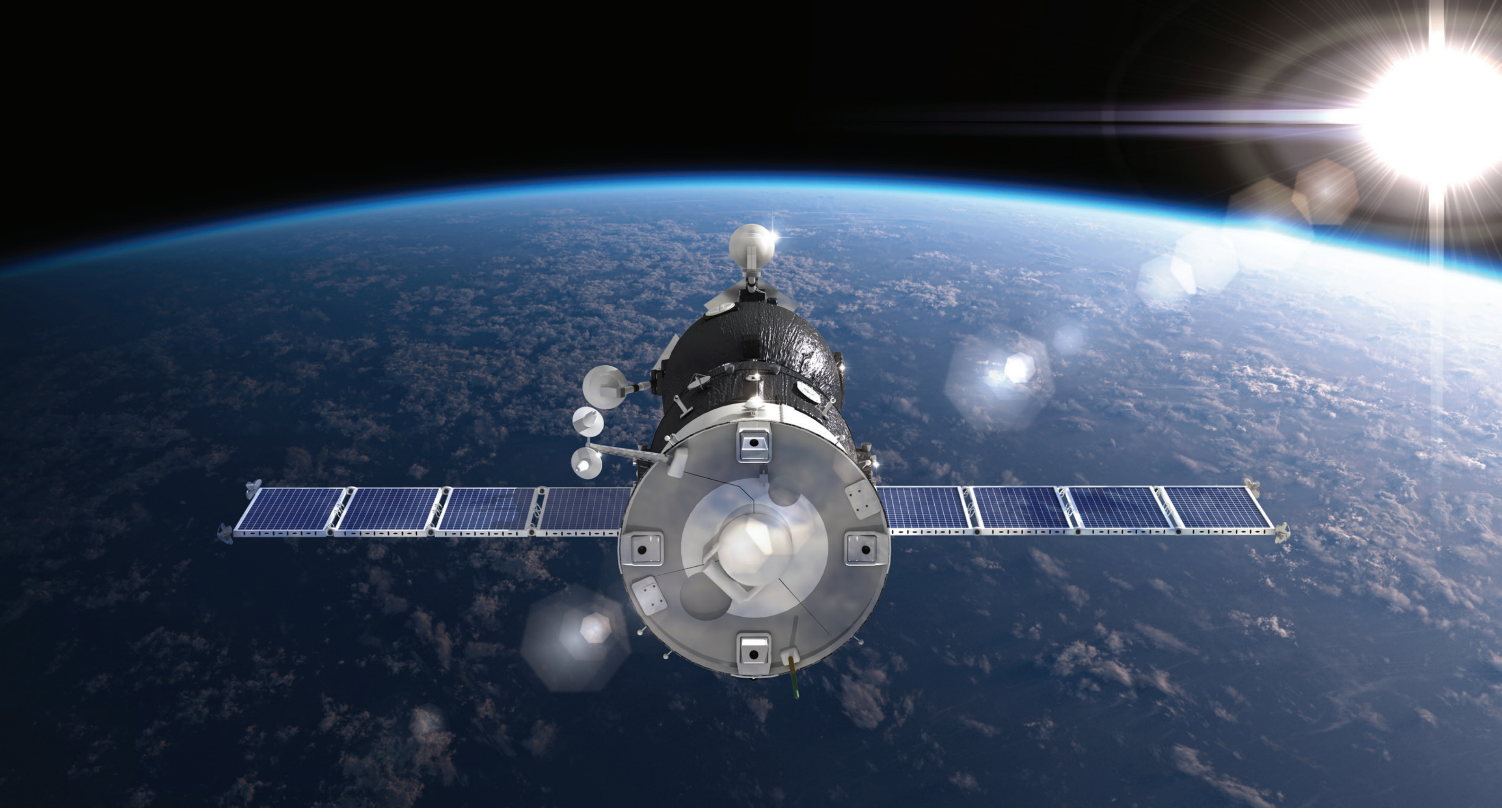

GUIDANCE NOTES FOR **GNSS NETWORK RTK SURVEYING IN GREAT BRITAIN**

THE SURVEY ASSOCIATION

Newcastle University

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Collaboration between:

Ordnance Survey®

Leica Geosystems

TOPCON

Trimble

RICS

This leaflet has been produced to provide surveyors, engineers and their clients with guidelines for the use of Network RTK GNSS in land and engineering surveys. It has been produced by a joint working group comprising: The Survey Association (TSA), Ordnance Survey®, Newcastle University, Leica Geosystems, Topcon, Trimble and the Royal Institution of Chartered Surveyors (RICS).

