http://www.trimble.com/pdf/TSA_Report.pdf

- Rory Stanbridge, Secretary General, The Survey Association UK, and Dr Stuart Edwards, Research Team, Newcastle University invited, but could not make it
- Report made to Workshop on "Best Practice on RTK Use" in Gavle Sweden in April 2009 – Denmark, Finland, Norway, Sweden & Iceland
- Good information so I hope I can do it justice on behalf of the authors

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An examination of commercial network RTK GPS services in Great Britain

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The Survey Association

Ordnance Survey
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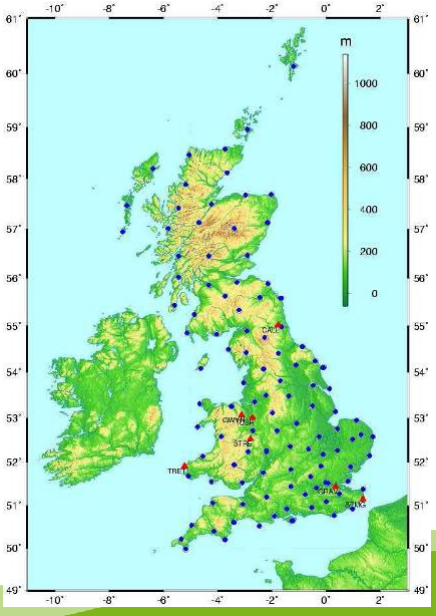
Background

- Ordnance Survey provide and maintain the national network of continuously operating GPS active stations, with a few stations of GLONASS capability.
- There are two available commercial networks that provide corrections based on data from Ordnance Survey, Leica 'SmartNet' and Trimble 'VRS NOW'.
- SmartNet network RTK solution is based on the so-called Master-Auxiliary Concept (MAC) and VRS NOW is based on Virtual Reference Station (VRS).
- Both systems capabilities are examined to obtain an impartial and objective indicator of the achievable accuracy (no ranking between the two network RTK systems).
- This study provides a basis for an extended and updated document that cover best practice guidelines for network RTK users in Great Britain.

Objectives

- Determine the accuries attainable from both system at a range of representative locations that users may experience.
- Determine coordinate repeatabilities attainable from the two systems (SmartNet and VRS NOW).
- Performance of the system at the geographical extents of the active station network (e.g. coastal zone).
- System performance when significant height differences exist between the OS Net reference stations and the rover.
- Examine the potential of network RTK solutions by integration of additional satellite constellations e.g. GLONASS.

OS Net reference stations and test sites



- Blue points : number of active OS Net reference stations: more than 100, target of 110 stations.
- Red triangles: seven test sites with some different criteria e.g.:
  - sites at the extent of the network (coastal zone)
  - different site elevations to OS stations (high and low differences)
  - different distances from site to OS stations etc.

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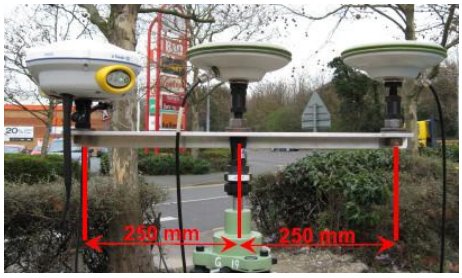
Instruments/settings and collection of data/coordinates



- Centre antenna orientated to North and connected to dual frequency receiver recording **static data**.
- 'True' coordinates recorded for central antenna, and baselines of 250 mm distances to provide SmartNet and VRS NOW receiver with 'true' coordinates.
- These short baselines (250 mm) made it possible to cancel tropospheric and ionospheric biases.
- 'True' coordinates were later compared with the network RTK solutions for the VRS NOW and SmartNet systems to assess overall system accuracies in each coordinate component.

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Data analysis

- All network RTK fixed solutions with worse than the following **instrument-reported** qualities were filtered:
  - 1st filter:
    - Horizontal Coordinate Quality > 50 mm
    - Coordinate Quality in height > 100 mm
  - 2nd filter:
    - DOP ≥ 3
- Statistics were generated for 1, 5, 180 and 300 second samples using only a single moving window average. Then for a double-window average the average of two such windows was used, separated by 20 or 45 minutes.

