  

Ultimate Advance in GNSS RTK Monitoring Accuracy

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- when it has to be **right**

GNSS RTK for Monitoring Applications

With powerful GNSS RTK processor, engineers are relaying more on that technology to get results that would even not be possible before.


GPS WORLD

Monitoring Hong Kong's Bridges

Real-Time Kinematic

Spans the Gap

by Kai-yuen Wong, King-leung Man, and Wai-yee Chan

Modern cable-supported bridges carry enormous loads across great distances, in part due to their designed capability to move, ever so slightly, under varied conditions. In Hong Kong, a real-time kinematic (RTK) GPS monitoring system provides the centimeter-level accuracy, in all weather conditions, to detect bridge movements beyond normal ranges. Engineers can then conduct inspections or maintenance needed to maintain longterm structural health.

Bridge Acronyms

GPS-OSIS	GPS On-Structure Instrumentation System
HKSAR	Hong Kong Special Administrative Region
HyD	Highways Department
KSMB	Kap Shui Mun Bridge
LFC-OSIS	Lantau Fixed Crossing — On-Structure Instrumentation System
TKB	Ting Kau Bridge
TMB	Tsing Ma Bridge
TMCA	Tsing Ma Control Area
WASHMS	Wind and Structural Health Monitoring System

Receiver atop Tsing Ma Bridge tower, with Kap Shui Mun Bridge in the distance

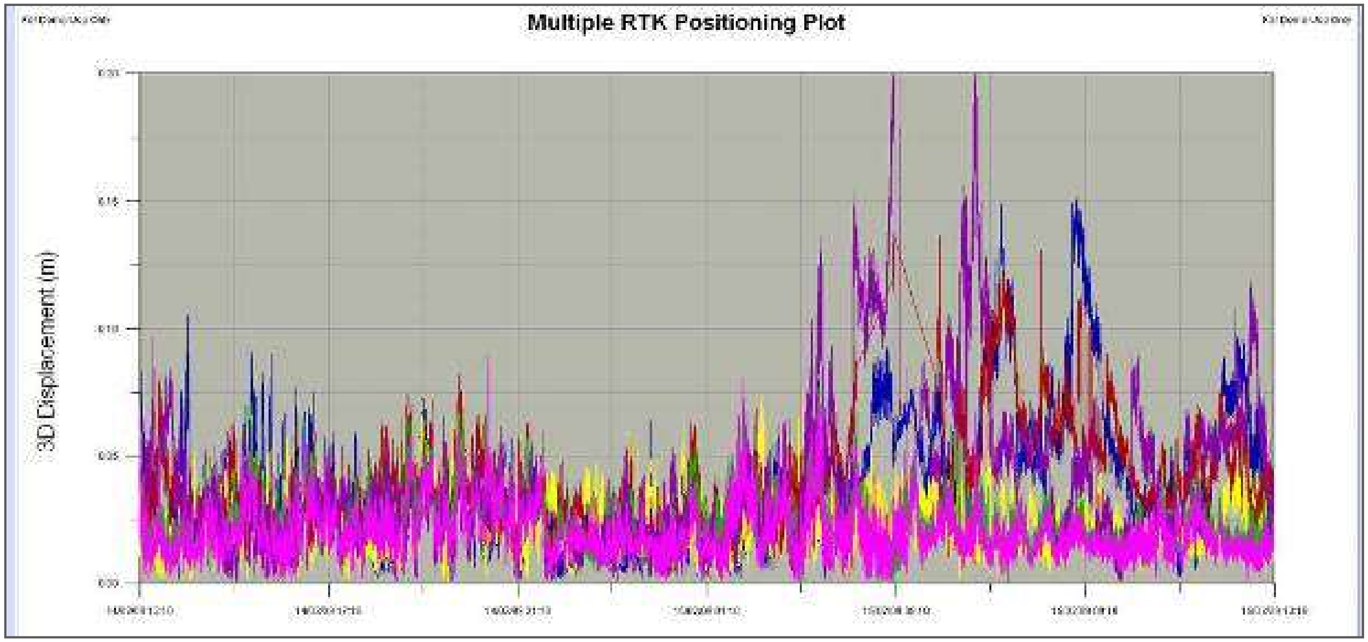
GNSS RTK for Monitoring Applications
Background

However the distance between the GNSS monitoring stations and the GNSS base station must be kept as short as possible. There is a risk that even the GNSS base station could be located in the area subject to deformation.

But the single RTK results that are processed even if the noise is scaled down by the short distance between the GNSS base station and the GNSS monitoring receivers still contain biases from the remaining un-modelled atmospheric corrections.

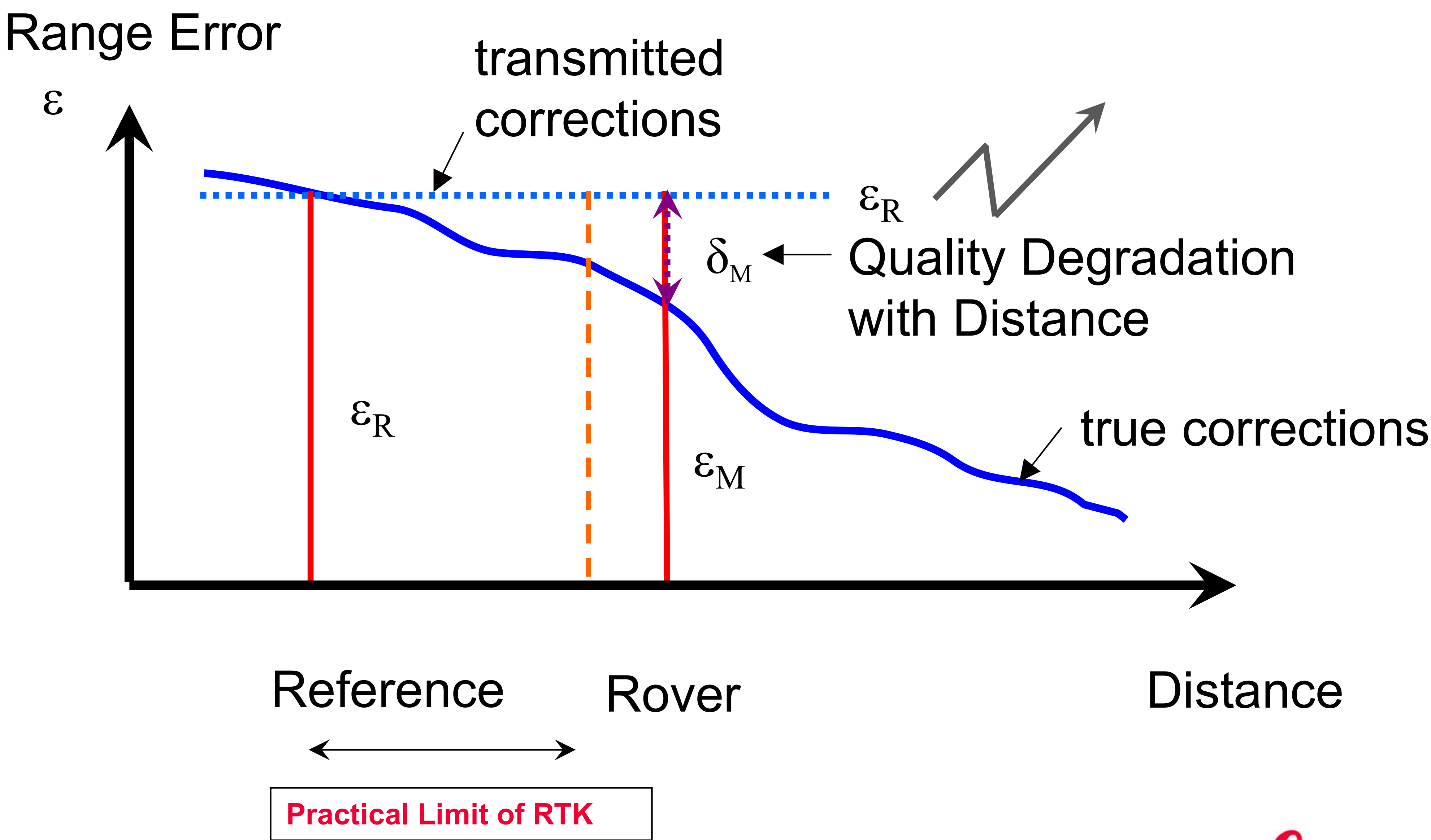
GNSS RTK for Monitoring Applications
Background

Projects located in the low latitude band can be compromised with high and unpredictable ionosphere turbulences in the afternoon period of time.



The noise in the results is induced by the severe atmospheric turbulences in the low latitude band. In that case the time series are difficult to be correctly interpreted. Is that a noise or a signal ?