The leaflet provides additional guidance on best practice for those using the various commercial Network RTK solutions available in Great Britain. The previous guidance notes (Nov 2008) provided key information on using Network RTK based predominantly on GPS signals only. This update confirms the previous work but importantly extends it to combined GPS/GLONASS Network RTK which is now widely available, and considers a wide variety of survey environments, network edge effects and base station failures.

Background

The guidelines presented in this leaflet have been established through a combination of previous experiments (in 2008) at seven mainly open-sky sites around Great Britain, and new tests undertaken in 2011 in a locality chosen to provide a wide range of urban and rural environments for GNSS survey. The previous experiments used stationary antennas to evaluate Network RTK positional accuracy, precision and the reliability of quality indicators. Also considered were base station to rover height difference effects, ocean tide loading and a limited study of surveying at the margins of the OS Net® GNSS base station network, whose data are used by commercial providers for the generation of Network RTK positional corrections. The new experiments enhance the previous work by occupying a total of 22 new test points (coordinated using a combination of static GPS and terrestrial survey) spread across 'easy', 'moderate', 'difficult' and 'severe' GNSS survey environment categories, examining Network RTK performance for both stationary and roving antennas, using both GPS-only and GPS+GLONASS position estimates from the Leica SmartNet, Topcon TopNet+ and Trimble VRS Now services. The experiments included single epoch positioning to simulate a detail survey, simulation of surveying both outside the extents of the OS Net base station network and in the presence of nearby OS Net base station outages, and tests of service provider and equipment interoperability. In all cases proprietary equipment and firmware configurations were used, whilst maintaining consistency across all manufacturers of user-definable settings such as elevation angle cut-off.

"As well as improving availability, using GPS + GLONASS rather than GPS-only can lead to small improvements of a few millimetres in both horizontal and vertical positional accuracy."

General

Whilst this leaflet addresses best practice for Network RTK surveying in Great Britain it does not address, but assumes the user adopts, general best practice for GNSS RTK surveying. The use of local base station RTK remains a viable option for land and engineering surveying although its attendant overheads of cost, security and efficiency make it less attractive in many situations.

Accuracy

- Accuracy is a measure of the difference between a particular measured coordinate and its true value, often quoted as the root mean square error (rms). If the measurement is unbiased and has normally distributed errors, then for each coordinate component roughly 68% of individual solutions will have errors smaller than the rms, and 95% will have errors smaller than twice the rms. However, systematic errors (biases) will reduce these percentages.
- Typically, commercial Network RTK solutions within Great Britain provide instantaneous results (i.e. single epoch coordinate solutions) that achieve rms accuracies of around 10 – 20 mm in plan and 20 – 40 mm in height, with relatively small biases.

"Accuracy is a measure of the difference between a particular measured coordinate and its true value."

Equipment configuration and provider interoperability

- Always ensure your Network RTK rover firmware is configured according to manufacturer guidelines. Significant variations from recommended settings may lead to unacceptable variations in determined coordinates.
- Always use integer-fixed solutions, not ambiguity-float solutions.
- Both Geometric Dilution of Precision (GDOP) and Position Dilution of Precision (PDOP) provide measures of the worsening of a GNSS solution. Manufacturer default GDOP/PDOP cut-off values are typically in the range 5-7. Reducing the GDOP/PDOP limit to 3 will increase the robustness of determined coordinates under challenging conditions (e.g. urban canyons) but does not reduce productivity in open/benign environments where GDOP/PDOP values between 2 and 3 predominate.
- For the three tested Network RTK service and equipment providers (Leica SmartNet, Topcon TopNet+ and Trimble VRS NOW), Network RTK service and receiver interoperability yields very similar position accuracies in all combinations.

