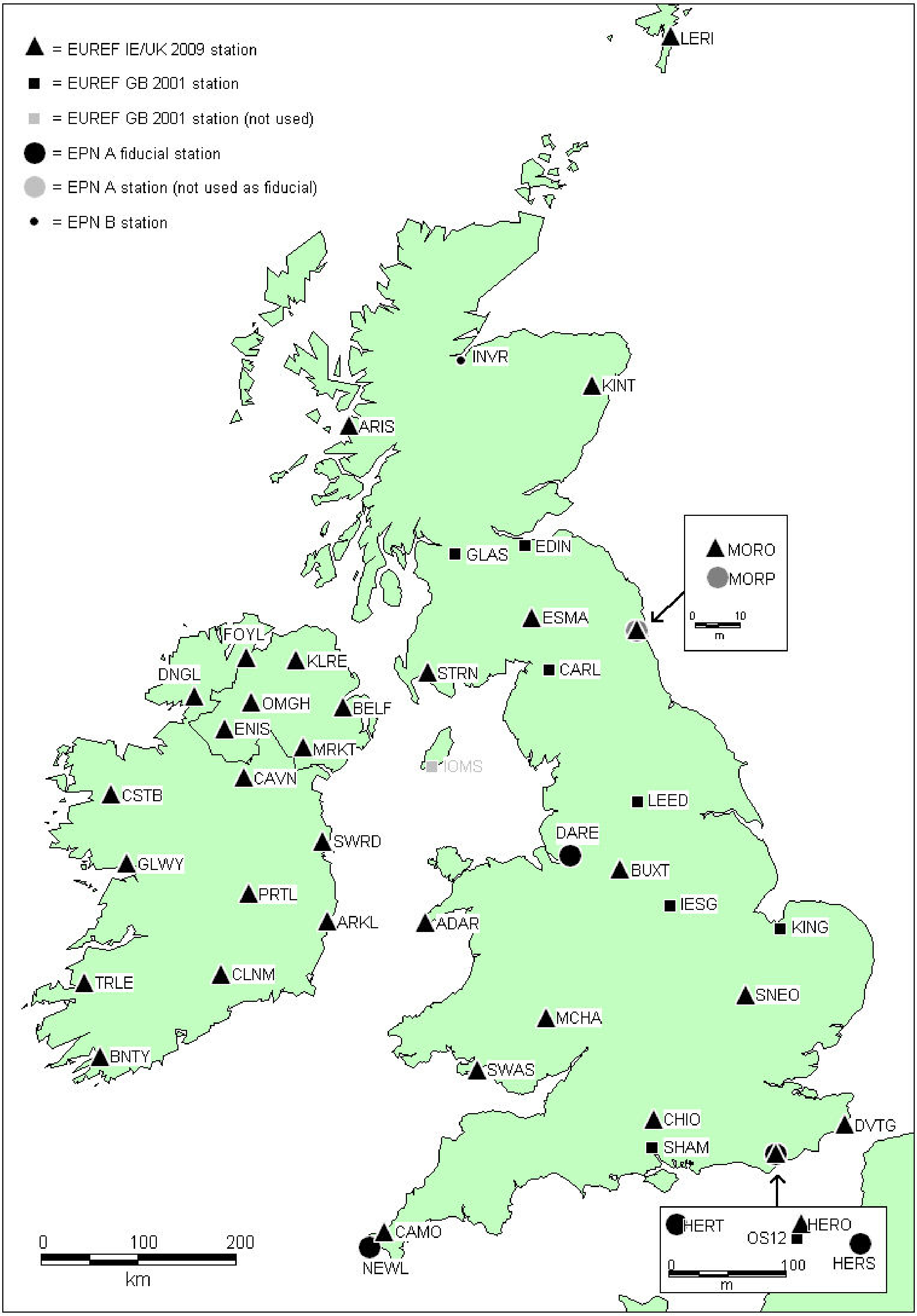


**Figure 1. EUREF IE/UK 2009 stations in United Kingdom and Ireland.**

**Table 2. Equipment and monument types.**

| Stn ID | Receiver | Antenna and radome | Monument type |
|---|---|---|---|
| ADAR | LEICA GRX1200+GNSS | LEIAR25 LEIT | Stainless steel pin in bedrock. |
| ARIS | LEICA GRX1200+GNSS | LEIAR25 LEIT | Stainless steel pin in bedrock. |
| BUXT | LEICA GRX1200+GNSS | LEIAR25 LEIT | Braced stainless steel rods in bedrock. |
| CAMO | LEICA GRX1200+GNSS | LEIAR25 LEIT | Galvanised steel helical pier quadpod driven to refusal. |
| CHIO | LEICA GRX1200+GNSS | LEIAR25 LEIT | Galvanised steel helical pier quadpod in chalk bedrock. |
| HERO | LEICA GRX1200+GNSS | LEIAR25 LEIT | Galvanised steel helical pier quadpod in clay. |
| KINT | LEICA GRX1200+GNSS | LEIAR25 LEIT | Stainless steel quadpod in bedrock. |
| LERI | LEICA GRX1200+GNSS | LEIAR25 LEIT | Stainless steel pin in bedrock. |
| MORO | LEICA GRX1200GGPRO | LEIAR25 LEIT | Stainless steel pin in monolith stone on bedrock. |
| SNEO | LEICA GRX1200+GNSS | LEIAR25 LEIT | Galvanised steel helical pier quadpod in sand/gravel. |
| STRN | LEICA GRX1200+GNSS | LEIAR25 LEIT | Stainless steel pin in bedrock. |
| SWAS | LEICA GRX1200+GNSS | LEIAR25 LEIT | Stainless steel pin in bedrock. |
| DVTG | ASHTECH UZ-12 | ASH701945C_M SNOW | Steel plate and carbon fibre pipe. |
| ESMA | LEICA GRX1200GGPRO | LEIAT504GG SCIT | Braced stainless steel rods in bedrock. |
| MCHA | LEICA GRX1200GGPRO | LEIAT504GG SCIT | Braced stainless steel rods in bedrock. |
| BELF | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Steel tripod on roof of building. |
| ENIS | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Steel tripod on concrete foundation. |
| FOYL | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Mast on gable of building. |
| KLRE | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Steel tripod on roof. |
| MRKT | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Steel tripod on concrete foundation. |
| OMGH | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Steel tripod on roof of building. |
| ARKL | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Mast on side of building. |
| BNTY | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Mast on side of building. |
| CAVN | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Mast on side of building. |
| CLNM | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Mast on side of building. |
| CSTB | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Mast on side of building. |
| DNGL | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Mast on side of building. |
| GLWY | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Mast on side of building. |
| PRTL | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Mast on side of building. |
| SWRD | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Mast on side of building. |
| TRLE | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Mast on side of building. |
| CARL | LEICA GRX1200+GNSS | LEIAR25 LEIT | Steel tripod on roof of building. |
| DARE | LEICA GRX1200+GNSS | LEIAR25 LEIT | Mast on side of building. |
| EDIN | LEICA GRX1200+GNSS | LEIAR25 LEIT | Mast on side of building. |
| GLAS | LEICA GRX1200+GNSS | LEIAR25 LEIT | Mast on side of building. |
| IESG | ASHTECH Z-XII3 | ASH700936D_M SNOW | Mast on side of building. |
| KING | LEICA GRX1200GGPRO | LEIAR25 LEIT | Steel tripod on roof of building. |
| LEED | LEICA GRX1200+GNSS | LEIAR25 LEIT | Steel tripod on roof of building. |
| OS12 | SEPT ASTERX2 | ASH701946.2 NONE | Forced centred pillar (not permanent receiver) |
| SHAM | LEICA GRX1200+GNSS | LEIAR25 LEIT | Steel tripod on roof of building. |
| INVR | LEICA GRX1200+GNSS | LEIAR25 LEIT | Mast on side of building. |
| HERS | ASHTECH Z-XII3 | ASH700936E NONE | Steel mast on concrete foundation. |
| HERT | LEICA GRX1200GGPRO | LEIAT504GG NONE | Concrete pillar on building roof. |
| MORP | TRIMBLE NETRS | AOAD/M_T NONE | Stainless steel pin in monolith stone on bedrock. |
| NEWL | ASHTECH UZ-12 | ASH700936D_M SNOW | Steel plate and carbon fibre pipe. |
| BRUS | ASHTECH Z-XII3T | ASH701945B_M NONE | Steel mast on concrete foundation. |
| GRAS | ASHTECH UZ-12 | ASH701945E_M NONE | Pillar on concrete foundation. |
| HOE2 | JPS LEGACY | TPSCR3_GGD CONE | Steel mast on building roof. |
| HOFN | TPS E_GGD | TPSCR3_GGD CONE | Pillar on concrete foundation on bedrock. |
| OSLS | TRIMBLE NETR8 | TRM55971.00 NONE | Steel mast on bedrock. |
| PDEL | LEICA GRX1200GGPRO | LEIAT504GG NONE | Steel mast on building roof. |
| TRDS | TRIMBLE NETR8 | TRM55971.00 NONE | Steel mast on bedrock. |
| VILL | ASHTECH UZ-12 | AOAD/M_T NONE | Pillar on concrete foundation. |
| ZIMM | TRIMBLE NETRS | TRM29659.00 NONE | Steel mast on concrete foundation. |
| BOR1 | TRIMBLE NETRS | AOAD/M_T NONE | Stable geodynamical pillar on the roof. |
| CAGL | TRIMBLE 4700 | TRM29659.00 NONE | Pillar on concrete foundation. |
| GLSV | NOV OEMV3 | NOV702GG NONE | Steel pillar on roof. |
| JOZE | TRIMBLE 4000SSI | TRM14532.00 NONE | Stable geodynamical pillar on concrete foundation. |
| MATE | LEICA GRX1200GGPRO | LEIAT504GG NONE | Stable pillar on the roof. |
| METS | ASHTECH Z-XII3 | AOAD/M_B NONE | Steel mast on bedrock. |
| NICO | LEICA GRX1200GGPRO | LEIAT504GG LEIS | Pillar on concrete foundation. |
| NOT1 | TRIMBLE 4000SSI | TRM29659.00 NONE | Pillar on concrete foundation. |
| POLV | TRIMBLE 4700 | TRM29659.00 NONE | Stable pillar on the roof. |
| RABT | ASHTECH UZ-12 | TRM29659.00 SCIS | Steel pin on roof. |
| RAMO | LEICA RS500 | ASH701945B_M SNOW | Brass nail in bedrock |
| SFER | TRIMBLE NETRS | TRM29659.00 NONE | Steel mast on building roof. |
| WTZR | LEICA GRX1200GGPRO | LEIAR25 LEIT | Steel plate on concrete survey tower. |


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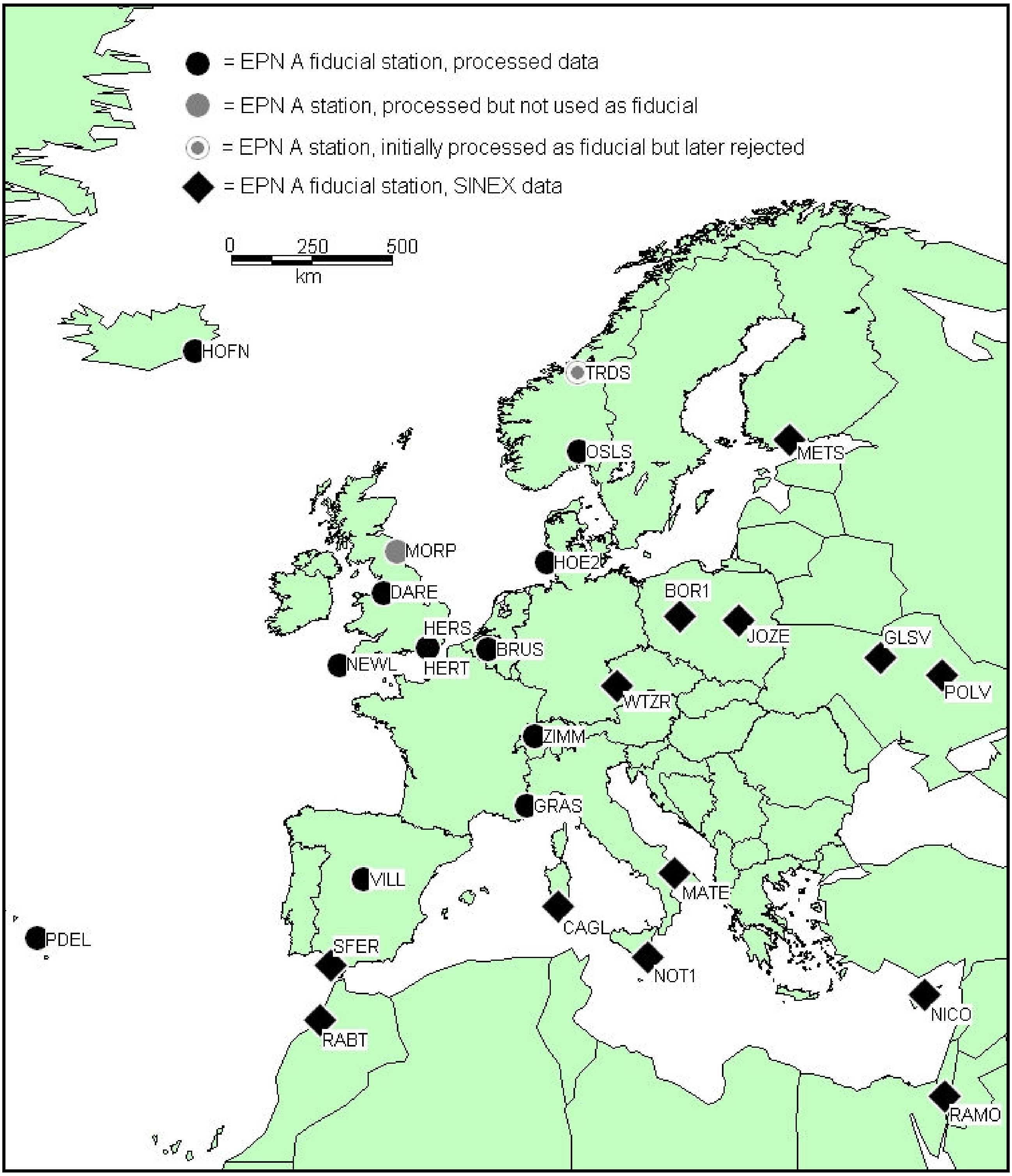


**Figure 2. EPN A stations used as fiducials.**

# 4 Data processing

Processing software was the Bernese GPS Software Version 5.0 (BSW). The baseline processing strategy was broadly similar to the one recommended for double difference processing in the BSW manual [Dach et al 2007].

## 4.1 External data

All external data files used in the processing are listed in Table 3 below.