Window Size (sec)	Single window			20 min separation			45 min separation		
	N (mm)	E (mm)	U (mm)	N (mm)	E (mm)	U (mm)	N (mm)	E (mm)	U (mm)
1	6	5	9	5	4	8	4	3	7
5	6	4	9	5	4	7	4	3	6
180	6	4	8	4	3	7	3	3	6
300	6	4	8	4	3	7	3	3	6

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Results/analysis

Network RTK accuracies

Coordinate Quality filter

Site Name		GRAG		
		North	East	Up
Purple	min (mm)	-62	-41	-2470
	max (mm)	1263	1220	143
	mean (mm)	22	22	-42
	rms (mm)	134	123	261
	Mean CQ	4.380	3.922	4.689
Pink	min (mm)	-55	-43	-129
	max (mm)	65	59	119
	mean (mm)	9	8	-9
	rms (mm)	16	14	34
	Mean CQ	1.228	1.124	1.533

Coordinate Quality + DOP filter

Site Name		GRAG		
		North	East	Up
Purple	min (mm)	-62	-31	-129
	max (mm)	84	70	142
	mean (mm)	10	9	-14
	rms (mm)	23	18	38
	Mean CQ	0.669	0.530	0.604
Pink	min (mm)	-55	-43	-129
	max (mm)	65	59	119
	mean (mm)	9	8	-9
	rms (mm)	16	14	34
	Mean CQ	1.231	1.124	1.533

- In overall the DOP filter did not imply to affect the overall rms statistics for all areas.
- However for high multipath areas, e.g. GRAG (table), the purple equipment accuracy improved greatly.
- This would suggest that DOP limit of 3 does not affect network RTK in open environment, but in challenging areas it can radically improve system reliability.

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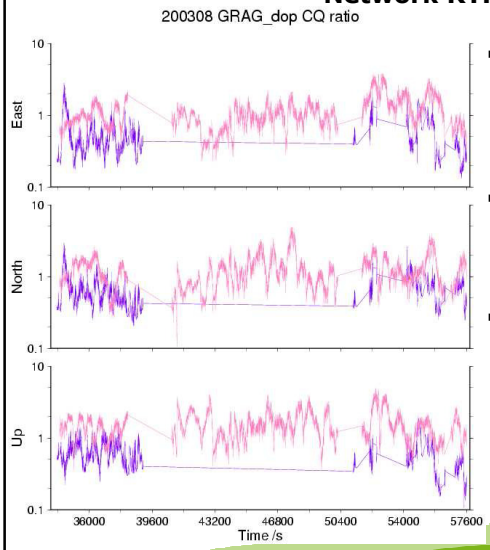
Results/analysis

Network RTK accuracies



- The ratio plots (CQ+DOP filter) has been generated by the obtained rms divided by the reported CQ values from the network RTK equipment.
- In challenging environments (e.g. GRAG) with high multipath, the pink network RTK equipment can give over-optimistic CQ values.
- Environments with high multipath, large distances or height differences to OS Net stations can give CQ values that are over-optimistic by a factor 3-5.

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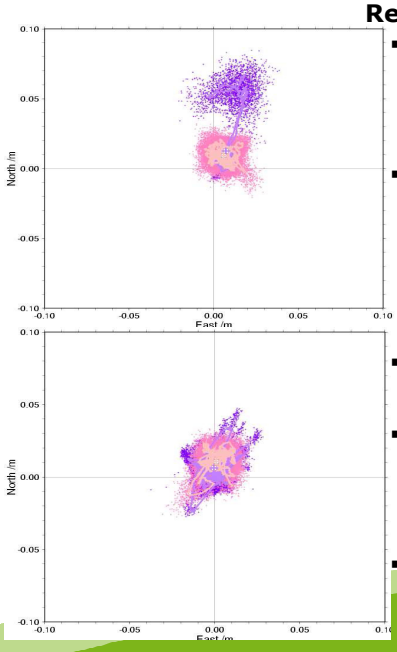
Results/analysis

Repeatabilities



- Site STRE (open environment) with a mean height difference of -255 m to nearest OS Net reference stations and 22-72km to nearest 4 OS stations.
- The plot reveals excursion of about 50 mm for the purple equipment. In problematic environments short term repeatability (seconds to minutes) can give a misleading impression of accuracy.
- Site TRET (the extent of the network) and has OS Net stations only to the east.
- After applying CQ filter the rms errors are: 10,7 and 19 mm (N,E,U) purple equipment and 13, 7 and 18 mm (N,E,U) pink equipment
- Despite these rms errors the plot reveals epoch-to-epoch excursions up to 30 mm.