Quality indicators

- > Always ensure your rover unit is set to display all available coordinate quality indicators for your position fix and pay close attention to them. In most situations these indicators reflect well the actual performance of your system. When positioning in severe environments however, CQ values may be over-optimistic. GPS+GLONASS CQ values tend to be slightly over-optimistic compared with their GPS-only counterparts in most environments.
- > Coordinate solutions where the reported quality is worse than 100 mm generally result from problems with satellite lock or ambiguity resolution, and should always be discarded.
- > In the most challenging environments (e.g. restricted satellite visibility, large distances or height differences to surrounding OS Net base stations, or high multipath), reported coordinate quality may be over-optimistic by a factor of 3 – 5 especially in the height component. This can be mitigated as below.

“The use of satellites from other global navigation constellations (e.g. GLONASS) improves overall satellite visibility.”

Improving solution robustness

- > For topographic survey, the use of a 5 second single window average will reduce the effect of individual coordinate solution variations.
- > For precise work, especially where the height component is important e.g. control station establishment, the process of double window averaging should be undertaken. You should observe an averaged window of around 3 minutes followed by another averaged window of the same length separated from the first by a suitable time period e.g. 20 minutes.
- > On average, a time separation of 20 minutes will yield a 10 – 20% improvement in coordinate accuracy and a 45 minute separation will yield improved accuracies at the 15 – 30% level compared to a single epoch solution. Window separations of greater than 45 minutes do not typically provide appreciable further improvement to the determined coordinates.

Additional satellite constellations e.g. GLONASS

> When surveying in challenging GNSS environments (e.g. urban canyons), the use of satellites from other global navigation constellations (e.g. GLONASS) improves overall satellite visibility and hence allows surveying to proceed with less downtime. Solution availabilities with acceptable CQ values and PDOP/GDOP values less than 3 improved by about 10-20% in easy and moderate environments when using GPS+GLONASS rather than just GPS, and by up to around 50% in difficult and severe environments.

> As well as improving availability, using GPS+GLONASS rather than GPS-only can lead to small improvements of a few millimetres in both horizontal and vertical positional accuracy. The use of multi-GNSS positioning is recommended in all such scenarios, for both rover and stationary occupations. Even position solutions in more favourable environments are slightly improved by the addition of other GNSS.

> If satellite availability is significantly diminished (e.g. under a tree or close to an overhang), use standard terrestrial survey techniques to radiate from a nearby unobstructed point. If Network RTK is used, it should be realised that the quality indicators are likely to be over-optimistic, and that erroneous positions may arise, even with multi-GNSS.