**Table 3. External data products used in processing.**

| Product | Source |
|---|---|
| Final, precise GPS orbits | *ftp://cddis.gsfc.nasa.gov/gps/product/wwww/*, igs*wwwwd*.sp3 files |
| Final, precise GLONASS orbits | *ftp://cddis.gsfc.nasa.gov/glonass/product/wwww/*, igl*wwwwd*.sp3 files |
| Earth rotation parameters | *ftp://cddis.gsfc.nasa.gov/gps/product/wwww/*, igs*wwwwd*.erp files |
| Satellite clocks | *ftp://cddis.gsfc.nasa.gov/gps/product/wwww/*, igs*wwwwd*.clk_30s files |
| Ionosphere maps | *ftp://ftp.unibe.ch/aiub/CODE/yyyy/*, COD*wwwwd*.ION files |
| Differential clock biases | *ftp://ftp.unibe.ch/aiub/CODE/yyyy/*, P1C1*yymm*.DCB & P1P2*yymm*.DCB files. |
| Antenna phase centre offsets | *ftp://ftp.epncb.oma.be/pub/station/general/epn_05.atx*, file modified with additional individual calibrations from OS and IESSG. See section 4.3. |
| Ocean tide loading parameters | *http://www.oso.chalmers.se/~loading/*, model FES2004, no correction for the motion of the centre of mass of the solid Earth. |
| EPN fiducial station coordinates | *ftp://ftp.epncb.oma.be/pub/station/coord/EPN/*, file EPN_A_ITRF2005_C1555.SSC |
| EPN weekly SINEX solutions | *ftp://igs.bkg.bund.de/EUREF/products/wwww/*, eur*wwww*7.snx files |

## 4.2 Reference frame coordinates

**Table 4. ITRF2005 (e2005.000) coordinates and velocities of fiducial stations.**

| Stn ID | e2005.000 X m (Vx) m/yr | e2005.000 Y m (Vy) m/yr | e2005.000 Z m (Vz) m/yr |
|---|---|---|---|
| BOR1 | 3738358.4570 (-0.0165) | 1148173.7100 (0.0155) | 5021815.7740 (0.0096) |
| BRUS | 4027893.7510 (-0.0126) | 307045.8250 (0.0161) | 4919475.1220 (0.0113) |
| CAGL | 4893378.8210 (-0.0139) | 772649.7870 (0.0199) | 4004182.1600 (0.0120) |
| DARE | 3811965.3620 (-0.0107) | -175799.8380 (0.0162) | 5093615.7160 (0.0115) |
| GLSV | 3512888.9540 (-0.0190) | 2068979.8830 (0.0142) | 4888903.2000 (0.0092) |
| GRAS | 4581690.9040 (-0.0130) | 556114.8360 (0.0186) | 4389360.7960 (0.0119) |
| HERS | 4033470.1120 (-0.0122) | 23672.8900 (0.0164) | 4924301.3150 (0.0110) |
| HERT | 4033460.9240 (-0.0115) | 23537.8010 (0.0157) | 4924318.2560 (0.0120) |
| HOE2 | 3650022.6870 (-0.0140) | 532050.5530 (0.0158) | 5185984.5030 (0.0100) |
| HOFN | 2679689.9850 (-0.0032) | -727951.2240 (0.0147) | 5722789.3140 (0.0194) |
| JOZE | 3664940.1670 (-0.0173) | 1409153.8650 (0.0153) | 5009571.3890 (0.0099) |
| MATE | 4641949.5540 (-0.0176) | 1393045.4250 (0.0189) | 4133287.4610 (0.0155) |
| METS | 2892570.7930 (-0.0152) | 1311843.4470 (0.0144) | 5512634.1420 (0.0120) |
| NEWL | 4079953.9520 (-0.0107) | -395930.2480 (0.0167) | 4870196.9560 (0.0108) |
| NICO | 4359415.7180 (-0.0193) | 2874117.0730 (0.0106) | 3650777.8260 (0.0122) |
| NOT1 | 4934546.2290 (-0.0186) | 1321265.0120 (0.0169) | 3806456.1190 (0.0149) |
| OSLS | 3169981.8740 (-0.0120) | 579956.7700 (0.0134) | 5485936.6780 (0.0141) |
| PDEL | 4551595.9590 (-0.0056) | -2186893.1200 (0.0160) | 3883410.8450 (0.0116) |
| POLV | 3411557.3510 (-0.0209) | 2348463.9930 (0.0125) | 4834396.8940 (0.0078) |
| RABT | 5255617.6870 (-0.0104) | -631745.6900 (0.0171) | 3546322.5490 (0.0130) |
| RAMO | 4514721.8460 (-0.0211) | 3133507.8400 (0.0131) | 3228024.7010 (0.0180) |
| SFER | 5105519.0060 (-0.0079) | -555145.8730 (0.0158) | 3769803.3730 (0.0140) |
| VILL | 4849833.6940 (-0.0093) | -335049.0250 (0.0195) | 4116014.9330 (0.0128) |
| WTZR | 4075580.5590 (-0.0156) | 931853.8000 (0.0168) | 4801568.1400 (0.0104) |
| ZIMM | 4331297.0650 (-0.0131) | 567555.8810 (0.0179) | 4633133.9340 (0.0123) |

The ITRF2005, epoch 2005.00 coordinates of the fiducial stations and their corresponding velocities applicable to the campaign period were extracted from the *EPN_A_ITRF2005_C1555.SSC* file. See Table 4 above. The station velocities were applied to compute coordinates at the mid epoch of the campaign period – 00:00:00, Sunday 4th October 2009 (DoY 277, GPS week/day 15520), epoch 2009.756. The e2009.756 results are given in Table 5 below.

**Table 5. ITRF2005 e2009.756 coordinates of fiducial stations.**

| Stn ID | e2009.756 X m | e2009.756 Y m | e2009.756 Z m |
|---|---|---|---|
| BOR1 | 3738358.3785 | 1148173.7837 | 5021815.8197 |
| BRUS | 4027893.6911 | 307045.9016 | 4919475.1757 |
| CAGL | 4893378.7549 | 772649.8816 | 4004182.2171 |
| DARE | 3811965.3111 | -175799.7610 | 5093615.7707 |
| GLSV | 3512888.8636 | 2068979.9505 | 4888903.2438 |
| GRAS | 4581690.8422 | 556114.9245 | 4389360.8526 |
| HERS | 4033470.0540 | 23672.9680 | 4924301.3673 |
| HERT | 4033460.8693 | 23537.8757 | 4924318.3131 |
| HOE2 | 3650022.6204 | 532050.6281 | 5185984.5506 |
| HOFN | 2679689.9698 | -727951.1541 | 5722789.4063 |
| JOZE | 3664940.0847 | 1409153.9378 | 5009571.4361 |
| MATE | 4641949.4703 | 1393045.5149 | 4133287.5347 |
| METS | 2892570.7207 | 1311843.5155 | 5512634.1991 |
| NEWL | 4079953.9011 | -395930.1686 | 4870197.0074 |
| NICO | 4359415.6262 | 2874117.1234 | 3650777.8840 |
| NOT1 | 4934546.1405 | 1321265.0924 | 3806456.1899 |
| OSLS | 3169981.8169 | 579956.8337 | 5485936.7451 |
| PDEL | 4551595.9324 | -2186893.0439 | 3883410.9002 |
| POLV | 3411557.2516 | 2348464.0524 | 4834396.9311 |
| RABT | 5255617.6375 | -631745.6087 | 3546322.6108 |
| RAMO | 4514721.7457 | 3133507.9023 | 3228024.7866 |
| SFER | 5105518.9684 | -555145.7979 | 3769803.4396 |
| VILL | 4849833.6498 | -335048.9323 | 4116014.9939 |
| WTZR | 4075580.4848 | 931853.8799 | 4801568.1895 |
| ZIMM | 4331297.0027 | 567555.9661 | 4633133.9925 |

## 4.3 Antenna calibrations and ocean tide loading

Absolute antenna calibrations were used through out the processing. The *epn_05.atx* file (see 4.1) was used as a template to create a custom antenna calibration file for the campaign. Individual, robot antenna calibrations for Ordnance Survey's GeoNet stations and IESSG's geodetic stations were added to the file.

Ocean tide loading parameters used through out the processing were obtained from *http://www.oso.chalmers.se/~loading/*, using model FES2004 with no correction for the motion of the centre of mass of the solid Earth. Station coordinates used for the ocean tide loading parameter computation came from an initial precise point positioning (PPP) run through one whole day of data for all stations.

## 4.4 Processing strategy overview

An overview of the daily processing strategy is given in Table 6 below. Further details on key aspects of the processing are given in following sections. An elevation cut off angle of 3 degrees and "cos z" elevation dependant weighting was used through out the processing.

Table 6. Overview of daily processing strategy.

| Step | Program | Details |
|---|---|---|
| 1. | CCPREORB | Combine precise GPS and GLONASS orbit files into a single sp3c format file. |
| 2. | POLUPD | Create BSW ERP format file from precise IGS ERP file. |
| 3. | PRETAB | Create tabular orbit file using files from steps 1 and 2 as input. Also save satellite clocks. |
| 4. | ORBGEN | Generate standard orbit file. |
| 5. | CCRNXC | Create BSW format clock file from IGS precise 30 sec clock file. |
| 6. | RNXSMT | Clean and smooth RINEX files. |
| 7. | RXOBV3 | Import smoothed RINEX files into BSW format. GPS OBSERVATIONS ONLY. Export coordinates for use as a priori values. |
| 8. | CODSPP | Station by station single point positioning from code observations using precise SV clocks from step 5. Coordinate results used to update a priori coordinate values. Receiver clock estimates saved in observation files. |
| 9. | GPSEST | Station by station zero difference processing using precise IGS orbits (step 1), ERPs (step 2), clocks (step 5) and a priori coordinates from step 8. GPS OBSERVATIONS ONLY. Save coordinates, residuals and normal equations. |
| 10. | RESRMS & SATMRK | Screen and mark high residuals from previous GPSEST run. |
| 11. | GPSEST | Same as step 9 but use screened observation files from step 10 and a priori coordinates from step 9. |
| 12. | ADDNEQ2 | Combine individual station normal equations and a priori coordinates from step 11. Output final PPP coordinates and daily PPP normal equations. |
| 13. | CRDMERGE | Create new a priori coordinate file for double difference processing using final PPP coordinates from step 12. |
| 14. | RXOBV3 | Import RINEX files into BSW format. GPS and GLONASS observations. |
| 15. | CODSPP | Station by station single point positioning from code observations using SV clocks extracted from combined GPS and GLONASS orbit file in step 3. Receiver clock estimates saved in observation files. |
| 16. | SNGDIF | Create single difference observation files using the OBSMAX strategy. |
| 17. | MAUPRP | Observation pre processing. Filter out observations:<br>• Lower than 3° elevation;<br>• Unpaired (L1 but no L2 or vice versa);<br>• In "small pieces" (<301 seconds, gap between continuous obs <61seconds).<br>Identify data with no cycle slips and in remaining data find and if possible repair cycle slips. |
| 18. | GPSEST | Baseline by baseline ambiguity free solution. Troposphere parameters estimated. Residuals (normalised) and normal equations saved. |
| 19. | RESRMS & SATMRK | Screen and mark high residuals from previous GPSEST run. |
| 20. | GPSEST | Same as step 18 but use screened observation files from step 19. |
| 21. | ADDNEQ2 | Combine individual baseline normal equations from step 20. Output coordinates and troposphere parameters. |
| 22. | GPSEST | Baseline by baseline ambiguity resolution using the QIF algorithm. |
| 23. | GPSEST | Final free network processing of all baselines in a single run. Coordinates and normal equations saved. |
| 24. | HELMR1 | Helmert transformation of coordinates from step 23 to coordinates of EPN A fiducial stations to check for problems at fiducial stations. |

## 4.5 Troposphere and ionosphere strategy

A simple troposphere strategy was applied in programs CODSPP and MAUPRP (steps, 8, 15 and 17 in Table 6). CODSPP used the Saastamoinen model and MAUPRP used Niell (combined wet and dry) zenith path delay model and mapping function.

In the ambiguity free and ambiguity resolution GPSEST runs (steps 18 and 22 Table 6) the Dry Niell a priori model was used plus the estimation of zenith path delay Wet Niell parameters every hour with a 5 m a priori weight for the absolute and relative parameters.

For the final GPSEST runs for PPP and double difference processing (steps 11 and 23, Table 6) a Dry Niell a priori model was used plus the estimation of zenith path delay Wet Niell parameters every hour. Horizontal gradient parameters with a tilting model were also computed every 24 hours. A 5 m a priori weight for the absolute and relative parameters was used.

The ionosphere free L3 combination was used through out the processing to remove the effects of the ionosphere. The exception to this was at the QIF ambiguity resolution stage when the L1+L2 observable was used and an a priori ionosphere model introduced.

## 4.6 Ambiguity resolution

As recommended by the BSW manual [Dach et al 2007] only ambiguities for GPS observations were estimated. GLONASS ambiguities were not estimated.

The a priori coordinates for the ambiguity resolution processing were introduced from the previous ambiguity free stage and the *CODwwwwd.ION* model was introduced so ionosphere parameters were not estimated.

Following discussion with IESSG and also with reference to the BSW example campaign options a test was performed to see the effect of raising the elevation cut off angle for ambiguity resolution to 10 degrees. The final coordinate differences between processing at 10 and 3 degrees were insignificant so a 3 degree cut off was used in the final solution. More details of the test are in Annex A.

## 4.7 Daily free network solution processing

The final daily free network solutions were produced by processing all baselines in a single GPSEST run (step 23, Table 6). A priori coordinates from the ambiguity free processing were introduced. The “CORRECT” correlation strategy was used to ensure the statistically correct modelling of correlations between all baselines. The sampling interval was 180 seconds.

The troposphere and ionosphere strategy was as described in section 4.5 above. The previously resolved ambiguities were introduced as known integer values.

Normal equations were saved for later use in the final combined solution.

The EPN A fiducial station coordinates from this solution were transformed to their “correct” coordinates from the ‘*EPN_A_ITRF2005_C1555.SSC’* file. The residuals from this transformation were used to check the daily performance of the processed EPN A stations.

## 4.8 Final combined network solution

An a priori coordinate file was produced that contained the “correct” coordinates of the fiducial EPN A stations from the ‘*EPN_A_ITRF2005_C1555.SSC’* file – see section 4.2. A test was performed to study the impact of using only translation minimal constraint on the fiducial stations as opposed to using translation and scale. Details of the test are at Annex B. Using only translation constraints resulted in slightly better fiducial station coordinate recovery so this constraint was used for datum definition in the combined solution.

The daily solutions (see section 4.7) were combined using program ADDNEQ2 and the daily coordinate repeatabilities, compared to the combined solution, were analysed for outliers. A study was made of all the local analysis centre (LAC) summary files for the 2 weeks of the campaign in order to determine appropriate outlier limits for the RMS values of repeatabilities.

Figure 3 below shows a histogram of all the N, E and U RMS values for all the LACs. The histogram suggested that outlier limits for RMS values should be set at 3mm for N and E components and 9mm for U components. Outliers for individual, daily repeatabilities were set at the BSW defaults of 10mm for N and E and 20mm for U.

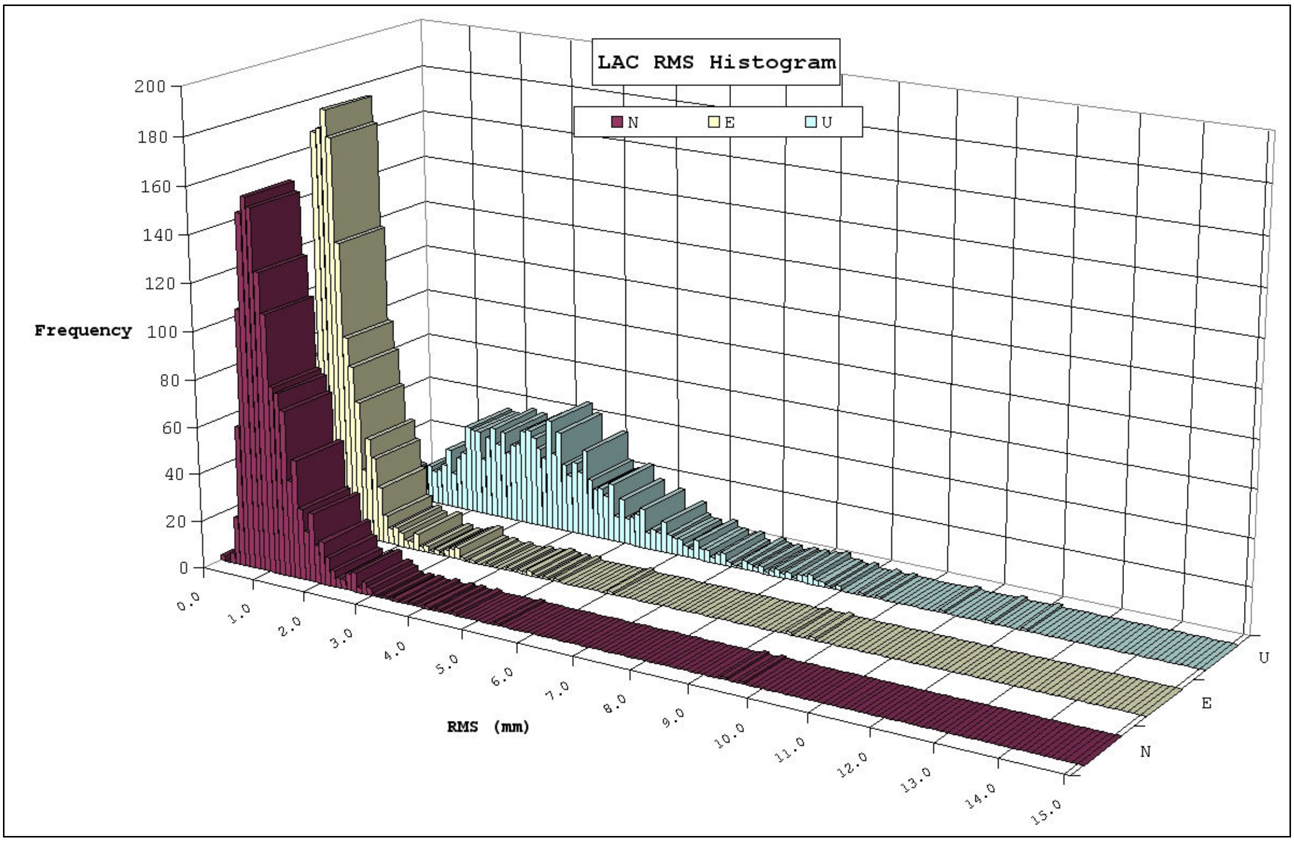


**Figure 3. Histogram of all RMS repeatabilities from all LACs.**

Outlier stations were removed and then the weekly EPN 'eur*wwww7*.snx' SINEX files were converted to BSW format normal equation files using the program SNX2NQ0.