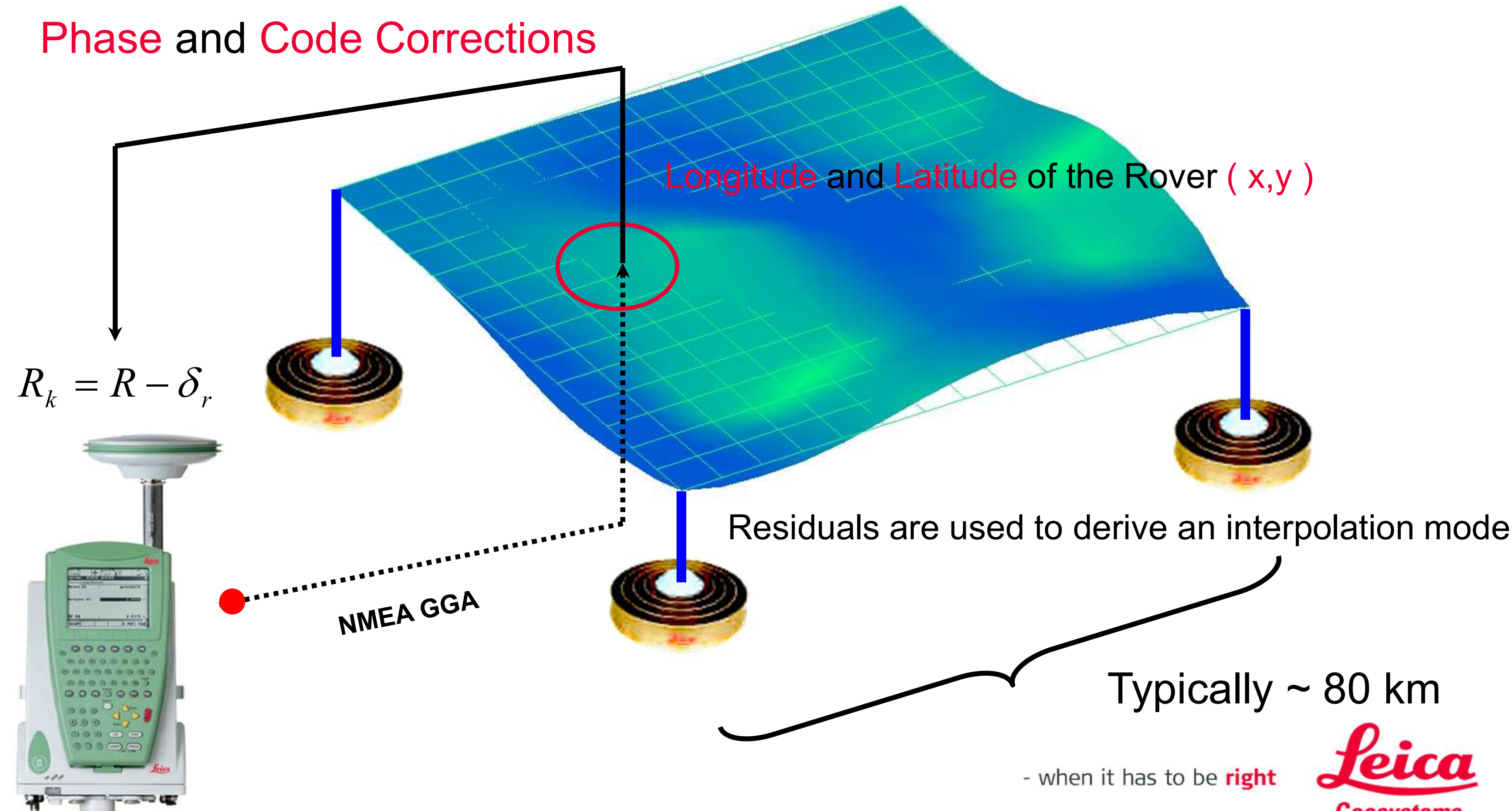
Distance Dependency



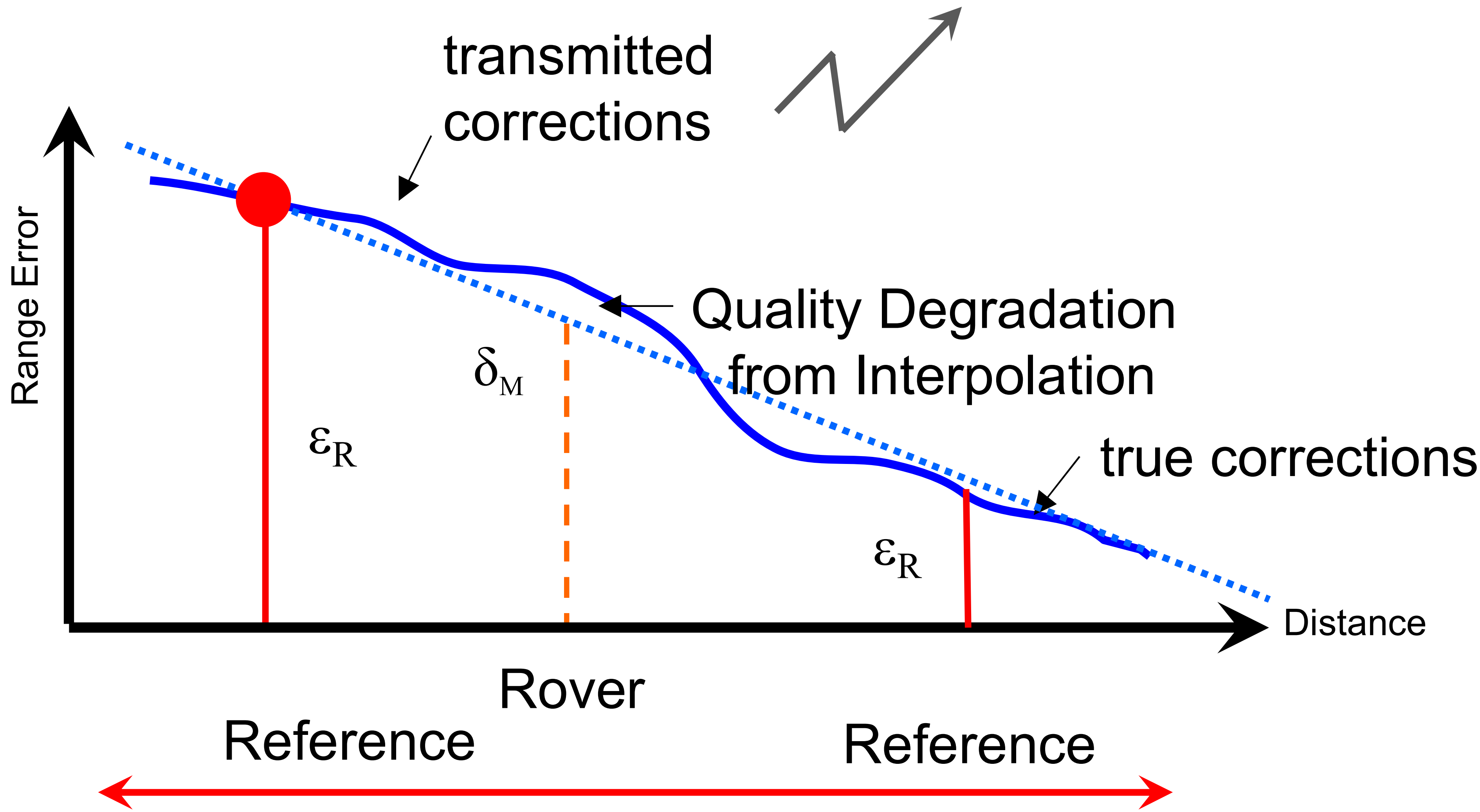
Derived Observation Corrections

$$\delta_{r0} = \alpha\left(N_0(\varphi - \varphi_R) + E_0(\lambda - \lambda_R)\cos(\varphi_R)\right)$$

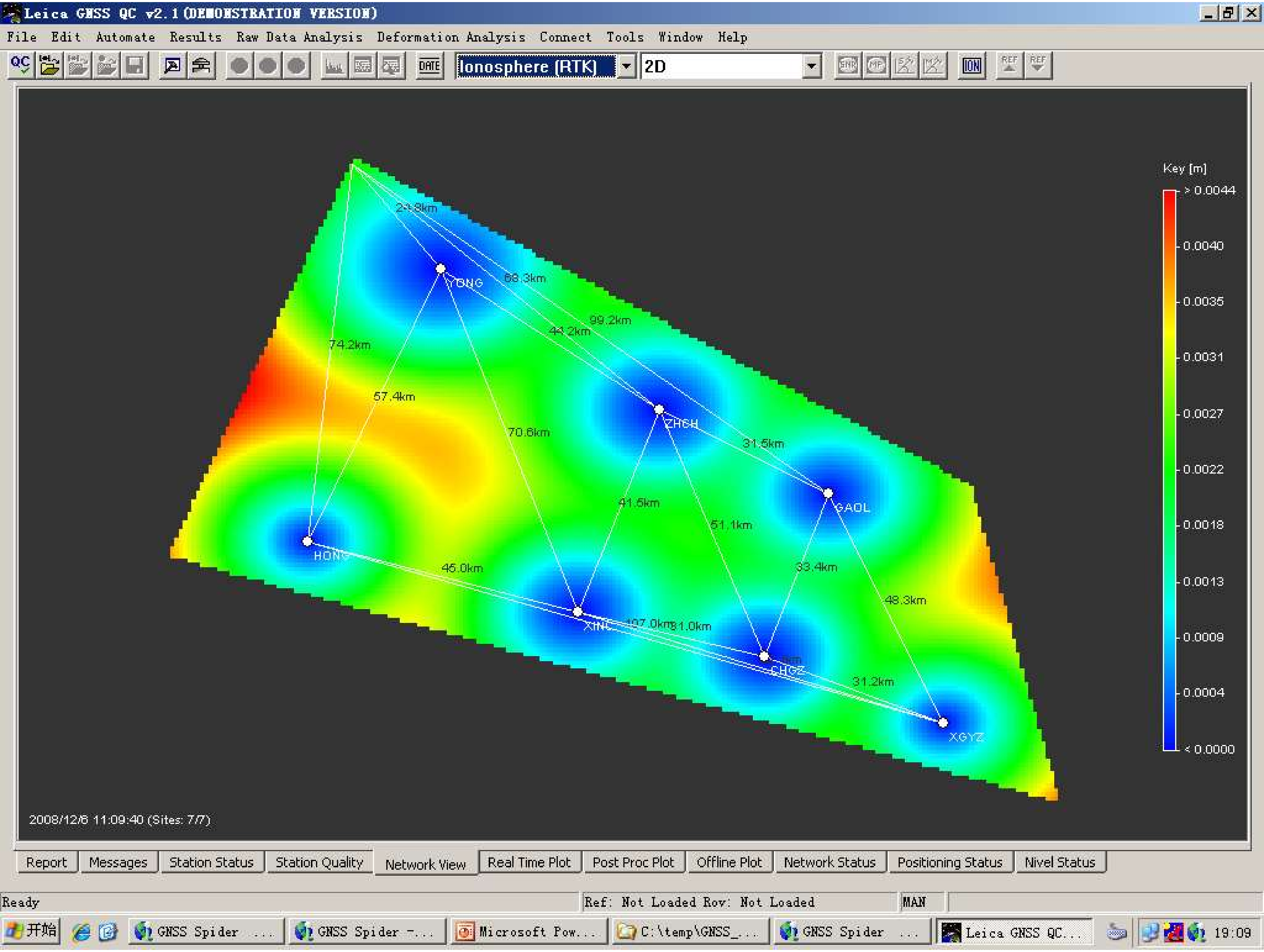
$$\delta_{r1} = \beta \cdot H\left(N_1(\varphi - \varphi_R) + E_1(\lambda - \lambda_R)\cos(\varphi_R)\right)$$