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Results/analysis
Height effects

Coordinate Quality + DOP filter

Site Name		TUSH			GWYN		
		North	East	Up	North	East	Up
Purple	min (mm)	-127	-61	-110	-48	-56	-107
	max (mm)	62	25	566	52	35	106
	mean (mm)	13	-4	-14	2	3	21
	rms (mm)	19	8	24	10	9	30
	Mean CQ	1.424	0.655	1.049	0.842	0.761	1.52
Pink	min (mm)	-33	-42	-81	-128	-73	-167
	max (mm)	37	33	89	54	51	82
	mean (mm)	5	-1	-11	5	1	-13
	rms (mm)	10	8	27	18	14	29
	Mean CQ	0.773	0.600	1.060	0.975	0.823	1.19

- Site TUSH and GWYN with mean height difference of 16 m respectively 254 m to nearest OS Net active stations were investigated.
- The table shows that the rms values for GWYN are in overall slightly worse, despite the height differences to nearby OS Net active stations.
- At places where the height differences increase even more, the mitigation of residual tropospheric effects cannot be guaranteed, at such circumstances windowing techniques should be considered.

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Results/analysis
Ocean Tide Load

- Instantaneous differences in displacement of Ocean Tide Load between the rover and base station can cause errors in the measured coordinates.

- Complicated coast line in Great Britain and shallow seas results in large variability of OTL displacement.
- Network RTK reduces OTL error to current system noise levels throughout most of the mainland of Great Britain; but where the OTL still remains it can be almost completely removed by taking two sets of coordinates with 6-6.5 hours of separation.

Note: The periodic redistribution of water due to ocean tides loads the Earth's surface resulting in time-varying **OTL displacement**.

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Recommendations for best practice 1(4)

Network RTK accuracy:

- Generally commercial network RTK solutions in Great Britain provide results that achieve horizontal accuracy of around **10-20 mm** and height accuracy of **15-30 mm** (one sigma).

Equipment configuration:

- Rover firmware should be configured according to manufacturer guidelines. Significant variations from recommendations may lead to unacceptable coordinate determination.
- DOP limit of 3 will in problematic areas improve the robustness of the determined coordinates.

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Recommendations for best practice 2(4)

Quality indicators:

- In most situations (open areas, etc.) the coordinate quality indicators reflect well the performance of the system.
- In more challenging areas, though, the CQ indicators may be over-optimistic by a factor of 3-5 (especially in height component).

Improving solution robustness:

- 180 sec (3min) single averaging window yielded a small improvement compared to one epoch (1 sec), however no further significant improvement were shown for a 5 minute single averaging window.

For precise work, e.g. control station establishment:

- A two window (3 min single window) with 20 minute separation yielded a 10-20% improvement in coordinate accuracy and a 45 minute separation a 15-30% improvement, all compared to a single epoch solution.

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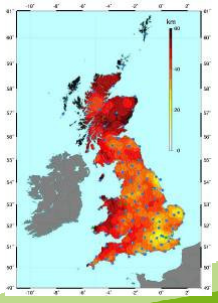
Recommendations for best practice 3(4)

Additional satellite constellation:

- It can be concluded that additional satellite constellation signals improve network RTK system availability, however further testing is recommended.
- Where the satellite visibility is limited (e.g. under a tree) the surveyor should consider to adopt standard terrestrial survey techniques instead of network RTK.

Surveying at the limits of the network:



- The figure shows the mean distance to the four nearest OS active stations and it can aid the planning of network RTK surveying.
- When working at the extent of the network, or with large mean distance, it is recommended that the user should consider windowing techniques.

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Recommendations for best practice 4(4)

Height effects:

- At places where the height differences increase the mitigation of residual tropospheric effects cannot be guaranteed, at such circumstances windowing techniques should be considered.

Ocean Tide Loading:

- Network RTK reduces OTL error to current system noise levels throughout most of the mainland of Great Britain. However, where the OTL still is a problem in network RTK system it can be completely removed by taking two sets of coordinates with 6-6.5 hours of separation.

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The End!

Thanks for listening

Questions?

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