To produce the final campaign solution the weekly EPN solutions and the daily free network campaign solutions (with outliers removed) were combined using program ADDNEQ2.

A further quality test was to compare the final coordinates of the EPN A fiducial stations with their "correct" coordinates from the '*EPN_A_ITRF2005_C1555.SSC'* file.

## 4.9 Transformation to ETRS89

When the final solution was complete the coordinates were transformed from the campaign reference frame – ITRF2005 e2009.756 to the ETRS89 using the transformation utility on the EPN web site - *http://www.epncb.oma.be/_dataproducts/coord_trans/*. The transformation utility applies the transformations detailed in [Boucher and Altamimi 2008].

The recommended ETRS89 frame for EUREF densifications is ETRF2000 [Bruyninx et al 2009]. The transformation to ETRS89 was performed in both ETRF2000 and ETRF97 since the previous EUREF GB 2001 campaign was based on ITRF97.

# 5 Processing results

## 5.1 Ambiguity resolution

The overall mean ambiguity resolution was 62.8% and the daily mean percentages are shown below in Figure 4.

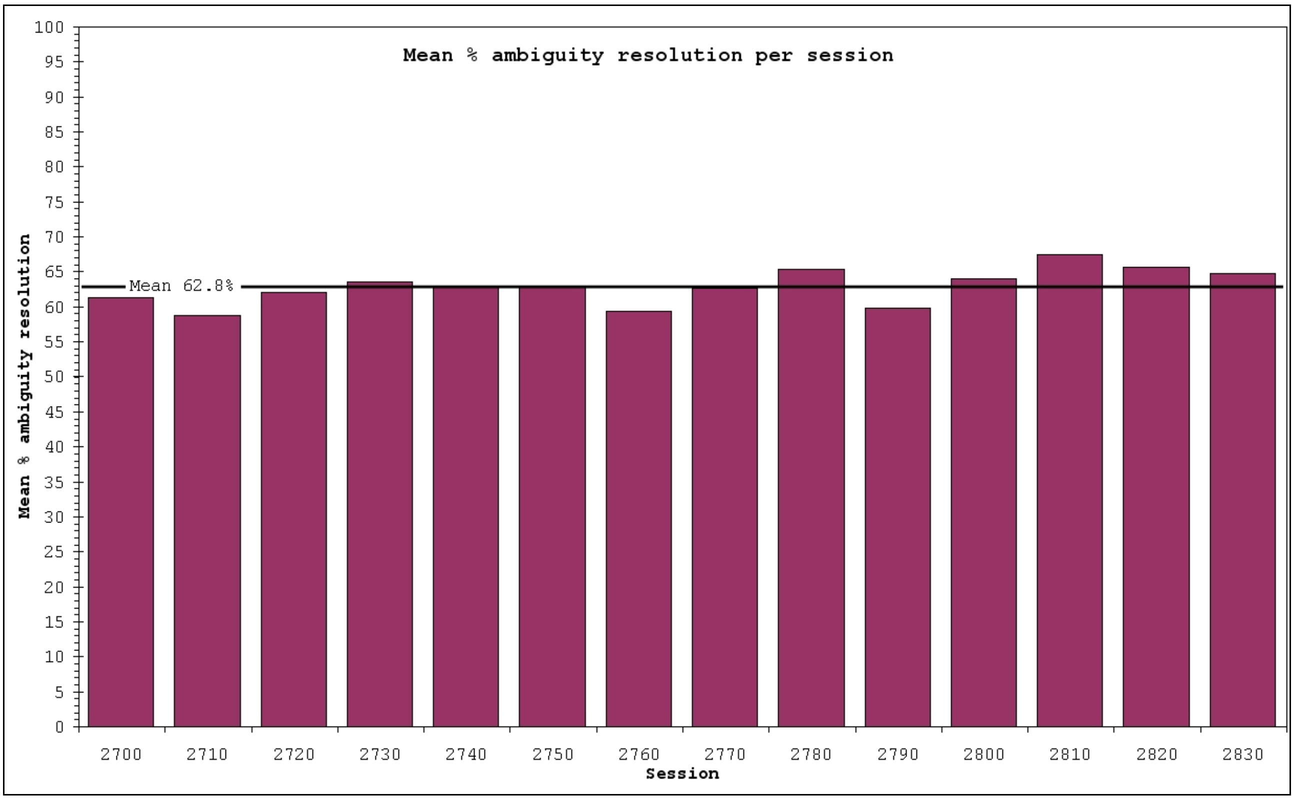


**Figure 4. Daily mean ambiguity resolution.**

## 5.2 Daily free network fiducial station tests

The results of the Helmert transformation tests on the fiducial station coordinates from the daily free network solutions are in Table 7 below (page 20).

The tests showed that station TRDS had poor performance on days 275, 281 and 282. The results for TRDS on these days are highlighted in Table 7.

Inspection of the RINEX data showed that on day 275 the TRDS data was incomplete – the file ended at 10:59:30. This could perhaps explain the poor performance on this day. The RINEX files for days 281 and 282 were complete so the poor TRDS performance on these days is harder to explain.

A study of local analysis centre (LAC) summary files showed that of the 3 LACs that process TRDS 2 of them rejected it on day 275 and 281 and 1 LAC rejected it on day 282.

TRDS was removed from further analysis on days 275, 281 and 282 using the “TYPE 003: HANDLING OF STATION PROBLEMS” section in the *.STA* station information file.

**Table 7. Transformation residuals of daily free network fiducial station coordinates compared to accepted coordinates.**

| | N (mm) | E (mm) | U (mm) | N (mm) | E (mm) | U (mm) | N (mm) | E (mm) | U (mm) | N (mm) | E (mm) | U (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 270 | | | 271 | | | 272 | | | 273 | | |
| BRUS | -1.0 | -0.4 | 0.1 | -0.8 | 0.2 | -6.3 | -0.9 | -0.5 | -3.7 | -1.1 | -1.2 | -2.8 |
| DARE | -1.1 | -1.0 | 3.8 | -2.0 | -0.5 | 8.1 | 0.0 | -0.8 | -6.9 | -0.4 | 0.2 | -4.4 |
| GRAS | 1.9 | -0.2 | 0.6 | 1.6 | -1.0 | 3.6 | 1.4 | 0.4 | 1.6 | 3.5 | -2.1 | 3.4 |
| HERS | -0.9 | 0.8 | 3.2 | -1.1 | 1.0 | 0.5 | -0.3 | 0.4 | -1.8 | -0.5 | 0.5 | -2.1 |
| HERT | 0.0 | -1.7 | 4.0 | 0.0 | -1.4 | 2.2 | 0.3 | -1.9 | -0.1 | 0.0 | -1.9 | 0.3 |
| HOE2 | -0.3 | -1.9 | -5.4 | 0.5 | -0.6 | -4.3 | -0.5 | -1.4 | 3.1 | -1.4 | -2.1 | 3.3 |
| HOFN | -3.4 | 1.6 | -0.1 | -4.6 | -1.4 | 4.7 | -1.8 | -1.7 | -2.6 | -1.0 | -1.3 | -3.8 |
| NEWL | -0.6 | 0.5 | -5.3 | 0.2 | 0.7 | -1.9 | -0.1 | -0.6 | -5.3 | -0.3 | 0.3 | -7.7 |
| OSLS | -1.2 | -4.3 | -4.2 | -1.4 | -1.6 | -3.4 | -1.2 | 0.3 | 1.1 | -2.8 | -0.4 | 3.3 |
| PDEL | 9.1 | 3.1 | -6.9 | 9.4 | 2.9 | -9.8 | 4.4 | 1.5 | 2.7 | 2.7 | 2.4 | 4.5 |
| TRDS | -3.4 | -2.7 | 2.6 | -2.8 | -3.1 | -3.7 | -2.1 | 0.8 | 8.2 | -1.7 | 2.0 | 7.2 |
| VILL | 3.7 | 3.2 | 9.1 | 3.6 | 2.5 | 8.2 | 1.2 | 3.6 | 4.7 | 3.1 | 3.7 | 2.1 |
| ZIMM | 0.8 | 0.1 | -9.2 | -0.5 | -0.3 | -4.8 | 0.1 | -1.4 | -3.4 | 0.9 | -1.2 | -6.7 |
| **RMS** | **3.3** | **2.2** | **5.3** | **3.4** | **1.7** | **5.6** | **1.6** | **1.6** | **4.3** | **1.9** | **1.9** | **4.6** |
| | 274 | | | 275 | | | 276 | | | 277 | | |
| BRUS | -1.0 | -0.7 | -3.1 | -0.7 | -0.2 | 3.9 | -1.5 | -2.5 | -4.5 | -1.5 | -1.6 | -3.0 |
| DARE | -1.5 | -1.2 | -0.5 | 0.0 | 0.8 | 4.7 | -1.1 | 0.1 | -1.2 | -1.2 | -0.6 | 1.8 |
| GRAS | 2.8 | -1.1 | -2.3 | 2.4 | -1.1 | -6.3 | 3.2 | -2.9 | -0.9 | 3.2 | -1.1 | 1.3 |
| HERS | -0.5 | -0.3 | 0.9 | 0.2 | 0.8 | 5.2 | -0.1 | 1.1 | -0.3 | -0.2 | -0.7 | 0.4 |
| HERT | -0.6 | -2.3 | 2.9 | 0.5 | -1.3 | 7.0 | 0.4 | -1.2 | 4.0 | 0.2 | -2.6 | 4.2 |
| HOE2 | -1.2 | -0.4 | 6.0 | -1.5 | -1.3 | 18.4 | -1.0 | -0.7 | 1.1 | -3.0 | 1.7 | 9.8 |
| HOFN | -2.0 | -2.2 | -2.2 | -3.0 | 0.9 | 16.9 | -2.6 | -1.6 | 3.9 | 0.6 | -2.6 | 2.5 |
| NEWL | -1.1 | -0.2 | 1.7 | 0.1 | 0.7 | -0.3 | -1.7 | -2.7 | 8.8 | -3.1 | -1.5 | 2.4 |
| OSLS | -2.5 | 0.2 | -1.2 | -1.7 | -0.2 | 13.6 | -2.6 | -0.1 | -1.3 | -0.6 | 0.1 | -5.3 |
| PDEL | 6.0 | 2.9 | -3.5 | 6.8 | 1.4 | -13.7 | 6.1 | 6.4 | -10.1 | 3.9 | 4.8 | -4.6 |
| TRDS | -1.2 | 0.5 | -0.3 | -4.2 | -6.7 | -52.3 | -3.1 | 1.1 | -5.6 | -1.5 | 2.3 | -5.2 |
| VILL | 3.1 | 3.5 | 4.4 | 3.1 | 3.3 | -0.9 | 4.8 | 2.2 | 7.7 | 3.2 | 2.0 | 0.1 |
| ZIMM | 0.7 | -0.6 | -7.7 | 0.7 | 0.3 | -4.2 | 1.3 | -1.0 | -8.8 | 0.7 | -1.6 | -8.2 |
| **RMS** | **2.5** | **1.7** | **3.7** | **2.8** | **2.3** | **18.0** | **2.9** | **2.5** | **5.8** | **2.3** | **2.2** | **4.9** |
| | 278 | | | 279 | | | 280 | | | 281 | | |
| BRUS | -1.7 | -1.5 | -2.1 | -0.4 | -2.4 | -5.5 | -2.0 | -1.9 | -6.2 | 0.0 | -0.5 | 2.4 |
| DARE | -0.9 | -1.2 | 1.7 | -0.6 | -1.5 | 1.2 | -2.7 | -1.7 | 8.4 | -2.4 | -0.6 | 13.7 |
| GRAS | 2.5 | -2.1 | 2.1 | 3.3 | -0.1 | 3.7 | 3.6 | -2.3 | 1.2 | 3.3 | -0.3 | -2.2 |
| HERS | 2.2 | 4.4 | -2.4 | 4.1 | 6.9 | -6.0 | 5.9 | 5.4 | 0.0 | 3.2 | 2.2 | 4.6 |
| HERT | -1.1 | -1.5 | 1.5 | -2.4 | -0.5 | -0.3 | -2.3 | 0.6 | 6.7 | -1.2 | -0.1 | 8.5 |
| HOE2 | -1.4 | -3.1 | 0.4 | -0.5 | -4.1 | -1.5 | -1.9 | -1.8 | 4.8 | -0.7 | -1.9 | 6.9 |
| HOFN | 0.0 | -1.4 | -0.6 | -1.6 | 0.9 | 5.9 | 0.8 | -2.4 | 1.9 | -2.2 | -2.4 | 17.2 |
| NEWL | -1.8 | -1.1 | -3.9 | -1.8 | 0.1 | 6.4 | 1.0 | -0.7 | -1.7 | -2.0 | -0.8 | 3.0 |
| OSLS | -2.3 | 0.4 | -1.7 | -3.9 | -3.6 | -3.3 | -4.4 | -1.7 | -2.1 | -1.2 | -1.7 | 5.4 |
| PDEL | 4.5 | 5.9 | -2.4 | 7.6 | 4.2 | -10.3 | 3.3 | 3.0 | -5.7 | 2.9 | -0.5 | -16.3 |
| TRDS | -1.8 | 0.8 | 4.9 | -3.2 | -2.2 | -2.2 | -1.7 | 0.3 | -6.3 | -3.8 | 3.0 | -42.3 |
| VILL | 3.2 | 1.2 | 6.2 | 2.5 | 1.8 | 11.9 | 1.7 | 3.1 | 3.5 | 2.0 | 2.7 | 0.8 |
| ZIMM | 0.9 | -2.4 | -8.5 | 0.6 | -2.4 | -7.7 | 0.2 | -2.1 | -9.0 | 1.5 | 0.1 | -6.3 |
| **RMS** | **2.3** | **2.7** | **3.9** | **3.3** | **3.1** | **6.3** | **3.0** | **2.5** | **5.4** | **2.4** | **1.7** | **15.2** |
| | 282 | | | 283 | | | | | | | | |
| BRUS | -0.6 | -0.8 | 0.6 | -0.6 | -1.7 | -4.5 | | | | | | |
| DARE | -0.5 | -0.1 | 8.0 | -1.1 | 0.1 | -1.2 | | | | | | |
| GRAS | 2.4 | -0.8 | 1.3 | 2.4 | -1.4 | 1.0 | | | | | | |
| HERS | 3.2 | 1.8 | -4.1 | 2.0 | 1.8 | 0.8 | | | | | | |
| HERT | -0.9 | -0.3 | 3.8 | -2.2 | -0.3 | 4.5 | | | | | | |
| HOE2 | -0.1 | -1.9 | 2.7 | -0.7 | -2.2 | 2.6 | | | | | | |
| HOFN | -2.7 | -3.6 | 11.6 | 0.3 | -2.4 | -2.3 | | | | | | |
| NEWL | -1.6 | -0.6 | 6.1 | -1.1 | -0.3 | -4.2 | | | | | | |
| OSLS | -2.5 | -0.6 | 1.7 | -2.1 | 0.2 | 6.7 | | | | | | |
| PDEL | 5.0 | 1.9 | -12.0 | 2.8 | 1.8 | 2.2 | | | | | | |
| TRDS | -5.5 | 0.7 | -23.5 | -0.9 | 1.7 | -2.6 | | | | | | |
| VILL | 3.4 | 2.8 | 2.2 | 1.4 | 2.8 | -2.0 | | | | | | |
| ZIMM | 0.8 | -0.7 | -4.0 | 0.5 | -1.1 | -3.3 | | | | | | |
| **RMS** | **2.9** | **1.7** | **9.1** | **1.7** | **1.7** | **3.5** | | | | | | |

## 5.3 Daily coordinate repeatability test

As stated in section 4.8 N, E, U outlier limits were set as follows:

- 10 mm N and E and 20 mm U for daily repeatabilities;
- 3 mm N and E and 9 mm U for RMS repeatabilities.