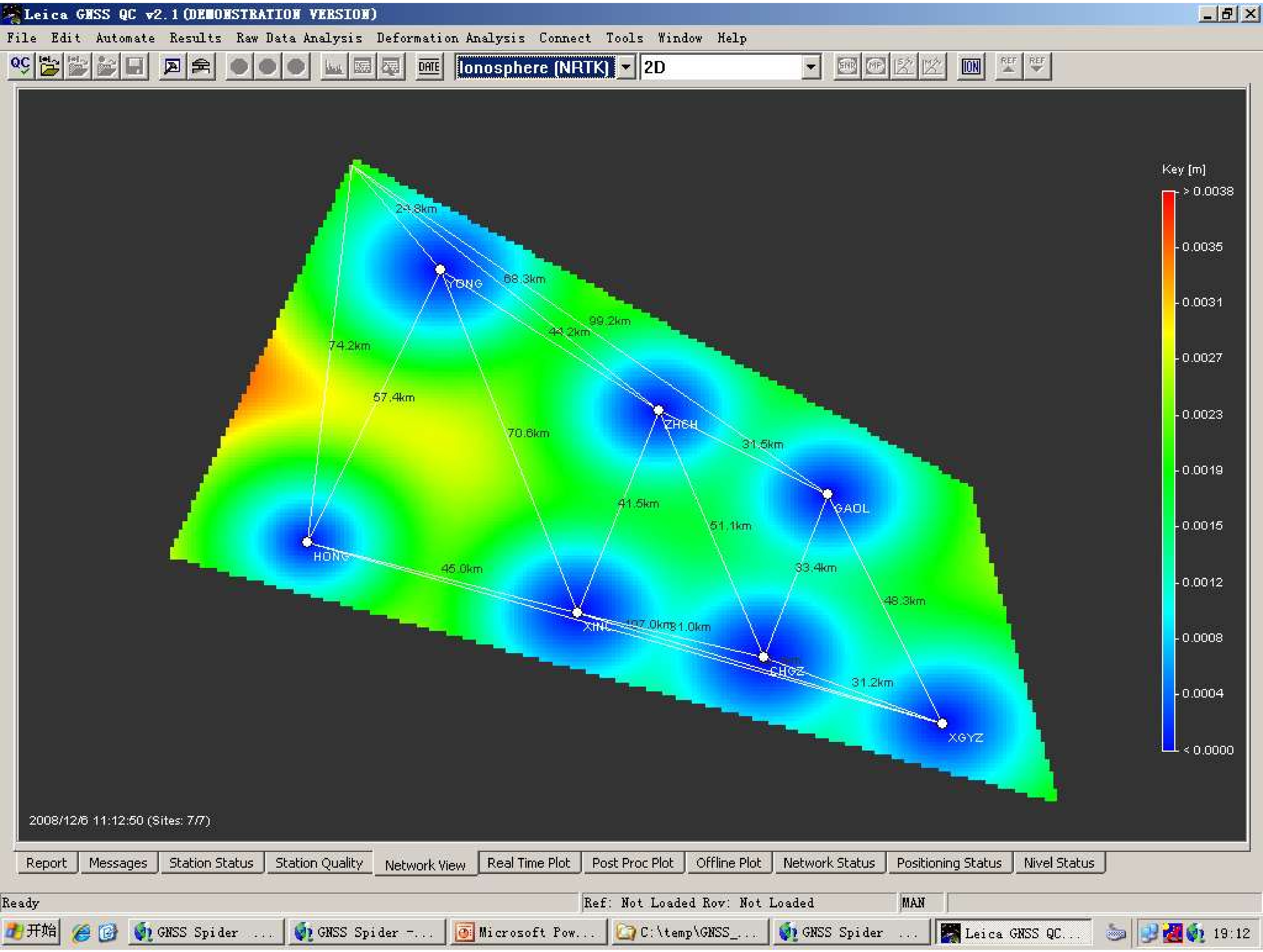
Master Station(s) in MAX



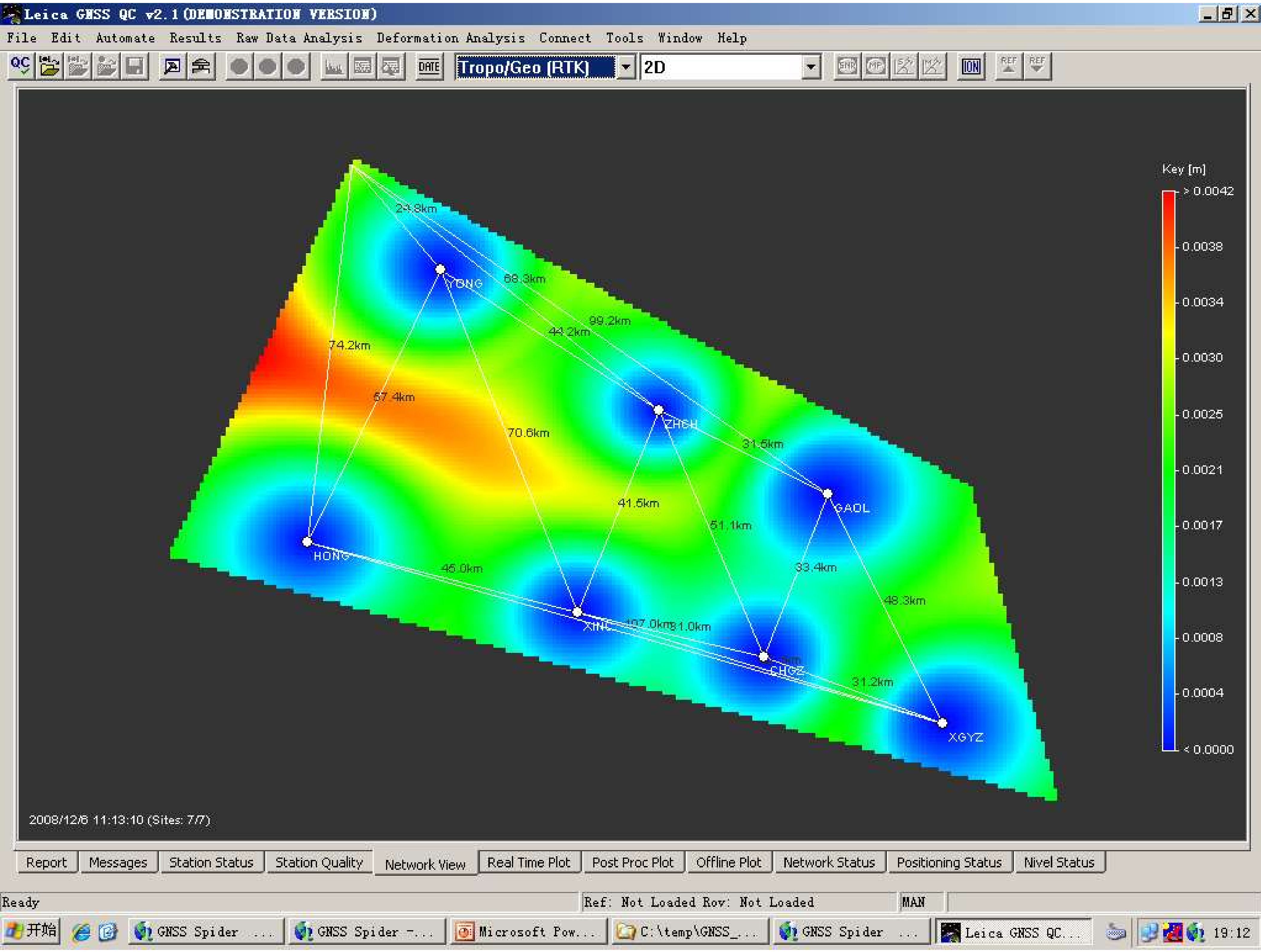
With a GNSS Network RTK (interpolation & extrapolation) no more distance dependency. The choice of the Master Station can be any Reference station selected within the cell.