Surveying at the limits of the network

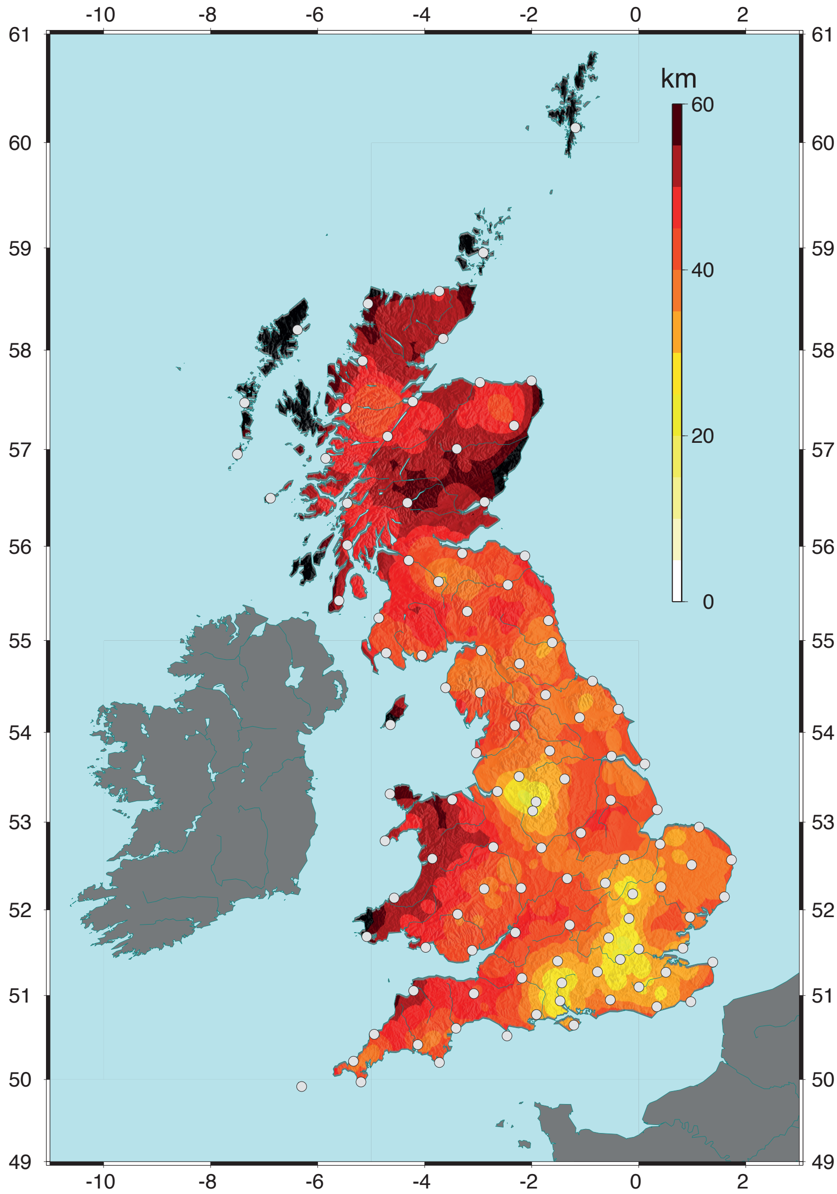
> If you frequently work in areas at the extents of the Network RTK infrastructure, a multi-GNSS solution is recommended to avoid tail-off in solution accuracy and to improve solution availability. Similarly, this approach can mitigate the case of nearby Network RTK base station failure.

> You should consider making greater use of single window averaging for normal topographic survey and double window averaging for control station establishment.

> To aid planning, Figure 1 (overleaf) shows the mean distance to the nearest four OS Net sites. If you frequently work in areas where this mean distance is large, or where you are outside the polygon formed by the nearest OS Net base stations, you should consider making greater use of window averaging.

Figure 1

Mean distance from nearest four OS Net base stations (April 2012)



Height effects and ocean tide loading

> For the majority of England and Wales, the errors caused by the tropospheric effects and height variations between OS Net sites and your Network RTK rover position are generally well modelled by Network RTK providers. However, where these height differences increase (e.g. Snowdonia, Lake District and Scottish highlands) as illustrated in Figure 2 (opposite), it is recommended that the window averaging procedures as for surveying at the limits of the network and improving solution robustness be adopted to reduce height error. Note that it is possible to be significantly below the nearby OS Net base stations.

> Ocean tide loading (OTL) is the time-varying displacement of the Earth's surface due to the weight of the ocean tides. It can reach ±60 mm in height and ±20 mm in plan in the South-West Peninsula and Western Isles, although it is typically less than half of this magnitude. Instantaneous differences in OTL between a rover and base station can cause errors in the measured coordinates. Such errors will usually be greatest when the rover to base station separation distance is large, as OTL effects tend to cancel out over short baselines (few tens of km).