Station MCHA, exceeded the daily outlier limit with a -12.6 mm repeatability in the E component on day 276. MCHA was therefore removed from the processing on day 276.

Station ESMA had an E RMS value over the threshold at 3.5 mm but there was no single daily outlier that exceeded the 10 mm threshold. However the residuals for days 271, 272 and 273 were markedly poorer than the others - ~7mm E on days 271 and 272 compared to ~2mm on other days and 15mm U on day 273 compared to ~5mm on other days. ESMA was therefore removed from the processing for days 271, 272 and 273.

Of more concern were the results for fiducial station TRDS, shown in Table 8 below.

**Table 8. Fiducial station TRDS repeatabilities.**

| | **RMS** | **270** | **271** | **272** | **273** | **274** | **275** | **276** |
|---|---|---|---|---|---|---|---|---|
| N | **1.8** | 3.1 | 1.5 | 1.7 | 1.0 | 1.0 | | 2.3 |
| E | **1.3** | 1.5 | 2.2 | -1.7 | -1.4 | -0.1 | | 0.0 |
| U | **12.6** | -12.0 | -5.7 | -17.1 | -18.4 | -12.0 | | -5.7 |
| | | **277** | **278** | **279** | **280** | **281** | **282** | **283** |
| N | | 1.2 | 1.7 | 2.0 | -0.1 | | | 1.1 |
| E | | -1.3 | -0.1 | 1.5 | 0.1 | | | 1.0 |
| U | | -7.1 | -18.3 | -11.5 | -7.2 | | | -6.4 |

The U RMS component was above the 9 mm threshold and the U repeatabilities on all days look generally poor when compared to the other stations. Average daily repeatability for the U component across all the other stations was in the ±5 to 6 mm range. Based on these results it was decided to remove TRDS completely from the computations.

The RMS repeatabilities from the combination of the daily solutions are shown below in Figure 5 and Table 9 below. The complete list of coordinate repeatabilities is in Table 19 at Annex C.

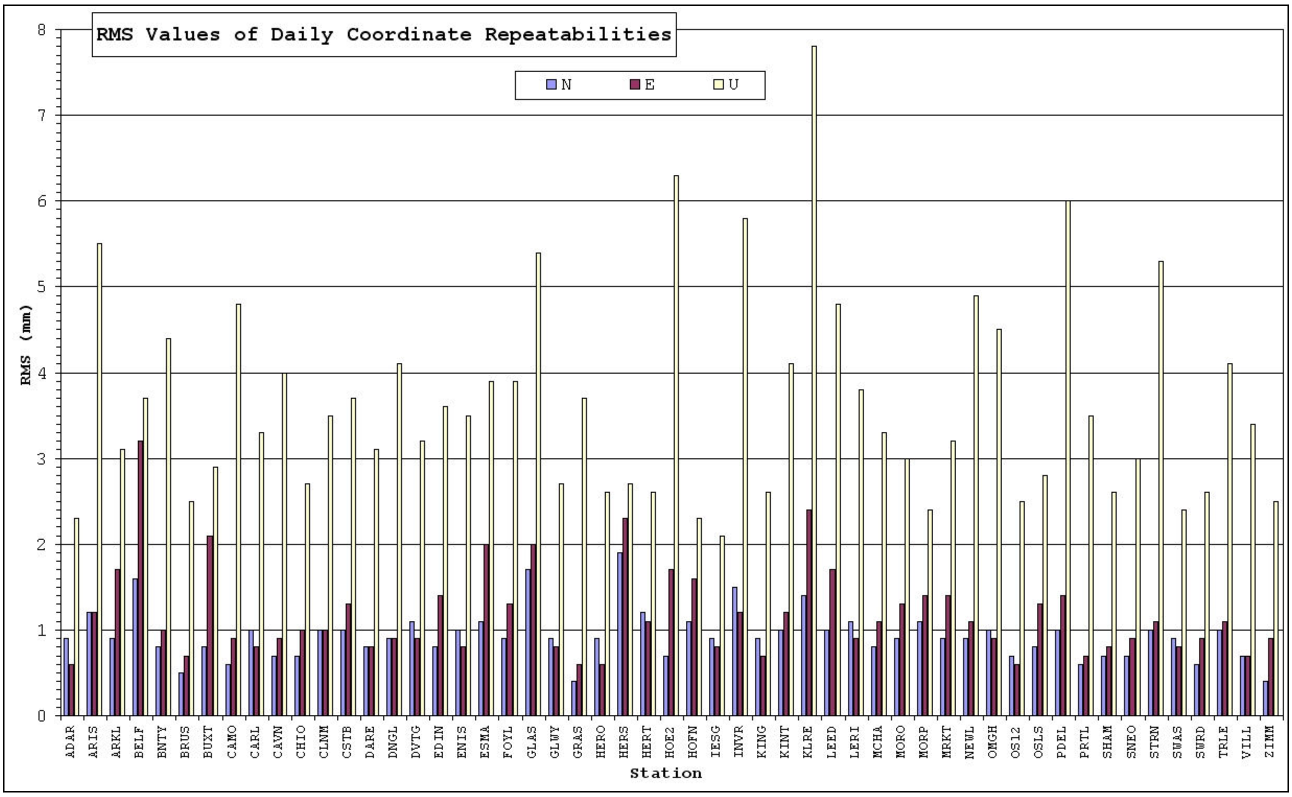


**Figure 5. RMS of coordinate repeatabilities from combination of daily solutions.**

**Table 9. RMS of coordinate repeatabilities from combination of daily solutions.**

| Stn | N (mm) | E (mm) | U (mm) |
|---|---|---|---|
| ADAR | 0.9 | 0.6 | 2.3 |
| ARIS | 1.2 | 1.2 | 5.5 |
| ARKL | 0.9 | 1.7 | 3.1 |
| BELF | 1.6 | 3.2 | 3.7 |
| BNTY | 0.8 | 1.0 | 4.4 |
| BRUS | 0.5 | 0.7 | 2.5 |
| BUXT | 0.8 | 2.1 | 2.9 |
| CAMO | 0.6 | 0.9 | 4.8 |
| CARL | 1.0 | 0.8 | 3.3 |
| CAVN | 0.7 | 0.9 | 4.0 |
| CHIO | 0.7 | 1.0 | 2.7 |
| CLNM | 1.0 | 1.0 | 3.5 |
| CSTB | 1.0 | 1.3 | 3.7 |
| DARE | 0.8 | 0.8 | 3.1 |
| DNGL | 0.9 | 0.9 | 4.1 |
| DVTG | 1.1 | 0.9 | 3.2 |
| EDIN | 0.8 | 1.4 | 3.6 |
| ENIS | 1.0 | 0.8 | 3.5 |
| ESMA | 1.1 | 2.0 | 3.9 |
| FOYL | 0.9 | 1.3 | 3.9 |
| GLAS | 1.7 | 2.0 | 5.4 |
| GLWY | 0.9 | 0.8 | 2.7 |
| GRAS | 0.4 | 0.6 | 3.7 |
| HERO | 0.9 | 0.6 | 2.6 |
| HERS | 1.9 | 2.3 | 2.7 |
| HERT | 1.2 | 1.1 | 2.6 |
| HOE2 | 0.7 | 1.7 | 6.3 |
| HOFN | 1.1 | 1.6 | 2.3 |
| IESG | 0.9 | 0.8 | 2.1 |
| INVR | 1.5 | 1.2 | 5.8 |
| KING | 0.9 | 0.7 | 2.6 |
| KINT | 1.0 | 1.2 | 4.1 |
| KLRE | 1.4 | 2.4 | 7.8 |
| LEED | 1.0 | 1.7 | 4.8 |
| LERI | 1.1 | 0.9 | 3.8 |
| MCHA | 0.8 | 1.1 | 3.3 |
| MORO | 0.9 | 1.3 | 3.0 |
| MORP | 1.1 | 1.4 | 2.4 |
| MRKT | 0.9 | 1.4 | 3.2 |
| NEWL | 0.9 | 1.1 | 4.9 |
| OMGH | 1.0 | 0.9 | 4.5 |
| OS12 | 0.7 | 0.6 | 2.5 |
| OSLS | 0.8 | 1.3 | 2.8 |
| PDEL | 1.0 | 1.4 | 6.0 |
| PRTL | 0.6 | 0.7 | 3.5 |
| SHAM | 0.7 | 0.8 | 2.6 |
| SNEO | 0.7 | 0.9 | 3.0 |
| STRN | 1.0 | 1.1 | 5.3 |
| SWAS | 0.9 | 0.8 | 2.4 |
| SWRD | 0.6 | 0.9 | 2.6 |
| TRLE | 1.0 | 1.1 | 4.1 |
| VILL | 0.7 | 0.7 | 3.4 |
| ZIMM | 0.4 | 0.9 | 2.5 |

## 5.4 EPN A fiducial station coordinate recoveries

Station TRDS was initially left in the combination of the daily solutions so the effect of its removal on the coordinate recovery of the other processed fiducial stations could be measured. The coordinate recovery residuals for both solutions are shown below in Table 10.

**Table 10. Fiducial station coordinate recovery residuals from daily solution combination.**

| | Including TRDS | | | Excluding TRDS | | |
|---|---|---|---|---|---|---|
| | N (mm) | E (mm) | U (mm) | N (mm) | E (mm) | U (mm) |
| BRUS | -1.4 | -1.7 | -3.1 | -1.2 | -1.6 | -3.0 |
| DARE | -0.9 | -0.6 | 1.3 | -1.0 | -0.5 | 0.7 |
| GRAS | 0.2 | 0.3 | -6.0 | 0.1 | 0.4 | -5.4 |
| HERS | 0.3 | 1.9 | -1.7 | 0.5 | 2.1 | -1.3 |
| HERT | -2.2 | -0.4 | 1.1 | -2.1 | -0.2 | 1.4 |
| HOE2 | -1.1 | -0.8 | 4.3 | -1.2 | -0.7 | 6.5 |
| HOFN | -1.7 | 0.1 | 12.6 | -0.9 | 0.2 | 14.5 |
| NEWL | -1.8 | -0.1 | -2.6 | -2.0 | 0.2 | -1.3 |
| OSLS | -2.4 | -1.2 | 8.4 | -2.0 | -0.2 | 7.3 |
| PDEL | 3.8 | -3.6 | -11.0 | 3.3 | -3.0 | -6.0 |
| TRDS | -3.4 | -0.5 | 11.9 | | | |
| VILL | -0.5 | 1.5 | -5.4 | -0.9 | 2.1 | -2.7 |
| ZIMM | -1.0 | -0.4 | -11.6 | -1.2 | -0.4 | -11.3 |
| **RMS** | **2.0** | **1.5** | **7.8** | **1.7** | **1.4** | **6.9** |

It can be seen that the removal of TRDS resulted in a small improvement of the coordinate recoveries.

After the introduction of the weekly EPN SINEX solutions, to produce the final campaign solution, the coordinate recovery of all fiducial stations was checked. The results are in Table 11 below.

**Table 11. Fiducial station coordinate recovery residuals from final solution.**

| Stn ID | N (mm) | E (mm) | U (mm) |
|---|---|---|---|
| BOR1 | -2.8 | -0.9 | -0.1 |
| BRUS | -1.2 | -1.2 | -0.3 |
| CAGL | -2.4 | 2.3 | -3.2 |
| DARE | -1.0 | 0.1 | 3.2 |
| GLSV | 1.8 | -1.4 | -1.7 |
| GRAS | 0.6 | 0.8 | -2.8 |
| HERS | 0.7 | 2.7 | 1.4 |
| HERT | -1.8 | 0.4 | 4.1 |
| HOE2 | -1.3 | -0.3 | 9.1 |
| HOFN | -1.2 | 1.3 | 16.9 |
| JOZE | -2.5 | -1.6 | -3.2 |
| MATE | 0.4 | 4.0 | -1.1 |
| METS | -2.1 | -0.9 | 11.2 |
| NEWL | -1.7 | 0.9 | 1.3 |
| NICO | -0.3 | 2.7 | -9.2 |
| NOT1 | -4.0 | 0.1 | -3.9 |
| OSLS | -2.3 | 0.0 | 10.0 |
| PDEL | 4.5 | -1.7 | -4.0 |
| POLV | 1.0 | -1.3 | -6.5 |
| RABT | 0.2 | -1.2 | -4.7 |
| RAMO | 1.6 | 1.7 | -5.2 |
| SFER | -0.5 | -2.2 | -3.0 |
| VILL | -0.2 | 2.8 | -0.3 |
| WTZR | -1.6 | -0.6 | -1.9 |
| ZIMM | -0.9 | -0.1 | -8.6 |
| **RMS** | **1.9** | **1.7** | **6.3** |

The Up coordinate recovery residuals for the final solution from Table 11 are shown in Figure 6 below. An apparent tilting trend to the residuals can be seen. The reason for this is not clear. What is clearer (and to be expected) is that the U residuals get larger out to the edge of the network.

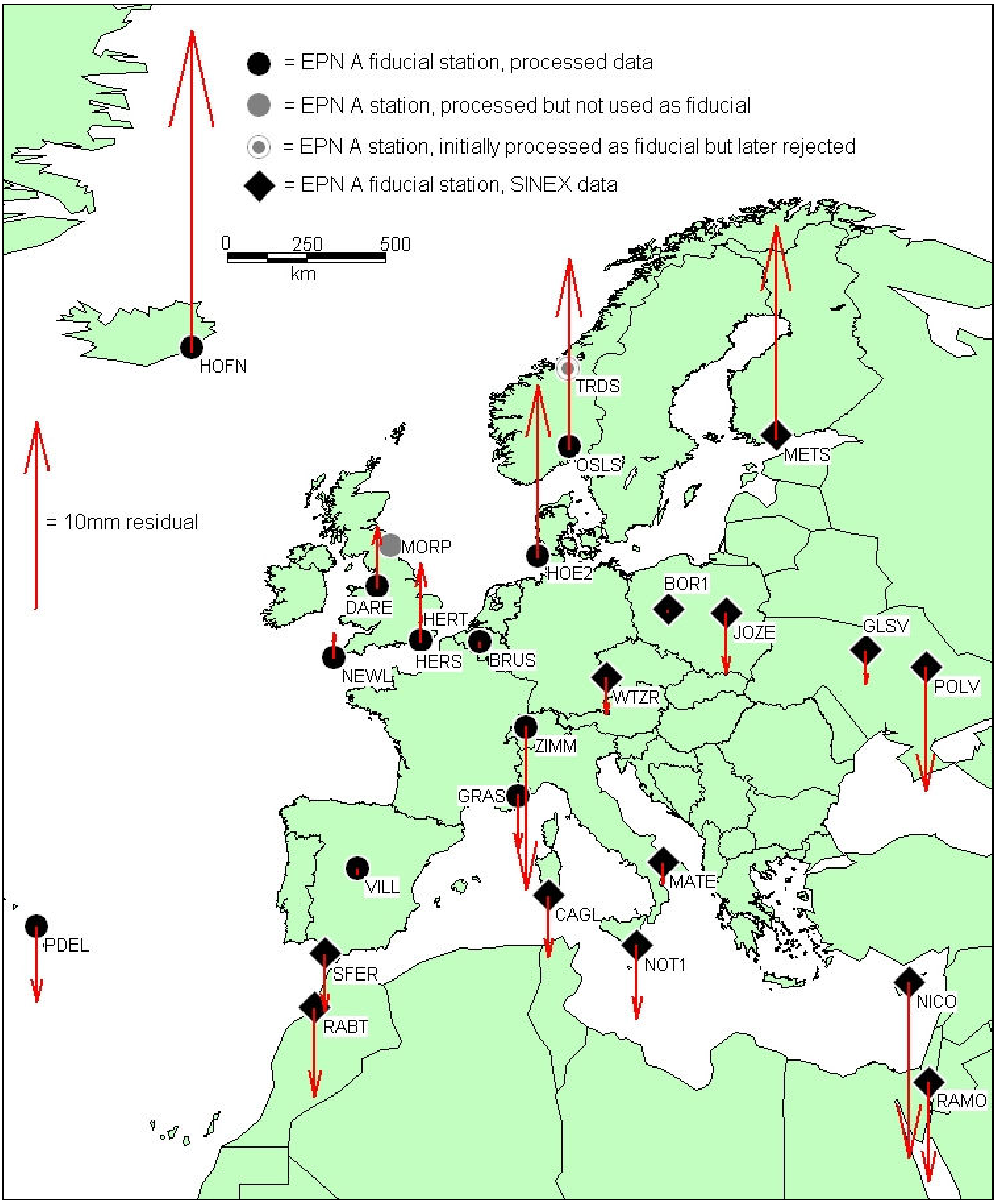


**Figure 6. Up residuals from fiducial station coordinate recoveries.**

## 5.5 Comparison with IESSG results

Staff from the Institute of Engineering Surveying and Space Geodesy (IESSG) and the Natural Environment Research Council (NERC) British Isles continuous GNSS Facility (BIGF), at the University of Nottingham also processed the campaign using Bernese software. The input data was of course the same and the densification guidelines [Bruyninx et al 2009] were followed but program settings and techniques were not discussed until after the processing was complete. This was to try and keep the two solutions as independent as possible.