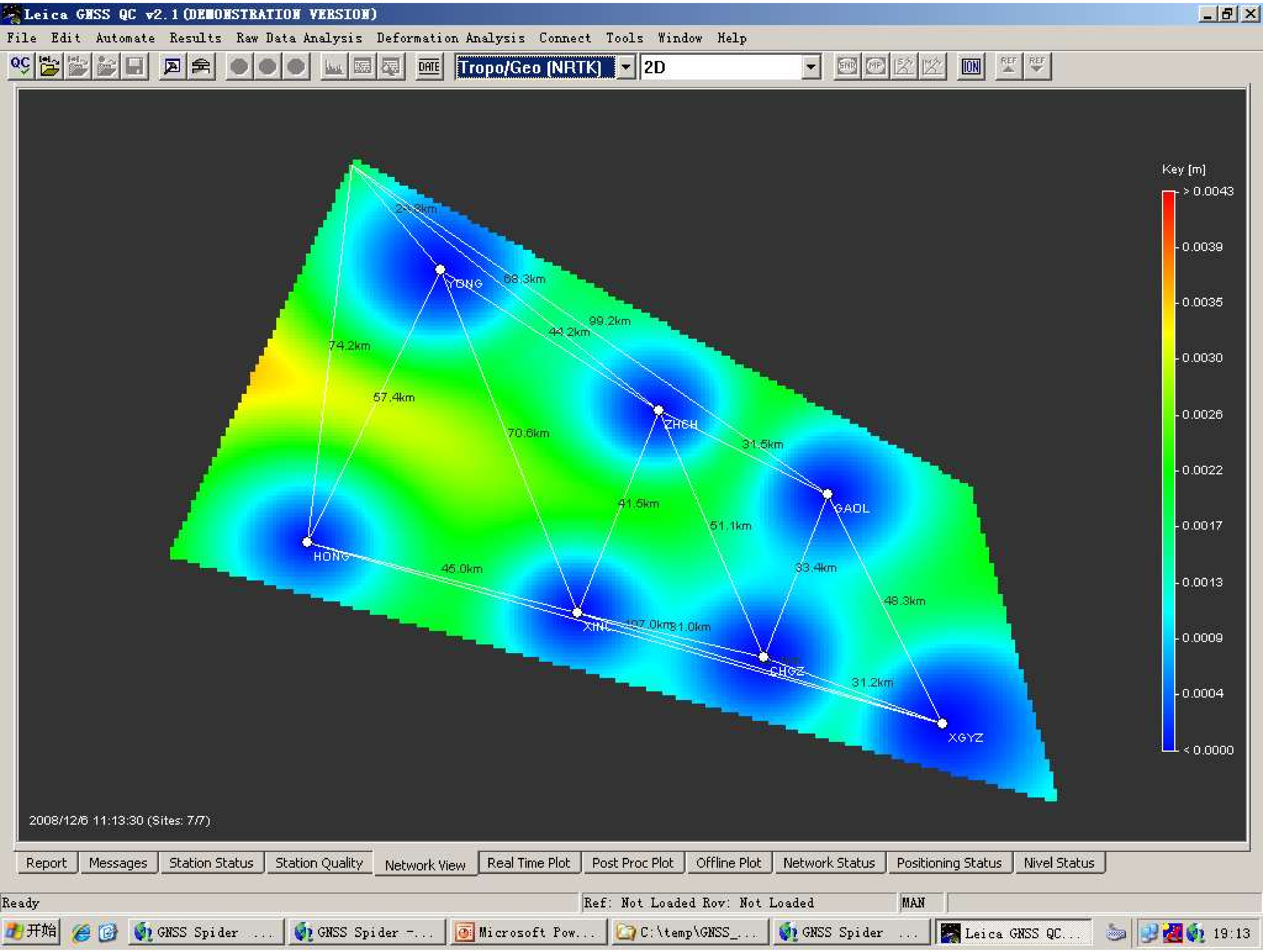


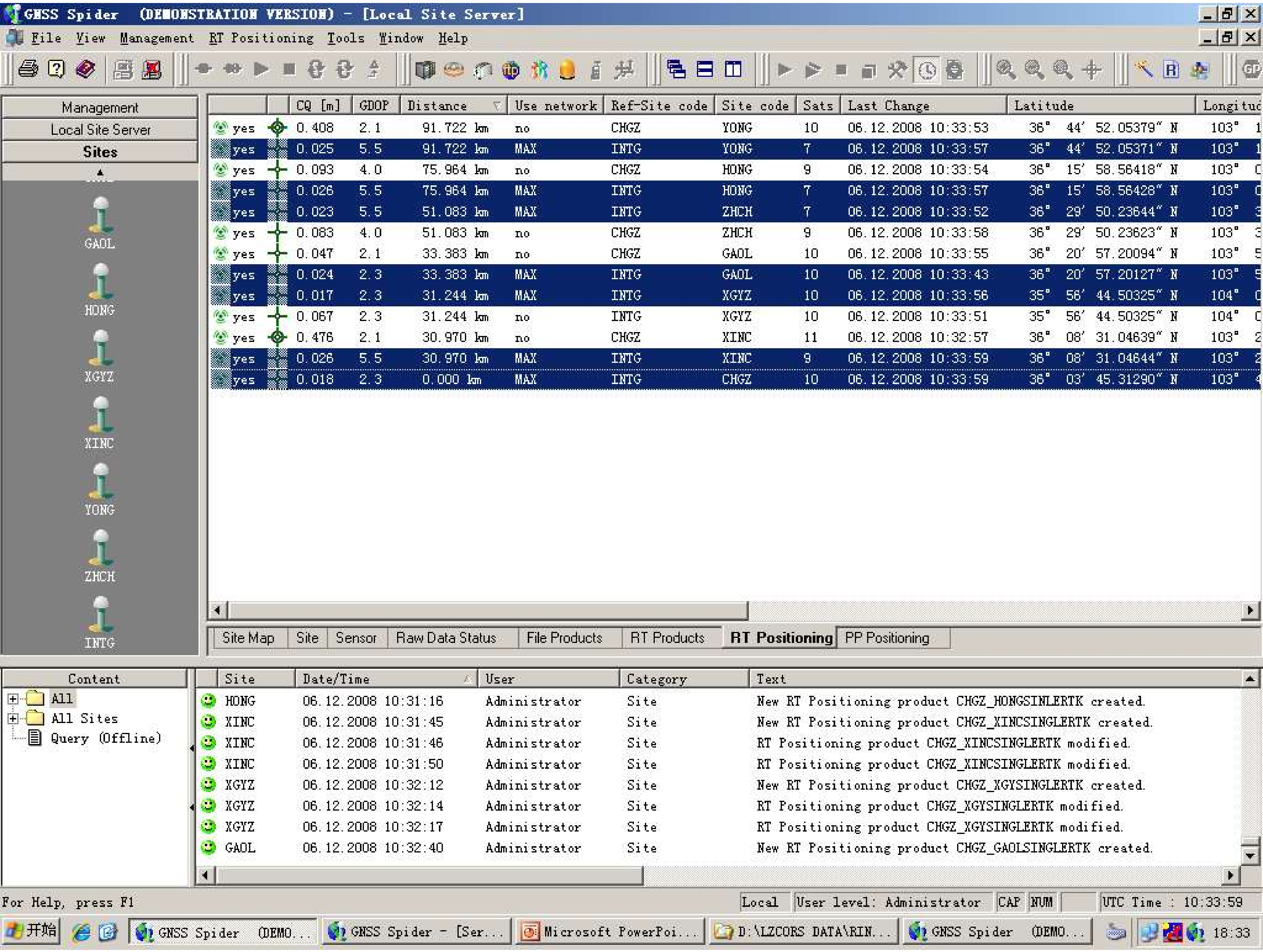
Leica GNSS QC v2.1 (DEMONSTRATION VERSION)
File Edit Automate Results Raw Data Analysis Deformation Analysis Connect Tools Window Help
Ionosphere (RTK)
2D
Key [m]
> 0.0044
0.0040
0.0035
0.0031
0.0027
0.0022
0.0018
0.0013
0.0009
0.0004
< 0.0000
YONG
ZHCH
GAOL
HONG
XING
CHGZ
XGYZ
68.3km
99.2km
44.2km
74.2km
57.4km
70.6km
31.5km
41.5km
51.1km
45.0km
33.4km
48.3km
107.0km
81.0km
31.2km
2008/12/6 11:09:40 (Sites: 7/7)
Report
Messages
Station Status
Station Quality
Network View
Real Time Plot
Post Proc Plot
Offline Plot
Network Status
Positioning Status
Nivel Status
Ready
Ref: Not Loaded Rov: Not Loaded
MAN
开始
GNSS Spider ...
GNSS Spider -...
Microsoft Pow...
C:\temp\GNSS_...
GNSS Spider ...
Leica GNSS QC...
19:09

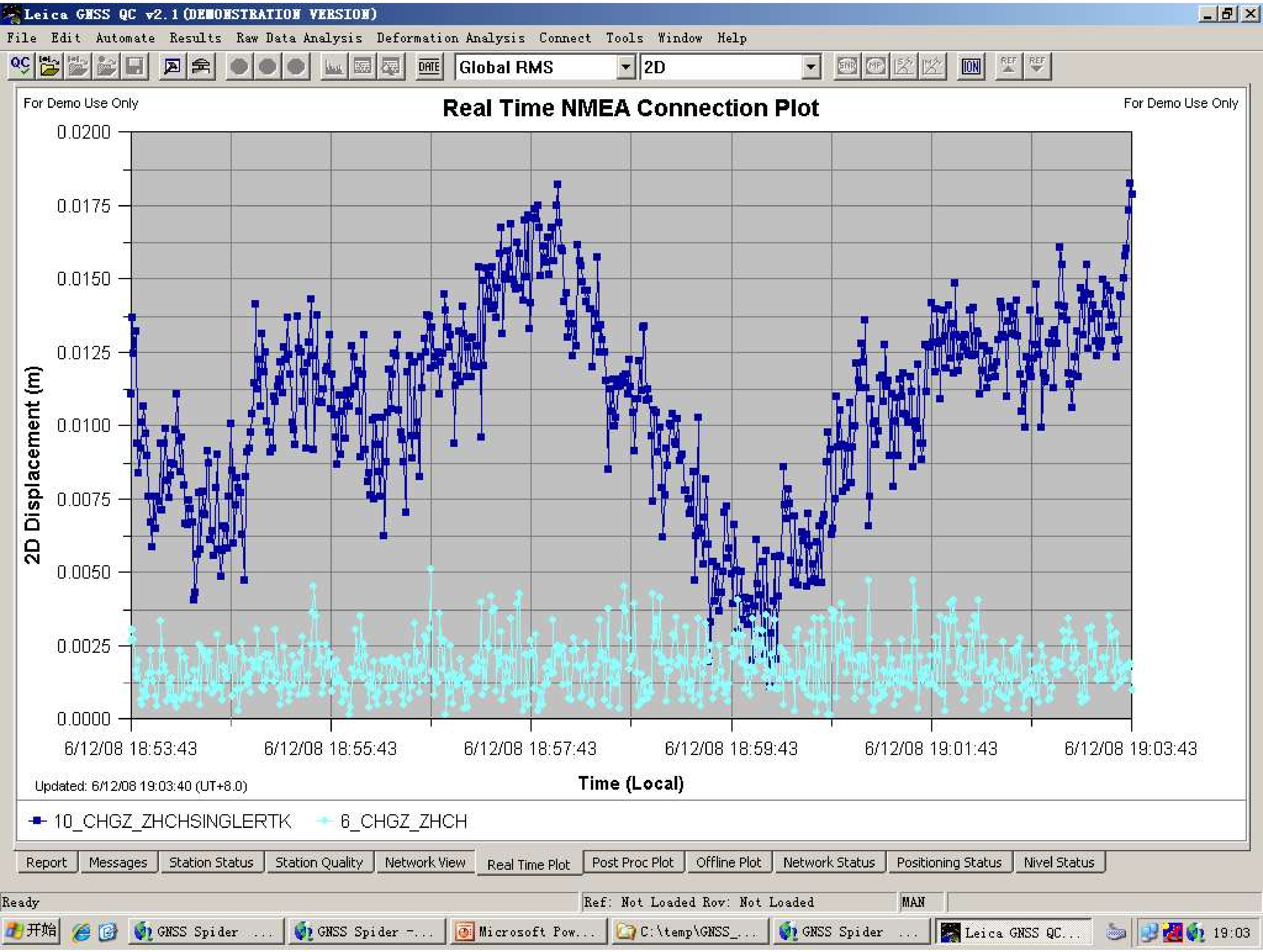


Leica GNSS QC v2.1 (DEMONSTRATION VERSION)
File Edit Automate Results Raw Data Analysis Deformation Analysis Connect Tools Window Help
Ionosphere (NRTK)
2D
Key [m]
> 0.0038
0.0035
0.0031
0.0027
0.0023
0.0019
0.0015
0.0012
0.0008
0.0004
< 0.0000
YONG
ZHCH
GAOL
HONG
XING
CHGZ
XGYZ
68.3km
99.2km
44.2km
74.2km
57.4km
70.6km
31.5km
41.5km
51.1km
33.4km
45.0km
48.3km
31.2km
81.0km
2008/12/6 11:12:50 (Sites: 7/7)
Report
Messages
Station Status
Station Quality
Network View
Real Time Plot
Post Proc Plot
Offline Plot
Network Status
Positioning Status
Nivel Status
Ready
Ref: Not Loaded Rov: Not Loaded
MAN
开始
GNSS Spider ...
GNSS Spider -...
Microsoft Pow...
C:\temp\GNSS_...
GNSS Spider ...
Leica GNSS QC...
19:12