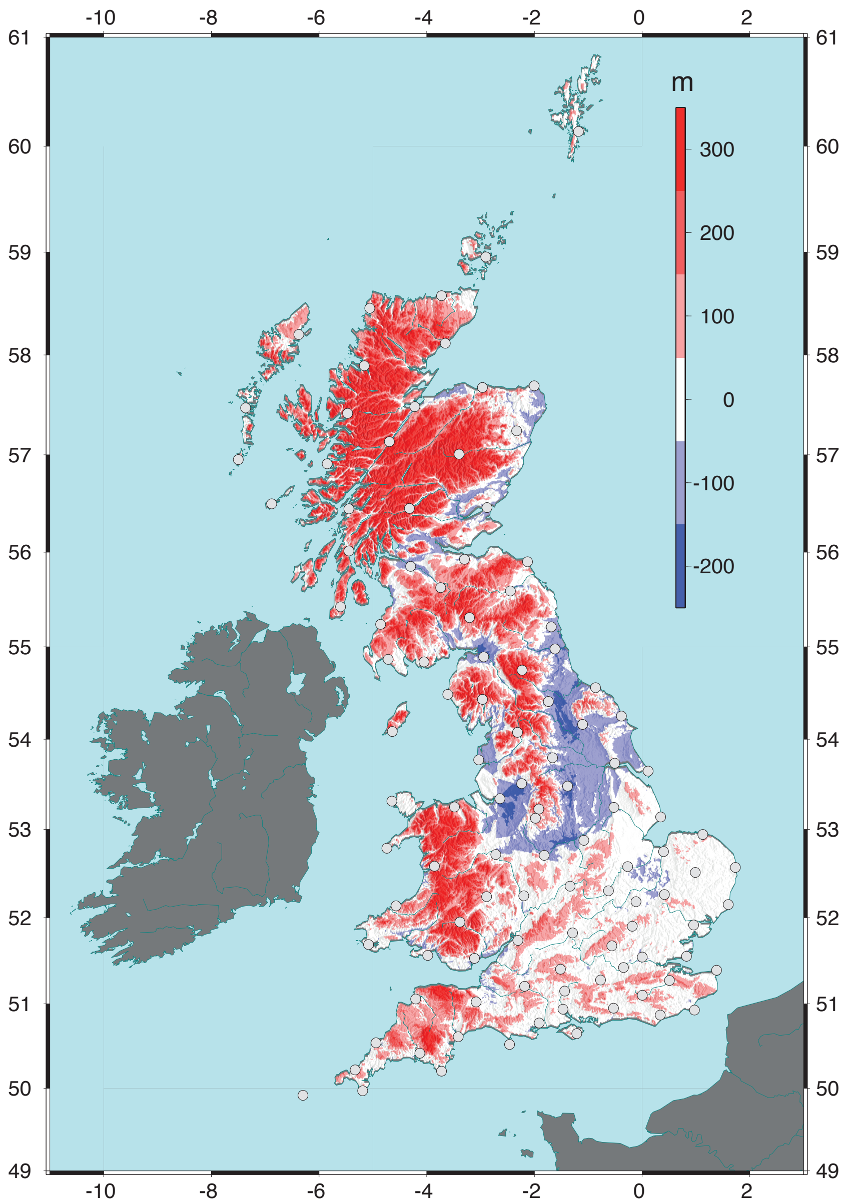


Figure 2

Mean height difference from nearest four OS Net base stations (April 2012)

> The use of Network RTK reduces OTL error to the current system noise level throughout the majority of mainland Britain. In areas where OTL may be problematic, its effect can be almost completely removed by taking the mean of two sets of coordinates collected with 6 – 6½ hour separation.

Further information and useful addresses

The Survey Association
http://www.tsa-uk.org.uk/

Newcastle University
http://www.ncl.ac.uk/ceg

Ordnance Survey
http://www.ordnancesurvey.co.uk/oswebsite/gps

Leica Geosystems
http://smartnet.leica-geosystems.co.uk/spiderweb/frmindex.aspx

Topcon
http://www.topnetplus.eu

Trimble
http://www.trimble.com/vrsnow.shtml

RICS
http://www.rics.org

Guidelines for the Use of GPS in Surveying and Mapping
RICS Guidance Note (2nd Ed. 2010), ISBN 978-1-84219-607-6

An examination of commercial Network RTK services in Great Britain
Newcastle University (2008)
Further testing of commercial Network RTK GNSS services in Great Britain (NetRTK-2)
Newcastle University (2012)
Reports for TSA, both downloadable at http://www.tsa-uk.org.uk/

Edwards S.J., P.J. Clarke, N.T. Penna and S. Goebell (2010)
An examination of Network RTK GPS services in Great Britain
Survey Review, 42 (316), 107-121

Clarke P.J. and N.T. Penna (2010)
Ocean tide loading and relative GNSS in the British Isles
Survey Review, 42 (317), 212-228

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