The residuals from a comparison of the final coordinates are shown in Table 12 below. The overall NEU RMS is 0.5, 0.3, 1.7 mm and the mean NEU is -0.1, -0.2, -0.8 mm.

**Table 12. Residuals from coordinate comparison with IESSG final solution.**

| Stn ID | N (mm) | E (mm) | U (mm) | Stn ID | N (mm) | E (mm) | U (mm) |
|---|---|---|---|---|---|---|---|
| ADAR | 0.0 | -0.2 | -1.4 | JOZE | 0.3 | -0.1 | 1.2 |
| ARIS | -0.5 | -0.3 | -2.3 | KING | -0.4 | -0.6 | -0.7 |
| ARKL | 0.1 | -0.2 | -0.8 | KINT | -0.1 | -0.4 | 0.9 |
| BELF | -1.5 | -0.6 | -0.9 | KLRE | -0.2 | -0.2 | -1.5 |
| BNTY | 0.1 | -0.2 | -1.5 | LEED | -0.4 | -0.5 | 0.2 |
| BOR1 | 0.8 | -0.1 | 2.7 | LERI | -0.2 | -0.2 | 1.2 |
| BRUS | -0.1 | 0.1 | -2.6 | MATE | 0.1 | -0.2 | 0.4 |
| BUXT | -0.5 | -0.3 | -0.8 | MCHA | 0.0 | -0.1 | -1.6 |
| CAGL | 0.9 | -0.2 | 2.8 | METS | 0.3 | 0.0 | 0.3 |
| CAMO | -0.1 | -0.3 | -1.6 | MORO | 0.2 | -0.1 | -1.8 |
| CARL | 0.2 | -0.2 | 0.3 | MORP | -0.3 | -0.3 | -1.7 |
| CAVN | -0.5 | 0.0 | -2.0 | MRKT | -0.6 | -0.2 | -2.7 |
| CHIO | -0.1 | -0.3 | -1.5 | NEWL | -0.2 | -0.4 | -1.9 |
| CLNM | -0.5 | -0.3 | -2.2 | NICO | 0.2 | 0.0 | 0.8 |
| CSTB | -0.7 | 0.0 | -2.1 | NOT1 | 1.1 | -0.1 | 3.0 |
| DARE | 0.2 | -0.4 | -0.4 | OMGH | -0.1 | -0.3 | -0.6 |
| DNGL | -0.1 | -0.2 | -1.0 | OS12 | -0.9 | -0.6 | -4.4 |
| DVTG | -0.3 | -0.3 | -1.0 | OSLS | -0.2 | -0.5 | -0.2 |
| EDIN | 0.1 | -0.3 | -1.1 | PDEL | -0.5 | -0.8 | -1.4 |
| ENIS | -0.5 | -0.3 | -3.1 | POLV | 0.5 | 0.1 | 2.3 |
| ESMA | -0.7 | -0.2 | -2.1 | PRTL | -0.1 | 0.0 | -1.4 |
| FOYL | 0.1 | -0.3 | -1.9 | RABT | 0.0 | -0.3 | 0.7 |
| GLAS | 0.9 | -0.4 | -0.4 | RAMO | 0.9 | 0.0 | 1.8 |
| GLSV | 0.2 | 0.0 | 1.0 | SFER | 0.6 | -0.4 | 1.9 |
| GLWY | -0.1 | -0.1 | -1.2 | SHAM | -0.1 | -0.3 | -0.7 |
| GRAS | -0.4 | -0.2 | -1.2 | SNEO | 0.1 | -0.3 | -0.8 |
| HERO | 0.0 | -0.4 | -0.1 | STRN | 0.1 | -0.3 | -0.1 |
| HERS | -0.2 | -0.1 | -1.9 | SWAS | -0.3 | -0.5 | -0.3 |
| HERT | -0.2 | -0.2 | -3.2 | SWRD | -0.6 | -0.2 | -2.0 |
| HOE2 | -0.1 | -0.2 | -2.5 | TRLE | -0.8 | -0.1 | -1.9 |
| HOFN | -0.5 | -0.5 | -3.4 | VILL | -0.5 | -0.4 | -1.7 |
| IESG | 0.0 | -0.1 | -1.9 | WTZR | 0.0 | -0.2 | -0.2 |
| INVR | -0.3 | -0.3 | -0.5 | ZIMM | -0.4 | -0.2 | -1.0 |

## 5.6 ETRS89 comparison with previous campaigns

Two comparisons were carried out - one to ETRF2000 and one to ETRF97 (see section 4.9 page 18).

In Great Britain the coordinates from the EUREF GB 2001 campaign were compared with both ETRF2000 and ETRF97 coordinates. The results are in Table 13 below.

**Table 13. Comparison of final ETRF2000 and ETRF97 coordinates with EUREF GB 2001 coordinates.**

| | ETRF2000 | | | ETRF97 | | |
|---|---|---|---|---|---|---|
| | N (mm) | E (mm) | U (mm) | N (mm) | E (mm) | U (mm) |
| CARL | 26.0 | 8.5 | 18.4 | -1.2 | -8.2 | -4.8 |
| DARE | 20.6 | -1.1 | 32.1 | -7.0 | -14.3 | 9.3 |
| EDIN | 28.8 | 8.5 | 28.2 | 1.7 | -10.4 | 4.8 |
| GLAS | 27.6 | 4.7 | 35.6 | -0.9 | -13.9 | 12.3 |
| IESG | 19.6 | 8.0 | 26.0 | -6.1 | -4.5 | 3.1 |
| KING | 16.9 | -2.2 | 22.4 | -6.5 | -14.2 | -0.6 |
| LEED | 23.9 | 4.3 | 23.9 | -2.1 | -10.0 | 0.9 |
| SHAM | 23.4 | 1.6 | 21.8 | -3.8 | -6.5 | -0.4 |
| OS12 | 13.8 | 5.6 | 0.0 | -10.9 | -2.4 | -22.3 |
| **RMS** | **23.7** | **5.7** | **26.6** | **5.5** | **10.2** | **9.4** |

EUREF GB 2001 was based on ITRF97 and it can be seen that the ETRF97 coordinates show better sympathy than the ETRF2000 coordinates. The new campaign agrees with the previous one at the 10 mm level. Some of the difference between the new campaign and EUREF GB 2001, in either ETRF2000 or ETRF97, can be attributed to the fact that all the EUREF GB 2001 station antennas have been changed.

For stations in Northern Ireland a comparison with ETRF2000 was done against coordinates from a campaign based on ITRF2000. This campaign was not submitted to EUREF but was carried out under the same principles using 60 days of data in 2002. The results are in Table 14 below.

**Table 14. Comparison of final ETRF2000 and ETRF97 coordinates with ITRF2000 based coordinates in Northern Ireland.**

| | ETRF2000 | | |
|---|---|---|---|
| | N.(mm) | E.(mm) | U.(mm) |
| BELF | 6.7 | -1.9 | 9.9 |
| KLRE | 16.1 | -4.1 | 4.3 |
| OMGH | 13.1 | -4.7 | 7.3 |
| ENIS | 7.8 | -3.4 | 13.6 |
| FOYL | -0.5 | 7.1 | 0.9 |
| MRKT | 9.4 | 20.9 | -0.5 |
| **RMS** | **10.2** | **9.5** | **7.7** |

The new campaign agrees with the previous one at the 10 mm level.

# 6 Conclusions

The internal quality of the solution, as indicated by the daily coordinate repeatabilities, is around 1 to 2 mm in N and E and around 3-5 mm in U.

The coordinate recoveries of the fiducial stations show that ITRF2005 is being realised to around 2 mm in N and E and around 6 mm in U although some stations at the outer edges of the network are at the 10 mm level in U with one (HOFN) at 17mm.

Comparison with the EUREF GB 2001 campaign (based on ITRF97) is at the 10 mm level when compared in ETRF97 but at the 25 mm level when compared in ETRF2000.

Comparison with an ITRF2000 solution for the stations in Northern Ireland is at the 10 mm level when compared in ETRF2000.

# 7 References

**Boucher, C., Altamimi, Z. (2008)**, Memo : Specifications for reference frame fixing in the analysis of a EUREF GPS campaign, Version 7 : 24-10-2008, *http://etrs89.ensg.ign.fr/memo-V7.pdf*.

**Bruyninx, C., Altamimi, Z., Caporali, A., Kenyeres, A., Lidberg, M., Stangl, G., Torres, G. A. (2009)**, Guidelines for EUREF Densifications, Version 1: 26-05-2009, *ftp://epncb.oma.be/pub/general/Guidelines_for_EUREF_Densifications.pdf*.

**Dach, R., Hugentobler, U., Fridez, P., Meindl, M. (eds) (2007)**, Bernese GPS Software Version 5.0, Astronomical Institute of the University of Bern, Switzerland.

# A Comparison of different elevation cut off angles in QIF ambiguity resolution.

Discussion with IESSG and also reference to the BSW example campaign and other recent EUREF densification campaigns highlighted the practice of raising the elevation cut off angle from 3 degrees to 10 degrees for the QIF ambiguity resolution stage of the processing.

In order to determine which approach to use the effect on the final coordinates of the different cut off angles was tested. The campaign processing was run twice, up to the combination of the daily solutions, using 3 degree cut off in one run and 10 in the other. Coordinates and QIF summary output information from the two runs was compared.

Figure 7 below shows the percentage of ambiguities resolved at each cut off angle and, as is expected, the 10 degree cut off results in a higher percentage of ambiguities resolved.

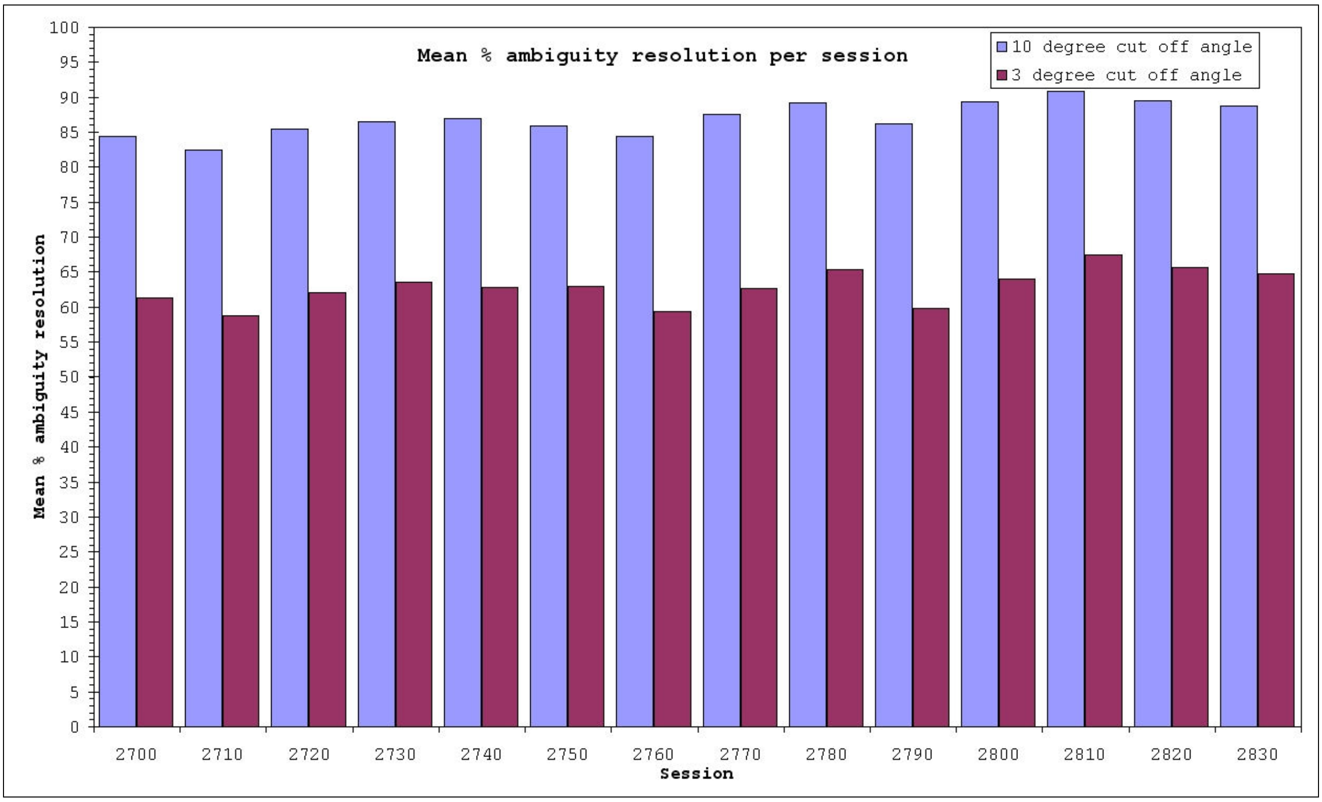


**Figure 7. Comparison of ambiguity resolution at 10 and 3 degree elevation cut off angles.**

The summary information from the QIF processing is in Table 15 (3 degrees) and Table 16 (10 degrees) below. It can be seen that the outputs are broadly similar with the main difference being the number of ambiguities set up – more for the 3 degree cut off. The number of ambiguities resolved in each case is very similar. These results suggest that only a small extra number of ambiguities are resolved in the 3 to 10 degree elevation cut off range.

A comparison of coordinates from the two processing runs showed RMS differences in NEU at the 0.3mm level with a max individual difference of 1mm (U at HOFN). These differences were deemed to be insignificant and the 3 degree elevation cut off was therefore used for the QIF stage of the campaign processing.