Leica GNSS QC v2.1 (DEMONSTRATION VERSION)
File Edit Automate Results Raw Data Analysis Deformation Analysis Connect Tools Window Help
Tropo/Geo (RTK)
2D
Key [m]
> 0.0042
0.0038
0.0034
0.0030
0.0025
0.0021
0.0017
0.0013
0.0008
0.0004
< 0.0000
YONG
ZHCH
GAOL
HONG
XING
CHGZ
XGYZ
24.8km
68.3km
99.2km
44.2km
74.2km
57.4km
70.6km
31.5km
41.5km
51.1km
33.4km
48.3km
45.0km
107.0km
31.0km
31.2km
2008/12/6 11:13:10 (Sites: 7/7)
Report
Messages
Station Status
Station Quality
Network View
Real Time Plot
Post Proc Plot
Offline Plot
Network Status
Positioning Status
Nivel Status
Ready
Ref: Not Loaded Rov: Not Loaded
MAN
开始
GNSS Spider ...
GNSS Spider -...
Microsoft Pow...
C:\temp\GNSS_...
GNSS Spider ...
Leica GNSS QC...
19:12


Leica GNSS QC v2.1 (DEMONSTRATION VERSION)
File Edit Automate Results Raw Data Analysis Deformation Analysis Connect Tools Window Help
Tropo/Geo (NRTK)
2D
Key [m]
> 0.0043
0.0039
0.0035
0.0030
0.0026
0.0022
0.0017
0.0013
0.0009
0.0004
< 0.0000
YONG
ZHCH
GAOL
HONG
XING
CHGZ
XGYZ
68.3km
99.2km
44.2km
74.2km
57.4km
70.6km
31.5km
41.5km
51.1km
33.4km
48.3km
45.0km
107.0km
81.0km
31.2km
2008/12/6 11:13:30 (Sites: 7/7)
Report
Messages
Station Status
Station Quality
Network View
Real Time Plot
Post Proc Plot
Offline Plot
Network Status
Positioning Status
Nivel Status
Ready
Ref: Not Loaded Rov: Not Loaded
MAN
开始
GNSS Spider ...
GNSS Spider -...
Microsoft Pow...
C:\temp\GNSS_...
GNSS Spider ...
Leica GNSS QC...
19:13


GNSS Spider (DEMONSTRATION VERSION) - [Local Site Server]
File View Management RT Positioning Tools Window Help
Management
Local Site Server
Sites
GAOL
HONG
XGYZ
XINC
YONG
ZHCH
INTG
CQ [m] GDOP Distance Use network Ref-Site code Site code Sats Last Change Latitude Longitude
yes 0.408 2.1 91.722 km no CHGZ YONG 10 06.12.2008 10:33:53 36° 44′ 52.05379″ N 103°
yes 0.025 5.5 91.722 km MAX INTG YONG 7 06.12.2008 10:33:57 36° 44′ 52.05371″ N 103°
yes 0.093 4.0 75.964 km no CHGZ HONG 9 06.12.2008 10:33:54 36° 15′ 58.56418″ N 103°
yes 0.026 5.5 75.964 km MAX INTG HONG 7 06.12.2008 10:33:57 36° 15′ 58.56428″ N 103°
yes 0.023 5.5 51.083 km MAX INTG ZHCH 7 06.12.2008 10:33:52 36° 29′ 50.23644″ N 103°
yes 0.083 4.0 51.083 km no CHGZ ZHCH 9 06.12.2008 10:33:58 36° 29′ 50.23623″ N 103°
yes 0.047 2.1 33.383 km no CHGZ GAOL 10 06.12.2008 10:33:55 36° 20′ 57.20094″ N 103°
yes 0.024 2.3 33.383 km MAX INTG GAOL 10 06.12.2008 10:33:43 36° 20′ 57.20127″ N 103°
yes 0.017 2.3 31.244 km MAX INTG XGYZ 10 06.12.2008 10:33:56 35° 56′ 44.50325″ N 104°
yes 0.067 2.3 31.244 km no INTG XGYZ 10 06.12.2008 10:33:51 35° 56′ 44.50325″ N 104°
yes 0.476 2.1 30.970 km no CHGZ XINC 11 06.12.2008 10:32:57 36° 08′ 31.04639″ N 103°
yes 0.026 5.5 30.970 km MAX INTG XINC 9 06.12.2008 10:33:59 36° 08′ 31.04644″ N 103°
yes 0.018 2.3 0.000 km MAX INTG CHGZ 10 06.12.2008 10:33:59 36° 03′ 45.31290″ N 103°
Site Map Site Sensor Raw Data Status File Products RT Products RT Positioning PP Positioning
Content
All
All Sites
Query (Offline)
Site Date/Time User Category Text
HONG 06.12.2008 10:31:16 Administrator Site New RT Positioning product CHGZ_HONGSINLERTK created.
XINC 06.12.2008 10:31:45 Administrator Site New RT Positioning product CHGZ_XINCSINGLERTK created.
XINC 06.12.2008 10:31:46 Administrator Site RT Positioning product CHGZ_XINCSINGLERTK modified.
XINC 06.12.2008 10:31:50 Administrator Site RT Positioning product CHGZ_XINCSINGLERTK modified.
XGYZ 06.12.2008 10:32:12 Administrator Site New RT Positioning product CHGZ_XGYSINGLERTK created.
XGYZ 06.12.2008 10:32:14 Administrator Site RT Positioning product CHGZ_XGYSINGLERTK modified.
XGYZ 06.12.2008 10:32:17 Administrator Site RT Positioning product CHGZ_XGYSINGLERTK modified.
GAOL 06.12.2008 10:32:40 Administrator Site New RT Positioning product CHGZ_GAOLSINGLERTK created.
For Help, press F1
Local User level: Administrator CAP NUM UTC Time : 10:33:59
开始 GNSS Spider (DEMO... GNSS Spider - [Ser... Microsoft PowerPoi... D:\LZCORS DATA\RIN... GNSS Spider (DEMO... 18:33


Leica GNSS QC v2.1 (DEMONSTRATION VERSION)
File Edit Automate Results Raw Data Analysis Deformation Analysis Connect Tools Window Help
Global RMS
2D
For Demo Use Only
Real Time NMEA Connection Plot
For Demo Use Only
0.0200
0.0175
0.0150
0.0125
0.0100
0.0075
0.0050
0.0025
0.0000
2D Displacement (m)
6/12/08 18:53:43
6/12/08 18:55:43
6/12/08 18:57:43
6/12/08 18:59:43
6/12/08 19:01:43
6/12/08 19:03:43
Updated: 6/12/08 19:03:40 (UT+8.0)
Time (Local)
10_CHGZ_ZHCHSINGLERTK
6_CHGZ_ZHCH
Report
Messages
Station Status
Station Quality
Network View
Real Time Plot
Post Proc Plot
Offline Plot
Network Status
Positioning Status
Nivel Status
Ready
Ref: Not Loaded Rov: Not Loaded
MAN
开始
GNSS Spider ...
GNSS Spider - ...
Microsoft Pow...
C:\temp\GNSS_...
GNSS Spider ...
Leica GNSS QC...
19:03

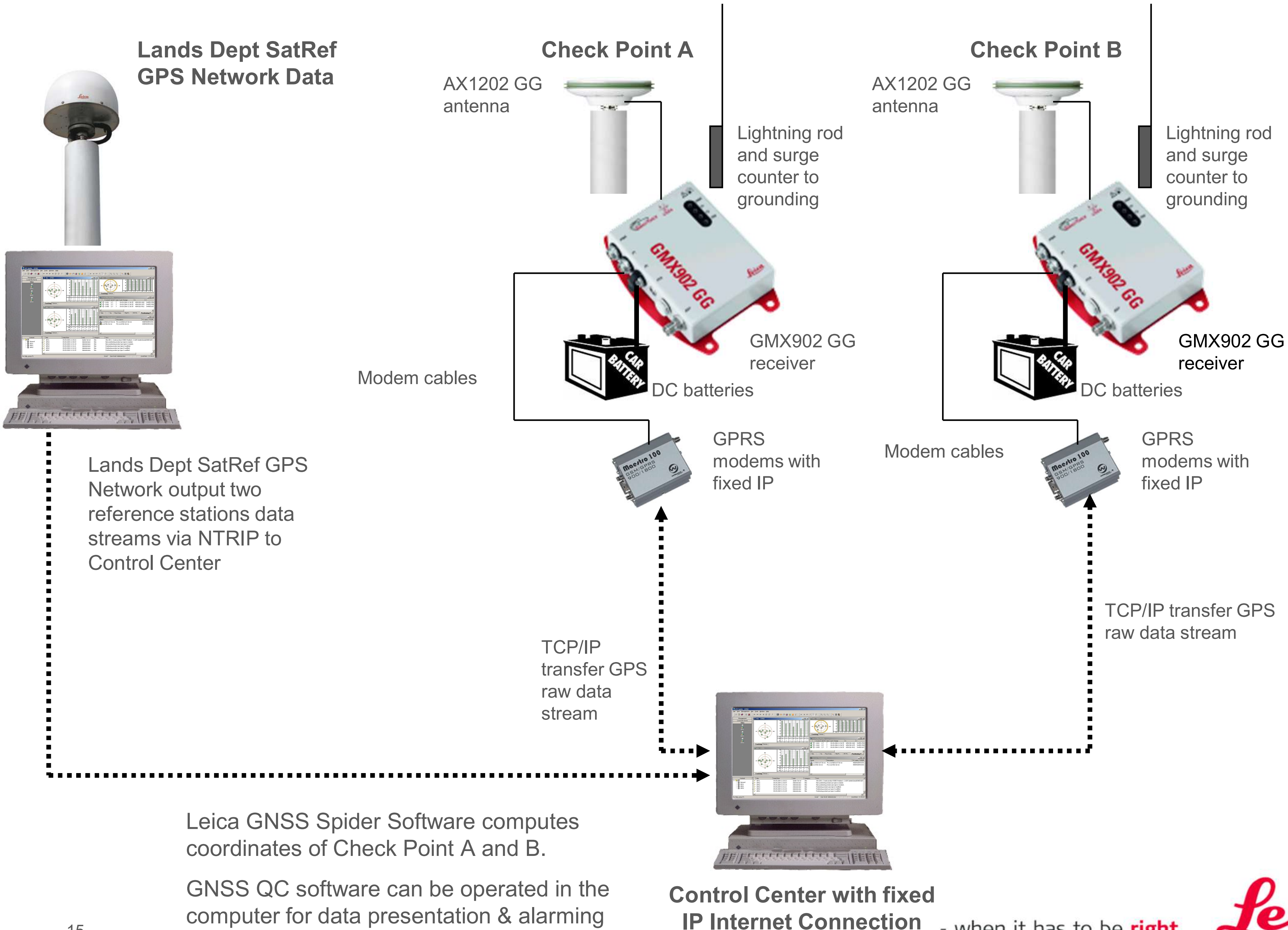
Practical trial in Hong Kong, PR China
Seawall Monitoring, CEDD Ports Work