**Table 15. QIF summary information for 3 degree elevation cut off.**

| Session | No. Amb. set up | RMSO (mm) | Max/RMS L5 Amb | | Max/RMS L3 Amb | | No. Amb. unsolved | % Solved | No. Amb. solved |
|---|---|---|---|---|---|---|---|---|---|
| 2700 | 8708 | 1.1 | 0.500 | 0.086 | 0.100 | 0.026 | 3366 | 61.3 | 5342 |
| 2710 | 8896 | 1.1 | 0.495 | 0.083 | 0.100 | 0.026 | 3678 | 58.7 | 5218 |
| 2720 | 8180 | 1.0 | 0.493 | 0.080 | 0.100 | 0.024 | 3112 | 62.0 | 5068 |
| 2730 | 8588 | 1.0 | 0.498 | 0.087 | 0.100 | 0.025 | 3126 | 63.6 | 5462 |
| 2740 | 8676 | 1.0 | 0.494 | 0.085 | 0.100 | 0.023 | 3228 | 62.8 | 5448 |
| 2750 | 8762 | 1.0 | 0.488 | 0.081 | 0.100 | 0.024 | 3238 | 63.0 | 5524 |
| 2760 | 8758 | 1.2 | 0.497 | 0.074 | 0.100 | 0.027 | 3566 | 59.3 | 5192 |
| 2770 | 8680 | 1.1 | 0.496 | 0.077 | 0.100 | 0.024 | 3244 | 62.6 | 5436 |
| 2780 | 8744 | 1.0 | 0.491 | 0.082 | 0.100 | 0.024 | 3028 | 65.4 | 5716 |
| 2790 | 8980 | 1.2 | 0.497 | 0.073 | 0.100 | 0.026 | 3606 | 59.8 | 5374 |
| 2800 | 8694 | 1.0 | 0.498 | 0.072 | 0.100 | 0.023 | 3134 | 64.0 | 5560 |
| 2810 | 7804 | 1.0 | 0.494 | 0.075 | 0.100 | 0.023 | 2534 | 67.5 | 5270 |
| 2820 | 8016 | 1.1 | 0.492 | 0.077 | 0.100 | 0.023 | 2746 | 65.7 | 5270 |
| 2830 | 8402 | 1.0 | 0.491 | 0.070 | 0.100 | 0.023 | 2962 | 64.7 | 5440 |

**Table 16. QIF summary information for 10 degree elevation cut off.**

| Session | No. Amb. set up | RMSO (mm) | Max/RMS L5 Amb | | Max/RMS L3 Amb | | No. Amb. unsolved | % Solved | No. Amb. solved |
|---|---|---|---|---|---|---|---|---|---|
| 2700 | 6194 | 1.1 | 0.493 | 0.084 | 0.100 | 0.026 | 964 | 84.4 | 5230 |
| 2710 | 6306 | 1.1 | 0.488 | 0.081 | 0.100 | 0.026 | 1106 | 82.5 | 5200 |
| 2720 | 5888 | 1.0 | 0.491 | 0.077 | 0.099 | 0.024 | 862 | 85.4 | 5026 |
| 2730 | 6306 | 1.0 | 0.500 | 0.084 | 0.100 | 0.024 | 850 | 86.5 | 5456 |
| 2740 | 6108 | 1.0 | 0.499 | 0.083 | 0.100 | 0.022 | 792 | 87.0 | 5316 |
| 2750 | 6218 | 1.0 | 0.491 | 0.077 | 0.100 | 0.024 | 874 | 85.9 | 5344 |
| 2760 | 6122 | 1.2 | 0.489 | 0.070 | 0.100 | 0.027 | 956 | 84.4 | 5166 |
| 2770 | 6102 | 1.0 | 0.496 | 0.075 | 0.100 | 0.023 | 760 | 87.5 | 5342 |
| 2780 | 6250 | 1.0 | 0.499 | 0.079 | 0.100 | 0.023 | 676 | 89.2 | 5574 |
| 2790 | 6142 | 1.1 | 0.477 | 0.071 | 0.100 | 0.025 | 850 | 86.2 | 5292 |
| 2800 | 6054 | 1.0 | 0.486 | 0.070 | 0.100 | 0.023 | 646 | 89.3 | 5408 |
| 2810 | 5638 | 1.0 | 0.494 | 0.072 | 0.099 | 0.022 | 516 | 90.8 | 5122 |
| 2820 | 5714 | 1.1 | 0.496 | 0.075 | 0.100 | 0.023 | 602 | 89.5 | 5112 |
| 2830 | 5938 | 1.0 | 0.497 | 0.067 | 0.100 | 0.023 | 664 | 88.8 | 5274 |

# B Comparison of different minimal constraint conditions

Following initial presentation of the campaign results to TWG it was suggested that datum definition minimal constraint of translation AND scale may be appropriate instead of translation only. Both approaches were tried and the coordinates and fiducial station coordinate recoveries were compared.

Table 17 below shows the comparison of coordinates from the two solutions. The NEU RMS (mm) is 0.2, 0.3, 2.4 and the NEU mean values are 0.0, -0.1, -2.2.

**Table 17. Coordinate comparison of solution using translation constraint and solution using both translation and scale constraints.**

| Stn | N (mm) | E (mm) | U (mm) |
|---|---|---|---|
| ADAR | 0.0 | -0.2 | -1.9 |
| ARIS | 0.2 | -0.3 | -2.0 |
| ARKL | 0.1 | -0.3 | -2.0 |
| BELF | 0.1 | -0.2 | -2.0 |
| BNTY | 0.1 | -0.4 | -2.0 |
| BOR1 | 0.0 | 0.3 | -2.9 |
| BRUS | 0.1 | 0.0 | -2.0 |
| BUXT | 0.0 | -0.1 | -2.0 |
| CAGL | -0.2 | 0.0 | -3.8 |
| CAMO | -0.1 | -0.3 | -1.9 |
| CARL | 0.2 | -0.2 | -2.0 |
| CAVN | 0.1 | -0.3 | -1.9 |
| CHIO | 0.0 | -0.1 | -2.1 |
| CLNM | 0.0 | -0.3 | -2.0 |
| CSTB | 0.0 | -0.4 | -2.0 |
| DARE | 0.1 | -0.3 | -1.9 |
| DNGL | 0.2 | -0.3 | -2.0 |
| DVTG | -0.1 | -0.1 | -2.0 |
| EDIN | 0.2 | -0.2 | -2.0 |
| ENIS | 0.1 | -0.3 | -1.9 |
| ESMA | 0.2 | -0.2 | -2.0 |
| FOYL | 0.2 | -0.3 | -2.0 |
| GLAS | 0.2 | -0.2 | -2.0 |
| GLSV | -0.1 | 0.6 | -2.5 |
| GLWY | 0.0 | -0.4 | -2.0 |
| GRAS | -0.3 | 0.1 | -2.0 |
| HERO | 0.0 | -0.1 | -1.9 |
| HERS | -0.1 | -0.1 | -2.0 |
| HERT | -0.1 | -0.1 | -2.0 |
| HOE2 | 0.2 | 0.1 | -2.0 |
| HOFN | 0.4 | -0.5 | -1.9 |
| IESG | 0.1 | -0.1 | -2.1 |
| INVR | 0.2 | -0.2 | -2.0 |

| Stn | N (mm) | E (mm) | U (mm) |
|---|---|---|---|
| JOZE | 0.0 | 0.4 | -2.7 |
| KING | 0.1 | -0.1 | -2.1 |
| KINT | 0.3 | -0.2 | -2.0 |
| KLRE | 0.1 | -0.2 | -2.0 |
| LEED | 0.1 | -0.1 | -2.1 |
| LERI | 0.4 | -0.1 | -1.9 |
| MATE | -0.4 | 0.3 | -2.6 |
| MCHA | 0.1 | -0.3 | -2.0 |
| METS | 0.3 | 0.5 | -2.3 |
| MORO | 0.2 | -0.1 | -2.1 |
| MORP | 0.2 | -0.1 | -2.1 |
| MRKT | 0.2 | -0.3 | -2.0 |
| NEWL | 0.0 | -0.2 | -2.1 |
| NICO | -0.7 | 0.7 | -2.9 |
| NOT1 | -0.1 | 0.1 | -5.0 |
| OMGH | 0.2 | -0.3 | -2.0 |
| OS12 | -0.1 | -0.1 | -2.0 |
| OSLS | 0.4 | 0.1 | -1.9 |
| PDEL | -0.7 | -0.7 | -1.7 |
| POLV | -0.1 | 0.7 | -3.2 |
| PRTL | 0.1 | -0.3 | -2.0 |
| RABT | -0.6 | -0.2 | -2.8 |
| RAMO | -0.6 | 0.5 | -5.9 |
| SFER | -0.3 | -0.1 | -3.8 |
| SHAM | 0.0 | -0.1 | -2.1 |
| SNEO | 0.0 | -0.1 | -2.1 |
| STRN | 0.1 | -0.2 | -2.0 |
| SWAS | 0.1 | -0.2 | -2.0 |
| SWRD | 0.1 | -0.2 | -1.9 |
| TRLE | 0.0 | -0.4 | -2.0 |
| VILL | -0.4 | -0.2 | -1.9 |
| WTZR | -0.1 | 0.2 | -2.3 |
| ZIMM | -0.2 | 0.1 | -2.0 |

The coordinate comparison suggests that using a scale constraint along side the translation constraint introduces negligible N and E coordinate change and a systematic -2mm U change.

Table 18 below shows the coordinate recovery residuals of the fiducial stations from the two different solutions. There was no significant overall difference in the N and E coordinate recovery but the translation only constraint solution showed slightly improved U recovery therefore datum definition in the final solution was by translation minimal constraint.

**Table 18. Fiducial coordinate recovery under different minimal constraint conditions.**

| | Translation constraint | | | Translation & scale constraint | | |
|---|---|---|---|---|---|---|
| Stn | N (mm) | E (mm) | U (mm) | N (mm) | E (mm) | U (mm) |
| BOR1 | -2.8 | -0.9 | -0.1 | -2.8 | -0.5 | -3.0 |
| BRUS | -1.2 | -1.2 | -0.3 | -1.1 | -1.2 | -2.3 |
| CAGL | -2.4 | 2.3 | -3.2 | -2.7 | 2.3 | -7.0 |
| DARE | -1.0 | 0.1 | 3.2 | -0.9 | -0.1 | 1.3 |
| GLSV | 1.8 | -1.4 | -1.7 | 1.6 | -0.8 | -4.2 |
| GRAS | 0.6 | 0.8 | -2.8 | 0.3 | 0.9 | -4.8 |
| HERS | 0.7 | 2.7 | 1.4 | 0.6 | 2.6 | -0.6 |
| HERT | -1.8 | 0.4 | 4.1 | -1.9 | 0.3 | 2.1 |
| HOE2 | -1.3 | -0.3 | 9.1 | -1.1 | -0.2 | 7.1 |
| HOFN | -1.2 | 1.3 | 16.9 | -0.8 | 0.7 | 15.0 |
| JOZE | -2.5 | -1.6 | -3.2 | -2.5 | -1.2 | -5.9 |
| MATE | 0.4 | 4.0 | -1.1 | 0.0 | 4.3 | -3.7 |
| METS | -2.1 | -0.9 | 11.2 | -1.8 | -0.4 | 8.9 |
| NEWL | -1.7 | 0.9 | 1.3 | -1.7 | 0.7 | -0.8 |
| NICO | -0.3 | 2.7 | -9.2 | -1.0 | 3.4 | -12.0 |
| NOT1 | -4.0 | 0.1 | -3.9 | -4.1 | 0.2 | -8.8 |
| OSLS | -2.3 | 0.0 | 10.0 | -1.9 | 0.2 | 8.1 |
| PDEL | 4.5 | -1.7 | -4.0 | 3.8 | -2.5 | -5.7 |
| POLV | 1.0 | -1.3 | -6.5 | 0.8 | -0.6 | -9.6 |
| RABT | 0.2 | -1.2 | -4.7 | -0.5 | -1.4 | -7.5 |
| RAMO | 1.6 | 1.7 | -5.2 | 1.0 | 2.2 | -11.1 |
| SFER | -0.5 | -2.2 | -3.0 | -0.8 | -2.4 | -6.8 |
| VILL | -0.2 | 2.8 | -0.3 | -0.6 | 2.6 | -2.2 |
| WTZR | -1.6 | -0.6 | -1.9 | -1.7 | -0.4 | -4.2 |
| ZIMM | -0.9 | -0.1 | -8.6 | -1.1 | -0.1 | -10.6 |
| **RMS** | **1.9** | **1.7** | **6.3** | **1.8** | **1.8** | **7.3** |