Objectives :

- Ensure safety of seawalls in HK
- Total 120km seawalls in HK
- Monitoring by traditional manual methods are time consuming and manpower involved with human life risk in typhoon periods.
- Real-time displacement presentation
- Multiple levels auto alert
- Fully automatic, day and night, 24/7

Seawall infrastructure in Hong Kong, PR China

GNSS Seawall Monitoring System Diagram

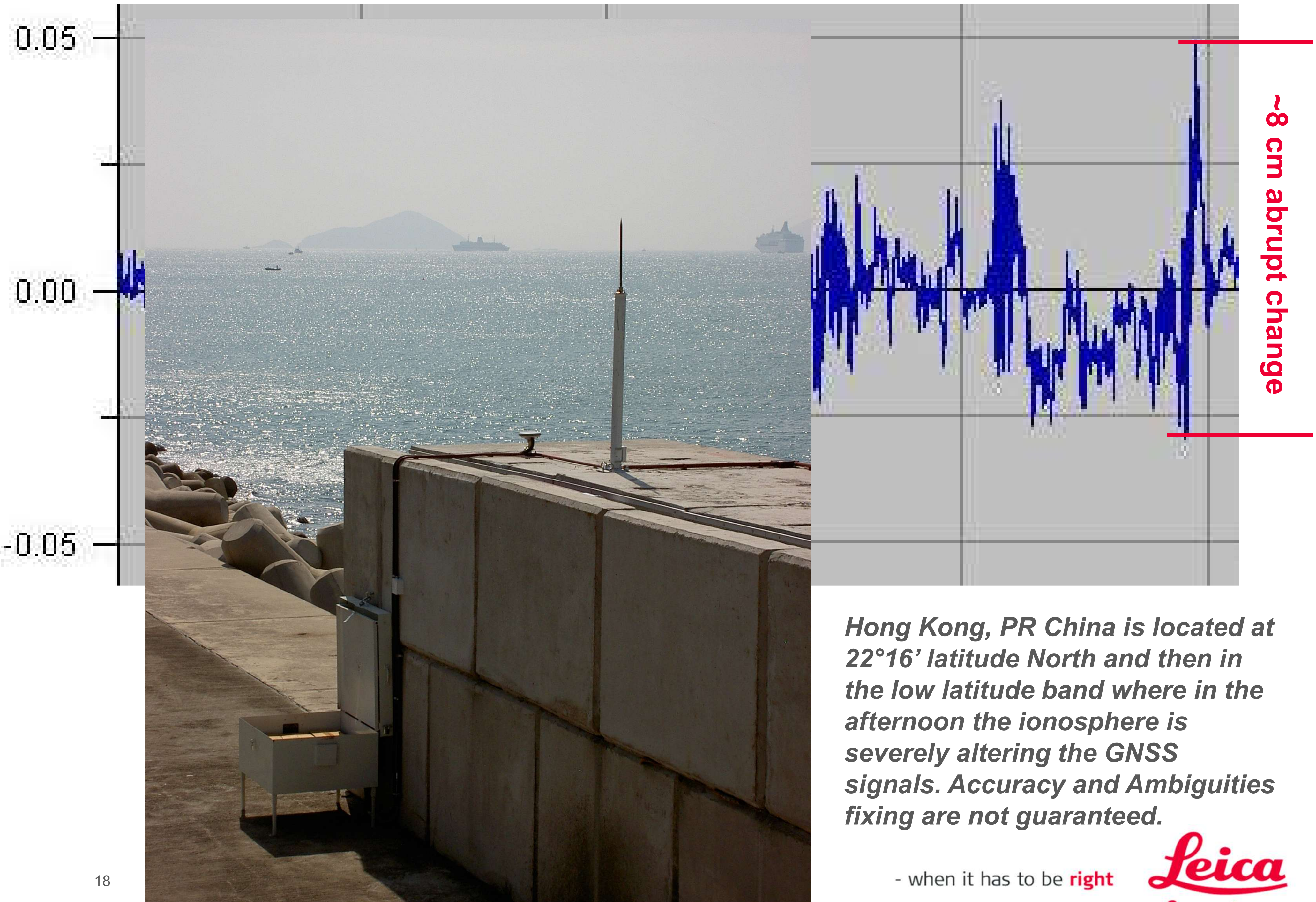


Leica Geosystems GNSS monitoring stations for checking Seawall infrastructure in Hong Kong, PR China

- when it has to be **right**

Leica Geosystems

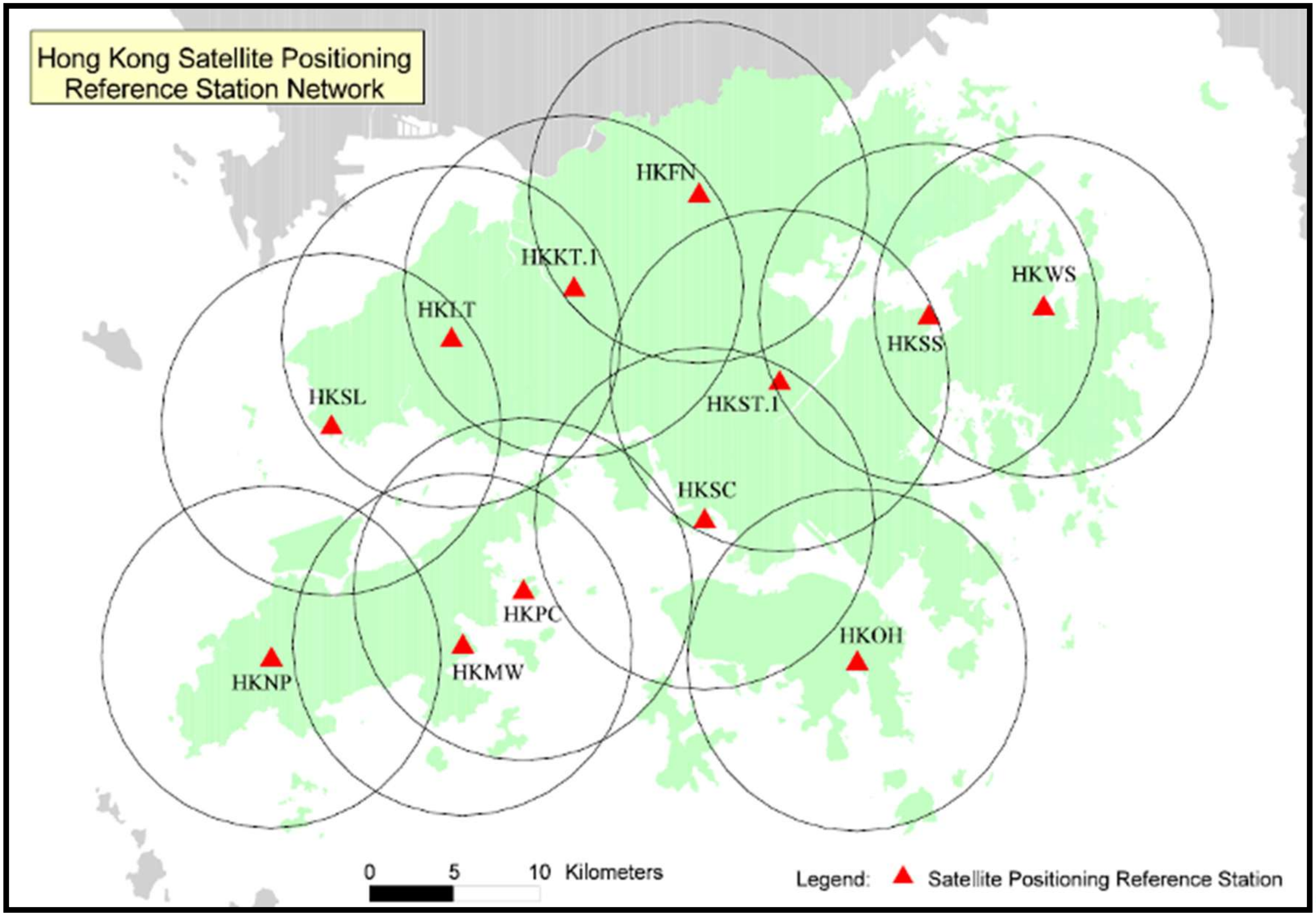
Leica Geosystems GNSS monitoring stations for checking Seawall infrastructure in Hong Kong, PR China