# C Complete list of coordinate repeatabilities

**Table 19. Coordinate repeatabilities from combination of daily solutions.**

| | | | Day | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **RMS** | 270 | 271 | 272 | 273 | 274 | 275 | 276 | 277 | 278 | 279 | 280 | 281 | 282 | 283 |
| ADAR | N | **0.9** | -0.4 | -1.3 | 0.5 | 0.7 | -1.4 | -0.6 | -0.5 | 1.5 | 0.1 | 0.1 | 0.9 | 0.0 | -0.2 | 1.2 |
| | E | **0.6** | -0.2 | -0.1 | -0.6 | -0.2 | -0.3 | 0.2 | -0.7 | 1.5 | 0.3 | 0.5 | 0.5 | -0.3 | -0.7 | 0.0 |
| | U | **2.3** | 1.8 | 0.0 | -2.4 | -1.3 | 1.9 | 3.2 | 1.7 | -0.3 | -3.9 | -0.8 | -4.6 | -1.4 | -0.8 | -0.1 |
| ARIS | N | **1.2** | -0.6 | 0.0 | 1.9 | 0.3 | -2.2 | 0.1 | -1.7 | -0.6 | 1.6 | 0.3 | -0.3 | 1.2 | 1.8 | -0.1 |
| | E | **1.2** | -0.8 | -0.5 | 1.6 | 0.6 | 1.2 | 0.5 | -2.2 | 0.9 | 0.7 | 1.4 | -0.7 | -0.2 | -0.8 | -1.6 |
| | U | **5.5** | 11.1 | 6.5 | -7.8 | -6.4 | 2.7 | 1.3 | 3.6 | -1.3 | -1.1 | -3.0 | -9.4 | -2.9 | 2.2 | -0.5 |
| ARKL | N | **0.9** | 0.2 | -1.5 | -0.5 | -0.2 | -0.8 | -1.3 | 1.5 | 0.5 | 0.1 | 0.2 | 1.0 | 0.5 | 1.3 | 0.3 |
| | E | **1.7** | 0.5 | 1.3 | -0.1 | -1.3 | 0.7 | 0.5 | -5.3 | 0.6 | 0.1 | 1.4 | 1.5 | -0.4 | -0.2 | -0.2 |
| | U | **3.1** | 0.9 | 2.2 | 5.7 | -2.2 | -1.5 | 2.1 | -1.1 | 3.5 | -4.7 | -0.2 | -4.0 | -4.3 | -2.9 | -0.7 |
| BELF | N | **1.6** | -1.5 | -1.2 | -1.2 | -1.7 | -1.8 | 2.5 | 2.7 | 0.6 | -1.1 | 1.9 | 1.4 | 0.2 | -0.6 | 0.6 |
| | E | **3.2** | 1.3 | 0.8 | 6.9 | 1.6 | 1.4 | -6.4 | -5.1 | 0.0 | -0.9 | -0.4 | 2.5 | 0.3 | 0.8 | -1.6 |
| | U | **3.7** | 0.9 | -6.3 | 4.0 | 5.1 | 3.5 | -3.8 | -3.4 | -2.5 | -1.1 | 3.4 | -4.7 | -3.6 | 0.6 | 2.3 |
| BNTY | N | **0.8** | -0.3 | -0.6 | -0.1 | -0.4 | -0.9 | -0.9 | -0.2 | 0.9 | -0.8 | 1.5 | 0.8 | 0.0 | 0.3 | 1.4 |
| | E | **1.0** | -0.1 | -0.7 | -0.9 | -1.2 | 0.2 | -1.0 | 2.6 | 0.9 | -0.1 | -0.3 | 1.3 | -0.2 | -0.6 | -0.4 |
| | U | **4.4** | -0.9 | -2.3 | 2.3 | -1.4 | -0.1 | 0.1 | 10.4 | 0.5 | -2.3 | 6.3 | -4.5 | -2.1 | -6.8 | -2.8 |
| BRUS | N | **0.5** | 0.3 | -0.8 | -0.4 | 0.1 | 0.0 | 0.0 | 0.2 | 1.1 | 0.3 | -0.3 | 0.4 | -0.1 | -0.4 | 0.1 |
| | E | **0.7** | 0.1 | -0.9 | -0.6 | -0.6 | -0.5 | -0.9 | 1.0 | 0.4 | 0.0 | 1.3 | 0.9 | -0.5 | -0.1 | 0.4 |
| | U | **2.5** | -4.0 | 3.3 | 2.3 | 1.2 | 0.0 | 0.3 | 2.8 | -0.7 | 0.8 | 2.8 | 3.9 | -3.1 | -1.8 | 2.4 |
| BUXT | N | **0.8** | 1.4 | -0.5 | -0.4 | 0.3 | -1.2 | -1.2 | 0.5 | 1.1 | 0.4 | 1.2 | 0.1 | 0.1 | -0.8 | -0.2 |
| | E | **2.1** | -0.8 | -3.3 | -2.8 | -2.2 | 0.2 | -2.1 | 0.4 | 1.1 | 2.1 | 2.1 | 3.2 | 1.7 | 2.0 | -1.7 |
| | U | **2.9** | 2.2 | 0.2 | -2.2 | 0.1 | 3.4 | -1.4 | 1.3 | 2.0 | -4.8 | 1.8 | -3.6 | -3.4 | -4.1 | 3.2 |
| CAMO | N | **0.6** | 0.0 | -0.3 | -0.8 | -0.9 | -0.4 | -0.3 | 0.7 | -0.1 | 0.4 | -0.3 | 0.3 | 1.1 | 0.8 | 0.2 |
| | E | **0.9** | 0.0 | 0.0 | 0.1 | -0.9 | 0.3 | -0.6 | -1.4 | -0.1 | -0.4 | 2.3 | 1.0 | 0.0 | 0.7 | -1.1 |
| | U | **4.8** | 2.4 | 2.7 | -0.1 | -0.3 | -2.1 | 0.6 | 12.1 | -3.5 | -1.5 | -7.9 | -0.8 | -7.4 | -1.8 | 1.1 |
| CARL | N | **1.0** | -1.2 | -1.4 | 0.8 | -0.4 | -1.0 | -1.2 | 0.7 | -0.4 | 0.4 | 1.4 | 1.8 | 0.4 | 0.3 | 0.8 |
| | E | **0.8** | 1.0 | 0.0 | -0.7 | -1.3 | 0.8 | -0.6 | 0.2 | 0.5 | 0.0 | 0.3 | 1.7 | 0.1 | -0.6 | -1.2 |
| | U | **3.3** | 3.6 | 3.6 | 3.2 | 3.1 | -1.1 | 3.3 | -4.6 | -0.7 | -4.7 | 0.5 | -5.1 | -2.6 | -1.7 | -0.5 |
| CAVN | N | **0.7** | 0.3 | 0.0 | 0.5 | -1.0 | -1.3 | 0.2 | 0.1 | -0.5 | 0.5 | 1.4 | 0.2 | 0.1 | 0.1 | 0.4 |
| | E | **0.9** | -0.4 | -0.7 | -1.0 | -1.1 | 0.1 | -1.2 | 0.1 | 0.9 | -0.3 | 1.0 | 1.7 | -0.1 | 0.9 | -0.3 |
| | U | **4.0** | -0.7 | 8.7 | -2.0 | -0.9 | -0.3 | 5.6 | 2.8 | 0.3 | -4.2 | -1.7 | -7.0 | -4.8 | -1.2 | -0.1 |
| CHIO | N | **0.7** | -0.8 | -1.3 | -1.1 | -0.1 | -0.4 | -0.1 | -0.1 | 0.9 | 0.3 | 0.7 | 0.9 | 0.8 | 0.2 | 0.7 |
| | E | **1.0** | -0.1 | -1.1 | -0.8 | -0.7 | 0.1 | -0.6 | 0.9 | 0.5 | -0.2 | 2.1 | 1.7 | -0.1 | -1.2 | -0.2 |
| | U | **2.7** | 2.1 | 2.8 | -0.9 | 1.3 | -2.9 | -4.9 | 4.6 | -1.5 | -1.8 | 0.0 | -3.8 | -1.3 | 0.1 | 2.2 |
| CLNM | N | **1.0** | -0.2 | 0.7 | 1.1 | 0.0 | 0.0 | -1.4 | -2.2 | -0.3 | 0.1 | 1.7 | 0.9 | 0.9 | -0.9 | 0.5 |
| | E | **1.0** | -0.3 | -1.1 | -1.2 | -1.4 | 0.0 | -0.8 | 1.1 | 0.3 | 0.1 | -0.6 | 1.6 | 0.7 | 1.4 | -0.3 |
| | U | **3.5** | -0.3 | 2.7 | 0.9 | 1.7 | 2.4 | -0.9 | 2.7 | 3.0 | -1.8 | 2.4 | -6.8 | -5.6 | -6.1 | 1.9 |
| CSTB | N | **1.0** | -0.3 | -0.7 | 1.0 | -0.7 | -1.8 | 0.4 | 0.2 | 0.6 | 0.1 | 1.7 | 0.9 | 0.0 | -1.2 | 1.1 |
| | E | **1.3** | -1.6 | -3.4 | 0.4 | -0.5 | -0.2 | -0.5 | 1.7 | 1.1 | 0.2 | -0.5 | 1.6 | 0.2 | 0.2 | 0.5 |
| | U | **3.7** | -0.1 | 0.0 | 6.9 | -0.5 | 2.9 | 3.0 | 2.4 | -3.4 | -2.9 | -7.2 | -5.5 | 0.2 | -2.2 | -0.7 |
| DARE | N | **0.8** | -0.8 | -0.6 | -0.9 | -0.6 | -0.2 | -0.5 | 0.3 | 0.2 | 0.2 | -0.4 | 1.9 | 1.4 | -0.2 | 0.6 |
| | E | **0.8** | 0.7 | 0.3 | 0.6 | -1.1 | 0.7 | -0.8 | -0.7 | -0.4 | 0.0 | 1.7 | 0.8 | -0.6 | -0.2 | -0.7 |
| | U | **3.1** | -1.1 | 0.8 | 2.1 | 2.8 | 1.9 | 1.7 | 2.2 | 0.6 | -2.6 | 4.0 | -6.3 | -5.7 | -0.5 | 1.3 |
| DNGL | N | **0.9** | -1.1 | -0.7 | -0.3 | -1.2 | -1.1 | 0.5 | 1.1 | 0.0 | 0.1 | 1.7 | 0.6 | 0.1 | 0.7 | 0.5 |
| | E | **0.9** | -0.1 | 2.2 | -1.2 | 0.3 | 0.4 | 0.2 | -0.6 | -0.4 | -0.4 | -0.3 | 1.0 | -0.6 | 0.7 | -1.4 |
| | U | **4.1** | 6.9 | -3.1 | 2.9 | 1.9 | 1.9 | -0.8 | 2.8 | 1.8 | -3.5 | -4.7 | -8.9 | -1.9 | -3.3 | 1.7 |
| DVTG | N | **1.1** | -0.3 | -0.6 | -0.1 | -0.7 | -1.5 | -0.2 | 0.0 | 0.8 | -0.2 | 2.7 | 1.4 | 0.4 | -1.7 | 0.8 |
| | E | **0.9** | -0.5 | -0.6 | 0.3 | -0.8 | -0.3 | -1.1 | 0.9 | 0.9 | -0.4 | 1.0 | 1.7 | 0.3 | 0.4 | -1.1 |
| | U | **3.2** | -0.4 | 3.1 | -1.6 | 0.6 | -0.7 | 0.0 | 5.8 | -1.8 | 0.0 | -6.7 | -3.3 | -1.7 | 4.4 | -2.7 |
| EDIN | N | **0.8** | -0.7 | -1.2 | 0.6 | 0.8 | -0.3 | 0.0 | 0.8 | -0.3 | 0.3 | 0.6 | 0.6 | 1.2 | -1.2 | 0.3 |
| | E | **1.4** | -0.9 | -3.5 | -0.1 | -0.9 | 0.3 | -0.8 | -0.8 | 2.3 | 0.4 | 1.7 | 1.5 | 0.6 | 0.8 | -0.7 |
| | U | **3.6** | 0.8 | 6.4 | 1.1 | 3.1 | -2.1 | 2.7 | -0.1 | -0.8 | 1.1 | -2.9 | -8.1 | -5.0 | -1.0 | 0.1 |
| ENIS | N | **1.0** | -0.5 | 1.8 | 1.1 | 0.1 | -1.1 | -1.1 | 0.3 | 0.1 | -1.7 | 0.6 | 0.8 | 0.8 | 0.4 | -0.7 |
| | E | **0.8** | 0.3 | 0.4 | -0.2 | -1.8 | -0.2 | -0.9 | -0.6 | 1.1 | 0.2 | 0.5 | 1.6 | -0.1 | 0.1 | -0.5 |
| | U | **3.5** | 1.3 | 2.0 | -1.9 | -1.0 | -0.2 | 6.4 | 0.1 | 3.9 | -1.4 | -7.4 | -4.6 | -0.9 | -2.5 | 1.9 |
| ESMA | N | **1.1** | 2.5 | | | | -1.7 | 0.4 | -0.5 | -0.4 | -0.4 | 1.3 | 0.8 | 0.5 | -0.5 | 0.0 |
| | E | **2.0** | -1.9 | | | | 1.5 | -3.8 | 1.9 | -1.1 | 1.6 | 1.1 | 3.1 | -1.3 | 1.3 | -0.5 |
| | U | **3.9** | -7.0 | | | | 1.1 | -0.9 | 5.8 | -4.1 | 2.8 | -1.3 | -6.0 | 0.4 | 2.7 | -0.1 |
| FOYL | N | **0.9** | 0.2 | -0.4 | -0.2 | 0.9 | -1.3 | 0.7 | 0.6 | -0.9 | -0.2 | 1.9 | 1.1 | -0.6 | -1.1 | 0.4 |
| | E | **1.3** | -1.2 | -2.0 | -2.1 | -0.1 | 0.9 | -1.8 | 1.4 | 0.8 | 1.4 | 1.0 | 0.5 | 0.6 | 1.5 | -1.1 |
| | U | **3.9** | 5.6 | 6.1 | 1.1 | 2.3 | -1.6 | 2.2 | 1.3 | -0.8 | -1.1 | -6.4 | -7.0 | -3.2 | -2.5 | -1.2 |
| GLAS | N | **1.7** | -4.8 | 1.4 | 0.4 | 0.2 | -1.1 | 1.6 | -2.0 | 0.4 | 0.5 | 1.7 | 0.6 | 0.3 | 0.3 | 1.4 |
| | E | **2.0** | -2.8 | -4.7 | -0.3 | -0.8 | 2.1 | -1.0 | 1.0 | 3.4 | 0.8 | 1.4 | 0.8 | 0.2 | -0.2 | -0.2 |
| | U | **5.4** | 8.8 | 7.9 | -3.5 | -2.2 | -2.7 | -3.5 | 8.3 | -7.5 | 0.6 | -5.9 | -6.7 | -0.9 | 0.2 | 1.5 |
| GLWY | N | **0.9** | -1.2 | 0.1 | 0.2 | -0.8 | -1.1 | -0.7 | -1.1 | 0.8 | 0.0 | 0.9 | 1.1 | 0.8 | 0.8 | 1.1 |
| | E | **0.8** | -0.2 | -1.9 | -0.4 | -1.0 | 0.4 | -0.3 | -1.1 | 0.8 | 0.1 | 0.7 | 1.2 | 0.3 | 0.5 | 0.2 |
| | U | **2.7** | 0.0 | -3.6 | 1.1 | 0.1 | 1.8 | -1.5 | 3.9 | 0.9 | -0.9 | -1.3 | -6.7 | -0.1 | -2.2 | 1.9 |

| | | | Day | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **RMS** | 270 | 271 | 272 | 273 | 274 | 275 | 276 | 277 | 278 | 279 | 280 | 281 | 282 | 283 |
| GRAS | N | **0.4** | 0.2 | 0.2 | 0.6 | -0.1 | 0.2 | -0.1 | 0.0 | -0.6 | -0.2 | -0.6 | -0.5 | 0.2 | 0.6 | -0.4 |
| | E | **0.6** | 0.1 | 0.3 | -0.4 | 0.6 | -0.4 | -0.2 | 0.4 | -0.4 | 0.2 | -0.6 | 1.5 | -0.2 | 0.0 | -0.1 |
| | U | **3.7** | -3.9 | -4.7 | -0.4 | 0.8 | 4.8 | 8.1 | 0.4 | 1.5 | -1.2 | -4.5 | 1.3 | 4.2 | -1.6 | 1.1 |
| HERO | N | **0.9** | -0.5 | -0.9 | -1.1 | -0.4 | -0.4 | -0.6 | -0.4 | -0.3 | 0.5 | 1.8 | 1.7 | -0.5 | 0.4 | 0.9 |
| | E | **0.6** | 0.3 | 0.2 | 0.4 | -0.7 | 0.1 | -0.8 | -0.8 | 0.6 | 0.6 | 0.7 | 0.8 | 0.3 | -0.7 | -0.2 |
| | U | **2.6** | -3.3 | -1.7 | -2.1 | 1.0 | -5.2 | -3.2 | 2.6 | 1.4 | 1.1 | 3.4 | -0.9 | 0.1 | 2.1 | -1.5 |
| HERS | N | **1.9** | 2.0 | 1.4 | 1.2 | 1.8 | 1.4 | 0.9 | 1.2 | 1.9 | -0.8 | -2.3 | -4.4 | -1.6 | -1.3 | -0.6 |
| | E | **2.3** | 2.1 | 1.1 | 1.7 | 1.4 | 2.3 | 1.4 | 0.0 | 2.2 | -2.6 | -5.0 | -3.9 | -0.4 | 0.2 | 0.0 |
| | U | **2.7** | -3.2 | 1.3 | -0.5 | -0.5 | -1.9 | -0.6 | 1.0 | -0.6 | 2.2 | 2.9 | -0.9 | -1.0 | 7.7 | -1.5 |
| HERT | N | **1.2** | -0.7 | -1.0 | -1.2 | -0.6 | -0.6 | -1.2 | -1.2 | -0.7 | 0.3 | 2.0 | 2.2 | 0.7 | 0.9 | 1.3 |
| | E | **1.1** | 1.1 | 0.7 | 1.4 | 0.2 | 1.2 | 0.2 | 0.0 | 1.4 | -0.7 | -0.3 | -1.7 | -1.2 | -1.0 | -1.2 |
| | U | **2.6** | -0.3 | 0.3 | 1.2 | 0.2 | -0.4 | 0.3 | 0.5 | -0.8 | 2.3 | 2.9 | -5.7 | -2.3 | 4.9 | -3.2 |
| HOE2 | N | **0.7** | 0.6 | -0.5 | 0.6 | 0.2 | 0.2 | | -0.7 | 1.4 | 0.9 | 0.6 | 1.1 | 0.3 | -0.6 | -0.3 |
| | E | **1.7** | 2.0 | 0.3 | 0.8 | 0.5 | -0.7 | | -1.8 | -3.9 | 1.7 | 2.4 | 0.6 | -0.1 | 1.2 | 0.8 |
| | U | **6.3** | -0.5 | -1.5 | -6.9 | -4.5 | -11.8 | | -3.3 | -13.6 | -3.4 | -0.4 | -5.7 | -1.4 | -4.9 | -1.5 |
| HOFN | N | **1.1** | 0.1 | 2.0 | 0.5 | 0.6 | -0.4 | 1.5 | 0.2 | -1.7 | -1.1 | -0.9 | -0.4 | 0.2 | 1.1 | 1.0 |
| | E | **1.6** | -3.9 | -1.2 | -0.5 | 0.1 | 0.2 | 0.0 | 0.7 | 1.2 | -1.2 | -1.9 | 0.6 | 0.4 | 1.7 | 2.7 |
| | U | **2.3** | 3.0 | 0.9 | 2.5 | -0.9 | 3.6 | -1.4 | 2.2 | 1.3 | -0.9 | -2.7 | -1.5 | -1.3 | -4.0 | 0.7 |
| IESG | N | **0.9** | -0.9 | 0.8 | -0.3 | 0.1 | -1.0 | -0.3 | -0.9 | 1.0 | 0.2 | 1.7 | 1.4 | 0.0 | 0.2 | -0.9 |
| | E | **0.8** | 0.0 | -1.3 | 0.6 | -0.6 | 0.5 | -0.6 | -0.2 | 1.2 | 0.2 | 1.0 | 1.1 | -0.2 | -0.5 | -0.9 |
| | U | **2.1** | -0.3 | 3.9 | -3.1 | 2.5 | -0.3 | -0.5 | 2.5 | -1.9 | 0.0 | -1.0 | -2.5 | -1.7 | 0.8 | -2.7 |
| INVR | N | **1.5** | -0.1 | -1.9 | 1.3 | -0.9 | -2.0 | 0.4 | -2.2 | 0.3 | 0.4 | -0.4 | 2.3 | 1.1 | 1.0 | 2.2 |
| | E | **1.2** | 2.1 | 1.9 | 0.2 | -0.2 | 1.3 | 0.0 | -2.0 | 0.2 | -0.9 | -1.7 | -0.5 | -0.3 | 0.4 | 0.1 |
| | U | **5.8** | 14.2 | 7.2 | -4.9 | 1.0 | 2.3 | 2.3 | 2.0 | -4.0 | -4.1 | -3.6 | -5.6 | -3.1 | 0.3 | -8.0 |
| KING | N | **0.9** | -0.1 | 0.1 | -1.8 | -0.1 | -1.0 | -0.2 | -0.8 | 0.2 | 1.1 | 1.6 | 0.6 | 1.1 | -0.3 | 0.2 |
| | E | **0.7** | 0.3 | -0.6 | 0.0 | -0.5 | 0.5 | -0.7 | -0.1 | 1.4 | -0.7 | 0.2 | 1.5 | 0.2 | -0.8 | 0.2 |
| | U | **2.6** | 0.5 | -2.9 | 1.0 | -0.3 | -0.5 | 2.0 | 4.3 | 0.0 | -2.0 | -0.4 | -5.7 | -4.4 | 0.5 | 1.0 |
| KINT | N | **1.0** | 1.3 | -0.2 | 1.0 | -0.2 | -2.4 | 0.1 | -0.4 | 0.4 | 0.8 | 1.5 | 1.2 | -0.4 | -0.9 | 0.0 |
| | E | **1.2** | -1.5 | 0.3 | -0.5 | -2.3 | 0.5 | -0.8 | -1.0 | 0.4 | 0.5 | 1.5 | 2.4 | 0.1 | 0.8 | -0.4 |
| | U | **4.1** | 5.3 | 6.2 | 1.6 | 0.6 | -1.8 | 2.5 | -0.7 | -4.0 | -5.0 | 2.6 | -0.4 | -9.5 | 0.1 | -2.1 |
| KLRE | N | **1.4** | 0.1 | -3.0 | -0.2 | 0.5 | -0.8 | -0.3 | 0.7 | -0.4 | 1.1 | 1.6 | 2.1 | | | |
| | E | **2.4** | 0.8 | -5.6 | -2.7 | 1.3 | 1.2 | 0.4 | -1.8 | 1.0 | 1.2 | 2.8 | 1.7 | | | |
| | U | **7.8** | 10.2 | 7.3 | -1.8 | 5.5 | 6.2 | 1.8 | -5.1 | -3.8 | -6.8 | -9.7 | -14.2 | | | |
| LEED | N | **1.0** | -0.9 | 0.5 | 0.7 | -0.4 | -1.4 | -1.7 | 1.2 | -0.1 | 0.4 | -0.8 | 1.5 | 0.9 | 1.2 | 0.0 |
| | E | **1.7** | -0.5 | -3.1 | -2.9 | -1.0 | 0.3 | 0.5 | -0.7 | 2.5 | 0.0 | 2.3 | 1.9 | 0.4 | 0.3 | -0.3 |
| | U | **4.8** | 1.0 | 6.5 | 8.6 | -0.5 | -5.5 | 4.7 | -2.3 | 0.7 | -2.7 | 1.6 | -6.9 | -6.8 | -3.2 | 1.8 |
| LERI | N | **1.1** | 0.7 | 1.3 | 1.6 | 0.9 | -1.9 | 0.6 | -1.5 | -1.3 | 1.4 | -0.5 | 0.3 | -0.3 | 0.2 | 0.7 |
| | E | **0.9** | 1.6 | -0.2 | -0.3 | -0.6 | 1.4 | -0.8 | -1.9 | -0.3 | -0.1 | 0.8 | 0.8 | 0.0 | 0.1 | -0.3 |
| | U | **3.8** | 7.4 | 1.0 | 0.1 | -1.4 | -2.4 | 0.8 | 2.9 | -2.0 | -2.0 | -2.1 | -4.4 | -8.0 | 1.5 | 3.6 |
| MCHA | N | **0.8** | -0.2 | 1.0 | 0.3 | -0.2 | -0.6 | -0.5 | | 0.1 | -0.1 | -1.5 | 1.3 | 0.2 | | 0.8 |
| | E | **1.1** | 0.2 | -2.0 | 0.6 | -0.6 | 1.0 | 0.3 | | 0.3 | 0.1 | -2.3 | 1.7 | 0.6 | | 0.2 |
| | U | **3.3** | -0.5 | 3.6 | 3.2 | -2.5 | 1.3 | -0.3 | | -2.5 | 3.4 | -7.8 | -3.0 | 0.0 | | 0.3 |
| MORO | N | **0.9** | 0.4 | 0.7 | -0.8 | 0.7 | -1.3 | 0.2 | -0.4 | -1.0 | -0.8 | 1.7 | 1.2 | -0.1 | 0.3 | 0.5 |
| | E | **1.3** | 0.7 | -1.9 | -0.6 | -2.0 | 1.4 | -1.4 | -1.1 | 2.0 | -0.1 | 0.6 | 1.9 | 0.1 | 0.5 | -0.1 |
| | U | **3.0** | -0.6 | 0.5 | 2.9 | 2.1 | 1.4 | 2.3 | 0.6 | -1.1 | -0.1 | 3.0 | -7.5 | -3.9 | -3.6 | -1.7 |
| MORP | N | **1.1** | 0.0 | 1.0 | -1.5 | 0.5 | -1.1 | 0.5 | -0.7 | -0.4 | -0.8 | 2.8 | 1.1 | -0.1 | -1.0 | 0.6 |
| | E | **1.4** | 0.9 | -2.4 | -0.8 | -2.6 | 1.1 | -1.2 | -0.1 | 2.2 | 0.5 | 1.0 | 1.3 | 0.5 | 0.3 | -0.5 |
| | U | **2.4** | -3.9 | -3.9 | 0.1 | -0.3 | 1.3 | 0.6 | -4.2 | 2.2 | 3.5 | 1.8 | 0.7 | -0.4 | -0.5 | -2.1 |
| MRKT | N | **0.9** | -0.8 | 1.6 | 1.5 | -1.3 | -1.2 | 0.6 | -1.0 | 0.4 | 0.3 | 0.8 | 0.5 | 0.0 | 0.2 | -0.2 |
| | E | **1.4** | 0.1 | -0.2 | -0.9 | -2.0 | 0.0 | -3.3 | -0.3 | 0.5 | 0.2 | 1.4 | 2.4 | 0.7 | 0.6 | 0.6 |
| | U | **3.2** | 3.0 | -3.7 | -1.7 | 1.3 | 4.2 | -4.7 | 1.0 | -0.5 | -2.3 | 0.5 | -5.6 | -0.5 | -2.3 | 4.6 |
| NEWL | N | **0.9** | -1.0 | -1.6 | -1.1 | -0.9 | -0.2 | -0.3 | 0.0 | 1.1 | 0.8 | 1.2 | -0.3 | 0.6 | 1.2 | 0.2 |
| | E | **1.1** | -0.4 | -0.6 | 0.2 | -1.1 | -0.1 | -0.9 | 2.4 | 1.9 | 0.4 | -1.3 | 0.3 | 0.7 | 0.0 | -0.7 |
| | U | **4.9** | 4.9 | 5.1 | 2.4 | 5.0 | 1.8 | 3.9 | -5.0 | -1.1 | 2.4 | -12.2 | -0.6 | 1.9 | -4.2 | 2.5 |
| OMGH | N | **1.0** | -0.7 | -0.3 | 0.5 | -1.1 | -1.4 | 0.6 | -1.0 | 0.2 | 0.5 | 2.3 | 0.7 | -0.1 | -0.3 | 1.4 |
| | E | **0.9** | 1.4 | -0.1 | -0.2 | -1.0 | -1.0 | 0.7 | -1.0 | 0.8 | -0.1 | 0.2 | 1.4 | -0.1 | 0.4 | -1.5 |
| | U | **4.5** | 6.7 | 4.7 | 2.2 | 0.7 | 1.9 | 0.9 | 0.7 | 1.4 | -0.8 | -10.0 | -8.3 | -3.6 | -1.4 | -0.3 |
| OS12 | N | **0.7** | -0.6 | -1.0 | -0.6 | 0.2 | 0.5 | -0.6 | -0.3 | -0.6 | 0.5 | 1.5 | 0.6 | 0.0 | -0.2 | 1.0 |
| | E | **0.6** | -0.3 | -0.3 | 0.2 | -0.7 | 0.7 | -0.6 | -0.6 | 0.8 | 0.1 | 0.8 | 1.1 | 0.5 | -0.2 | -0.5 |
| | U | **2.5** | 1.1 | 0.6 | 0.6 | -0.1 | -2.1 | -2.9 | -0.5 | -1.1 | 0.5 | 3.1 | -5.4 | -2.1 | 3.9 | -2.9 |
| OSLS | N | **0.8** | 0.0 | -0.9 | 0.2 | 1.0 | 0.4 | 0.4 | -0.8 | -1.5 | 0.2 | 1.0 | 1.1 | -0.7 | 0.7 | 0.4 |
| | E | **1.3** | 3.1 | 0.7 | -1.3 | -0.4 | -1.0 | -1.0 | -0.9 | -0.8 | -1.5 | 1.7 | 1.2 | 0.1 | 0.4 | 0.6 |
| | U | **2.8** | 4.5 | 1.0 | -1.5 | -3.4 | 0.8 | -1.8 | 2.0 | 5.1 | 1.6 | 3.2 | 0.1 | 0.3 | -3.1 | -3.3 |
| PDEL | N | **1.0** | -2.1 | -0.3 | -0.6 | -0.8 | -0.8 | 0.1 | 1.1 | 0.1 | 0.4 | -0.4 | 0.4 | 1.4 | 1.6 | -0.6 |
| | E | **1.4** | -2.5 | -1.0 | -1.4 | 0.7 | 0.1 | -0.2 | 0.2 | -1.6 | 0.7 | 1.7 | 0.9 | 2.3 | 1.1 | -1.9 |
| | U | **6.0** | 2.8 | -1.0 | -0.8 | -4.3 | -2.7 | -11.8 | 1.4 | 1.1 | -4.3 | 9.9 | 10.1 | 3.2 | 7.7 | -2.7 |
| PRTL | N | **0.6** | -0.5 | -0.4 | 0.4 | 0.5 | -0.6 | -0.3 | -0.2 | 0.4 | 0.6 | 1.4 | 0.8 | -0.5 | -0.4 | -0.4 |
| | E | **0.7** | 0.3 | -0.9 | 0.0 | -1.1 | 0.4 | -0.8 | -0.6 | 0.9 | 0.1 | 0.2 | 1.1 | 0.0 | 0.1 | -0.3 |
| | U | **3.5** | 0.2 | 4.3 | 2.7 | -1.8 | 0.8 | -4.6 | 4.4 | 0.4 | -3.6 | 0.6 | -6.9 | -1.8 | -4.4 | 2.6 |
| SHAM | N | **0.7** | 0.1 | -0.3 | -0.9 | 0.8 | -0.7 | 0.4 | -0.7 | 0.6 | 0.5 | -1.0 | -0.1 | 0.8 | 0.4 | 1.0 |
| | E | **0.8** | -0.4 | -0.5 | -1.2 | -0.9 | 0.5 | -1.1 | 0.3 | 0.9 | 0.2 | 0.3 | 1.9 | 0.1 | 0.4 | -0.5 |
| | U | **2.6** | 2.0 | -2.6 | -2.7 | 1.5 | -3.8 | -1.0 | 4.5 | 1.2 | 1.9 | -3.6 | 1.0 | -1.7 | -2.8 | 1.0 |


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| | | | Day | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **RMS** | 270 | 271 | 272 | 273 | 274 | 275 | 276 | 277 | 278 | 279 | 280 | 281 | 282 | 283 |
| SNEO | N | **0.7** | -0.1 | -0.5 | -1.0 | 0.1 | -0.5 | -1.0 | -0.3 | 1.2 | 0.4 | -0.4 | 1.0 | 0.7 | 0.3 | 0.2 |
| | E | **0.9** | 0.1 | 0.5 | 0.0 | -1.5 | 0.3 | -1.0 | -0.9 | 1.0 | 0.2 | 1.4 | 1.7 | -0.6 | 0.3 | -0.9 |
| | U | **3.0** | -1.2 | -0.3 | -1.2 | -1.1 | 1.9 | -0.1 | 3.5 | 1.3 | 5.0 | -1.4 | 0.6 | -7.4 | -3.5 | -2.0 |
| STRN | N | **1.0** | 1.2 | -0.4 | 0.0 | -1.2 | -1.8 | 0.1 | 1.8 | -0.2 | -0.1 | 0.9 | 0.7 | -0.2 | -0.6 | 1.0 |
| | E | **1.1** | 0.0 | -1.0 | -2.1 | -0.8 | 0.6 | -1.1 | -0.4 | 1.1 | -0.4 | 1.2 | 2.1 | 0.7 | 0.4 | -0.7 |
| | U | **5.3** | 0.5 | 2.3 | -11.9 | -0.2 | 2.8 | 1.6 | 4.9 | 8.4 | -0.8 | 0.6 | -9.6 | -3.6 | -1.8 | -2.3 |
| SWAS | N | **0.9** | 0.3 | 0.1 | 0.0 | -0.7 | -0.9 | 0.4 | 0.4 | -2.2 | -0.5 | 0.7 | 1.0 | 0.2 | 0.6 | 1.2 |
| | E | **0.8** | 0.3 | -0.9 | 0.4 | -1.3 | 0.6 | -1.0 | -0.6 | 0.9 | 0.3 | 0.6 | 1.0 | 0.1 | 0.4 | -0.9 |
| | U | **2.4** | -1.8 | 1.5 | 0.6 | 3.6 | -3.5 | 1.2 | 0.1 | -0.8 | 2.6 | -0.1 | 0.5 | 0.2 | -3.1 | -5.0 |
| SWRD | N | **0.6** | -0.3 | -0.4 | 0.0 | 0.4 | -0.7 | -0.4 | -0.3 | 0.6 | -0.4 | 1.0 | 0.7 | 0.0 | -0.1 | 0.9 |
| | E | **0.9** | -0.4 | -1.3 | -0.8 | -1.5 | -0.1 | -1.0 | -0.1 | 0.8 | 0.4 | 0.7 | 1.5 | 0.0 | 1.3 | 0.1 |
| | U | **2.6** | 1.3 | 3.0 | 2.0 | -1.6 | 3.2 | 2.5 | -1.4 | -2.2 | -1.4 | -0.1 | -6.2 | -2.2 | -2.4 | -0.3 |
| TRLE | N | **1.0** | -0.4 | -0.5 | -0.2 | -0.4 | -1.7 | -0.4 | -0.3 | 0.2 | 0.1 | 1.5 | 0.8 | 0.0 | 2.5 | -0.2 |
| | E | **1.1** | -0.2 | -0.9 | -0.6 | -0.7 | 0.4 | 0.5 | -2.8 | 1.2 | 0.2 | 0.6 | 1.4 | 0.5 | 0.5 | -0.6 |
| | U | **4.1** | 1.5 | 3.3 | 1.4 | -1.2 | -1.5 | -0.4 | 3.7 | 7.1 | -4.1 | 0.0 | -10.1 | -3.2 | -1.8 | 1.1 |
| VILL | N | **0.7** | -1.6 | -0.1 | 0.4 | 0.0 | 0.4 | -0.2 | -0.7 | 0.0 | -0.4 | -0.6 | 1.4 | 0.6 | 0.0 | 0.0 |
| | E | **0.7** | -0.1 | 0.3 | -0.2 | -0.3 | -0.8 | -1.0 | -0.7 | 1.0 | 0.9 | 1.1 | 0.7 | 0.8 | -0.5 | -0.1 |
| | U | **3.4** | 1.4 | -0.7 | 2.8 | 1.1 | 1.5 | -0.2 | -5.5 | 4.0 | 1.5 | -4.6 | 1.6 | 2.6 | 3.3 | 6.8 |
| ZIMM | N | **0.4** | -0.6 | 0.3 | 0.5 | 0.1 | 0.1 | -0.1 | -0.3 | -0.2 | -0.6 | 0.2 | 0.6 | 0.2 | 0.3 | -0.7 |
| | E | **0.9** | 0.1 | -0.1 | 1.2 | -0.6 | -0.4 | -1.1 | -1.2 | 0.1 | 0.9 | 1.8 | 1.3 | -0.9 | -0.2 | 0.0 |
| | U | **2.5** | -0.2 | -3.4 | -2.5 | 2.7 | 2.4 | -1.1 | 0.6 | 2.8 | 1.4 | 0.1 | 4.4 | 1.6 | -3.5 | -1.6 |


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