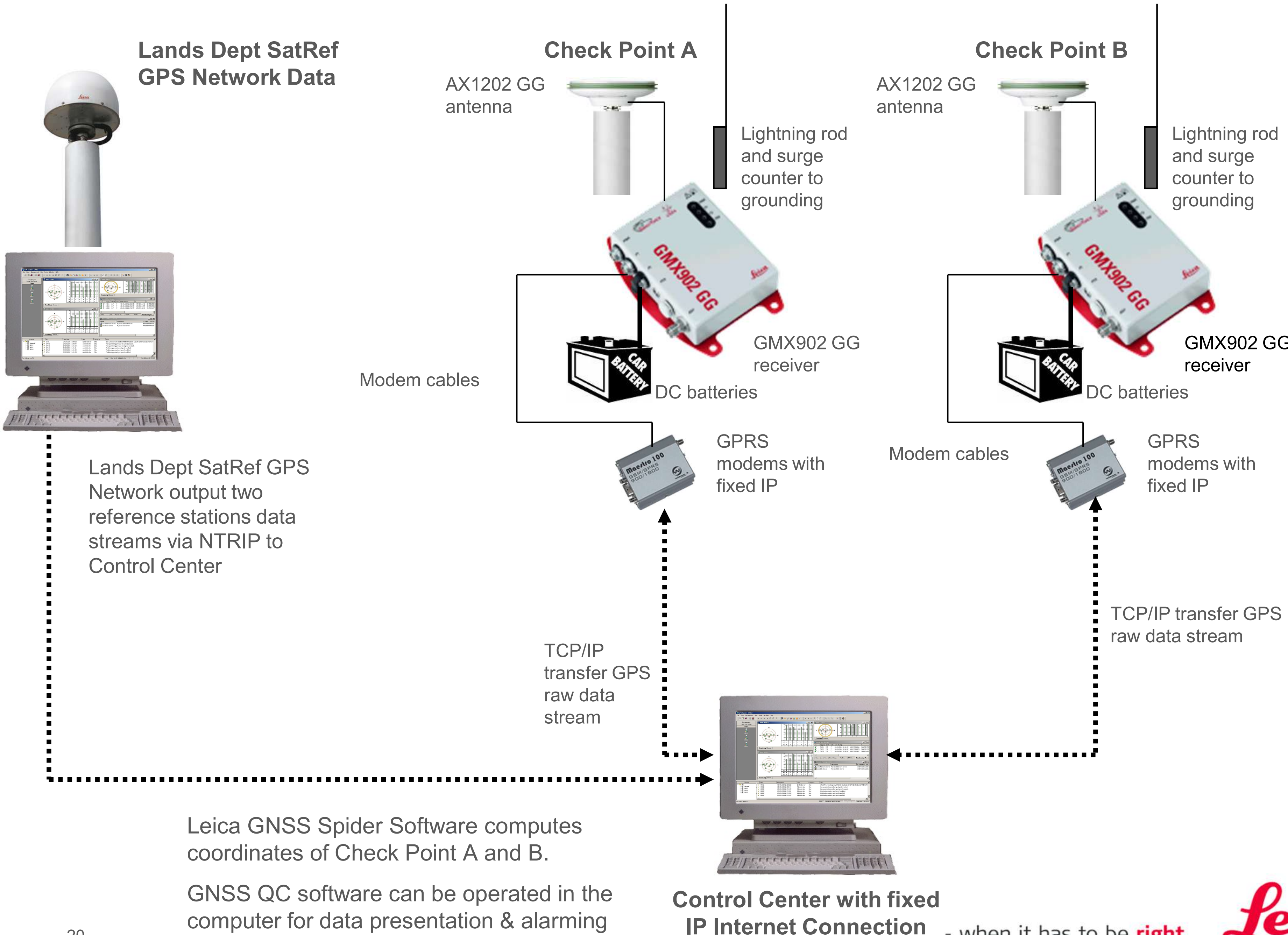
Hong Kong, PR China is located at 22°16' latitude North and then in the low latitude band where in the afternoon the ionosphere is severely altering the GNSS signals. Accuracy and Ambiguities fixing are not guaranteed.

Reference Station Data from HK SatRef Network

Own by the HK Lands Dept



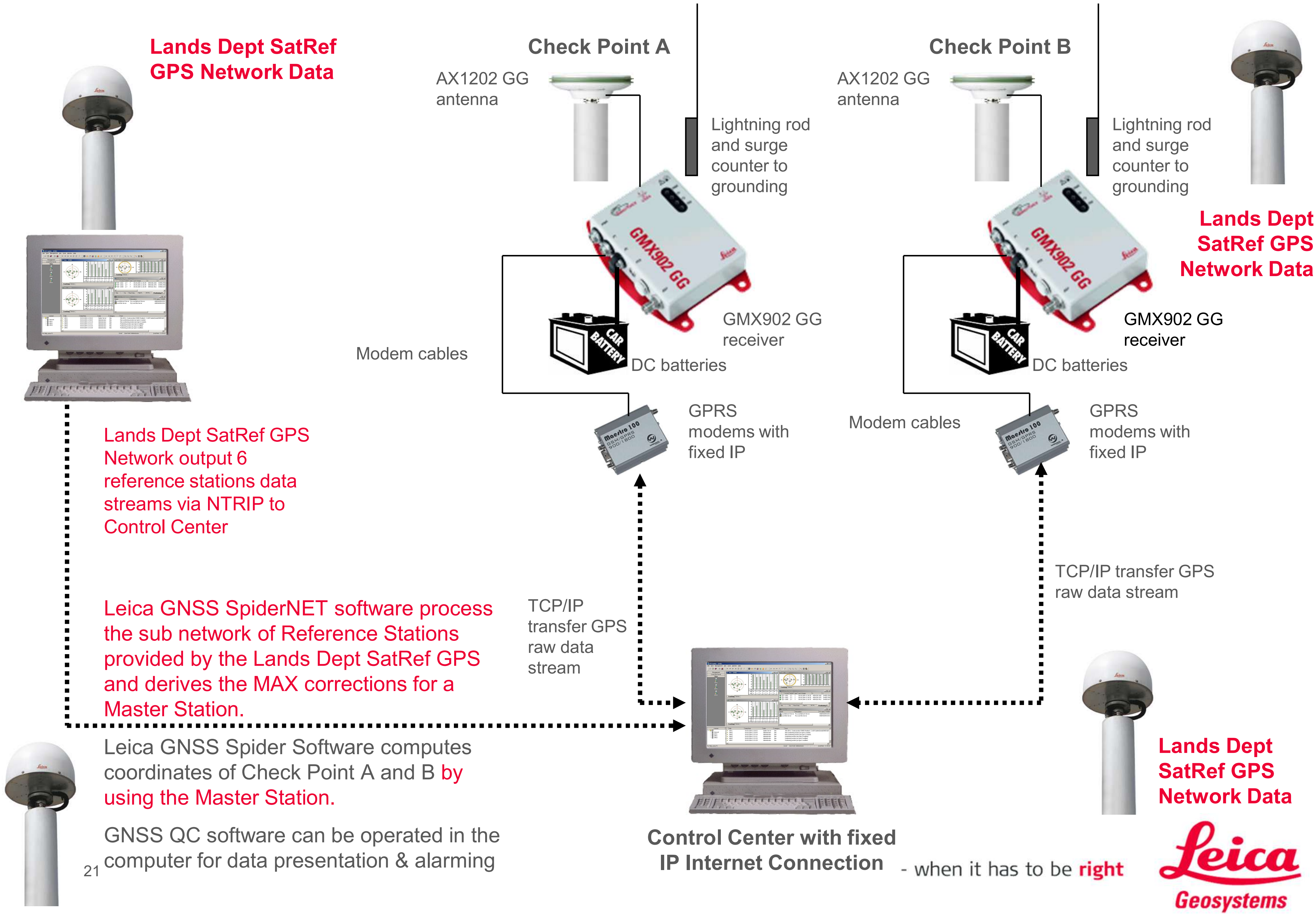
From GNSS Single RTK Seawall Monitoring System Diagram to …



Leica GNSS Spider Software computes coordinates of Check Point A and B.

GNSS QC software can be operated in the computer for data presentation & alarming

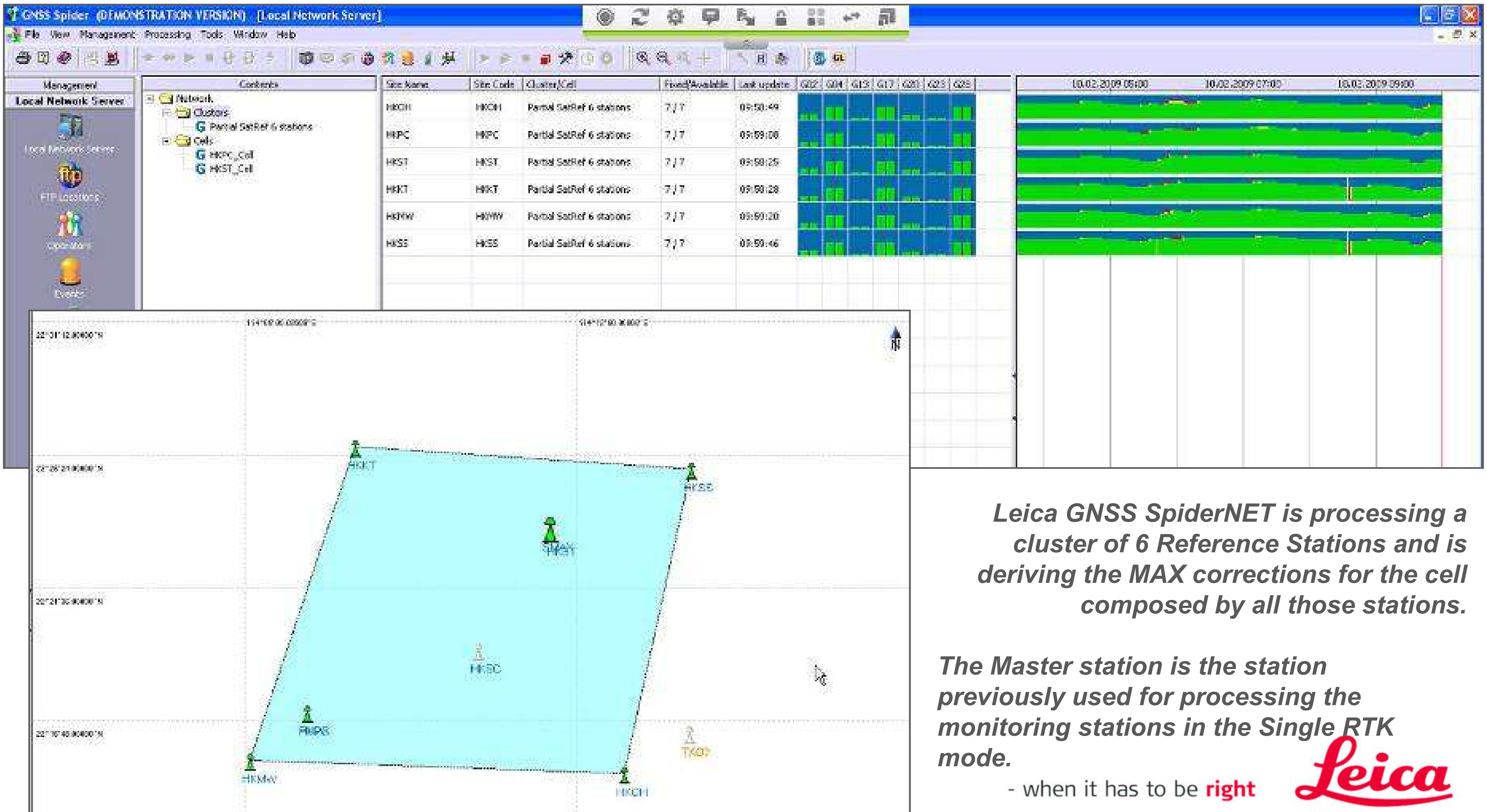
GNSS Network RTK aided Seawall Monitoring System Diagram



- when it has to be right

Leica GNSS SpiderNET for Network RTK

Processing in Real Time L1 & L2 GPS data



Leica GNSS SpiderNET is processing a cluster of 6 Reference Stations and is deriving the MAX corrections for the cell composed by all those stations.

The Master station is the station previously used for processing the monitoring stations in the Single RTK mode.

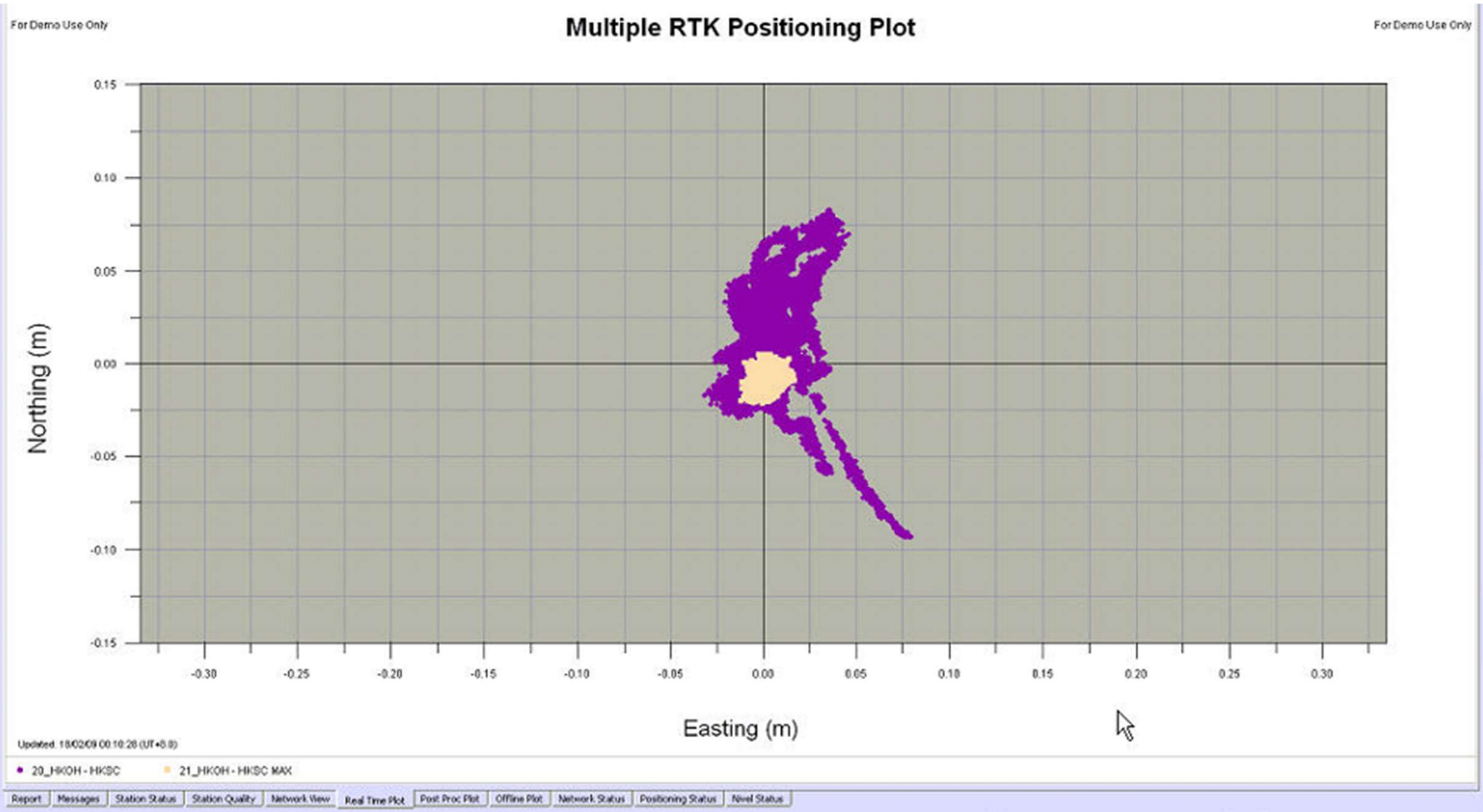
Leica GNSS Spider Site Server Positioning option

Processing in Real Time L1 & L2 , L1 only GPS data

		CQ [m]	GDOP	Sats	Last Change	Latitude	Longitude	Height	Distance	Product Name	Site code
yes		0.017	2.7	8	18.02.2009 00:26:33	22° 19' 19.81894" N	114° 08' 28.27695" E	20.2268	11.419 km	HKPC - HKSC	HKSC
yes		0.013	2.7	8	18.02.2009 00:25:47	22° 19' 19.81907" N	114° 08' 28.27663" E	20.2210	11.419 km	HKPC - HKSC MAX	HKSC
yes		0.019	2.7	8	18.02.2009 00:26:28	22° 19' 19.81923" N	114° 08' 28.27652" E	20.2247	9.233 km	HKST - HKSC	HKSC
yes		0.013	2.7	8	18.02.2009 00:25:58	22° 19' 19.81912" N	114° 08' 28.27657" E	20.2220	9.233 km	HKST - HKSC MAX	HKSC
yes		0.014	2.7	8	18.02.2009 00:26:26	22° 19' 19.81953" N	114° 08' 28.27658" E	20.2233	12.211 km	HKOH - HKSC	HKSC
yes		0.013	2.7	8	18.02.2009 00:26:32	22° 19' 19.81906" N	114° 08' 28.27667" E	20.2282	12.211 km	HKOH - HKSC MAX	HKSC
yes		0.030	2.7	8	18.02.2009 00:26:21	22° 19' 19.81934" N	114° 08' 28.27652" E	20.2130	9.233 km	HKST - HKSC L1 Only	HKSC
yes		0.018	2.7	8	18.02.2009 00:25:58	22° 19' 19.81917" N	114° 08' 28.27654" E	20.2231	9.233 km	HKST - HKSC MAX L1 Only	HKSC
yes		0.020	2.7	8	18.02.2009 00:26:02	22° 19' 19.81893" N	114° 08' 28.27689" E	20.2178	11.419 km	HKPC - HKSC L1 Only	HKSC
yes		0.016	2.7	8	18.02.2009 00:25:47	22° 19' 19.81908" N	114° 08' 28.27662" E	20.2231	11.419 km	HKPC - HKSC MAX L1 Only	HKSC
yes		0.020	2.7	8	18.02.2009 00:26:26	22° 19' 19.81946" N	114° 08' 28.27660" E	20.2222	12.211 km	HKOH - HKSC L1 Only	HKSC
yes		0.018	2.7	8	18.02.2009 00:26:32	22° 19' 19.81912" N	114° 08' 28.27668" E	20.2276	12.211 km	HKOH - HKSC MAX L1 Only	HKSC

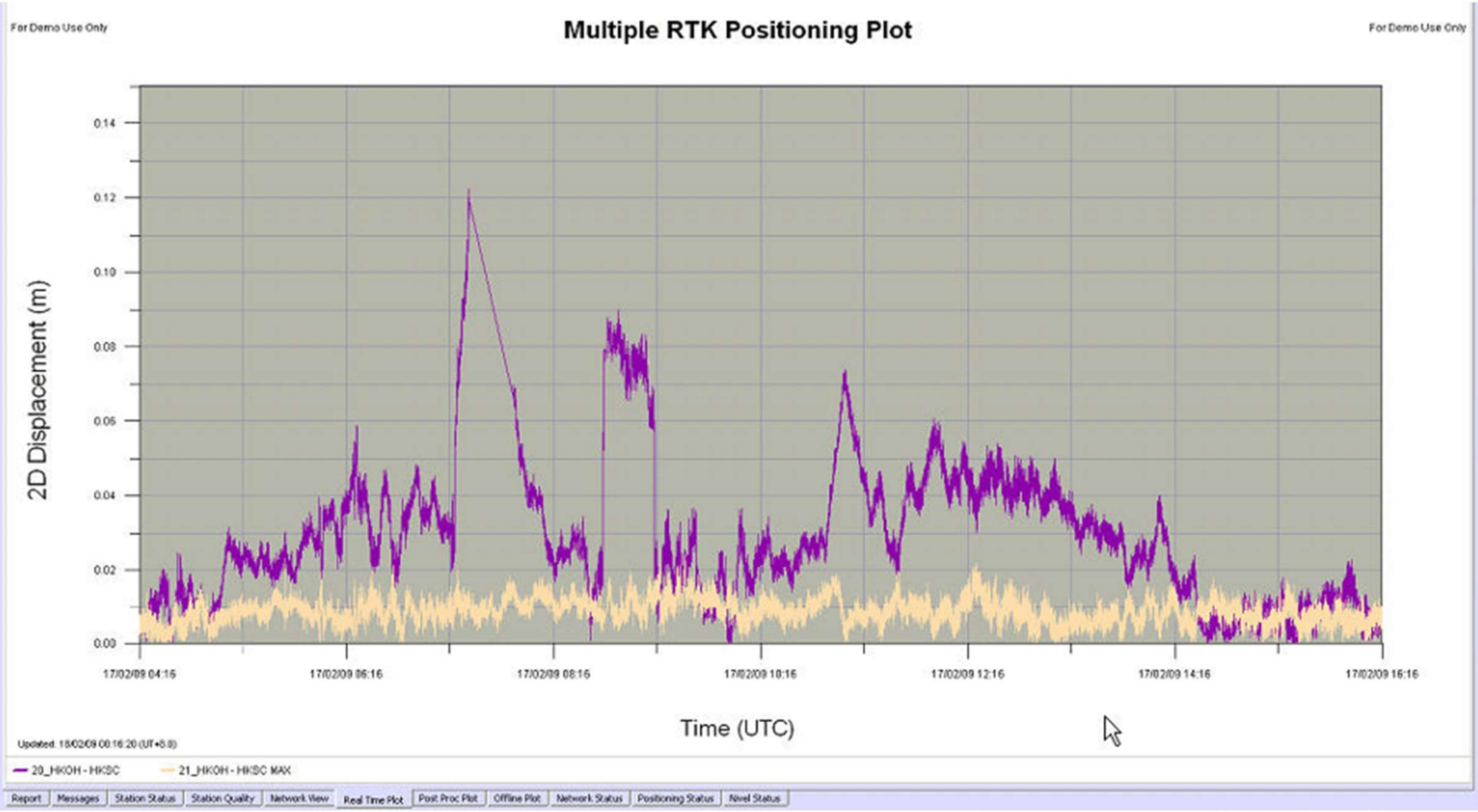
Leica GNSS Spider Site Server with the Positioning option allows the operator to process any combination of baselines between the reference stations and the monitoring stations by using L1 & L2 or L1 only and by using different strategies to solved the ambiguities in real time. The different baselines are processing using the Single RTK mode and the MAXMoM mode (MAX corrections issues of the SpiderNET Server)

Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 & L2 GPS data



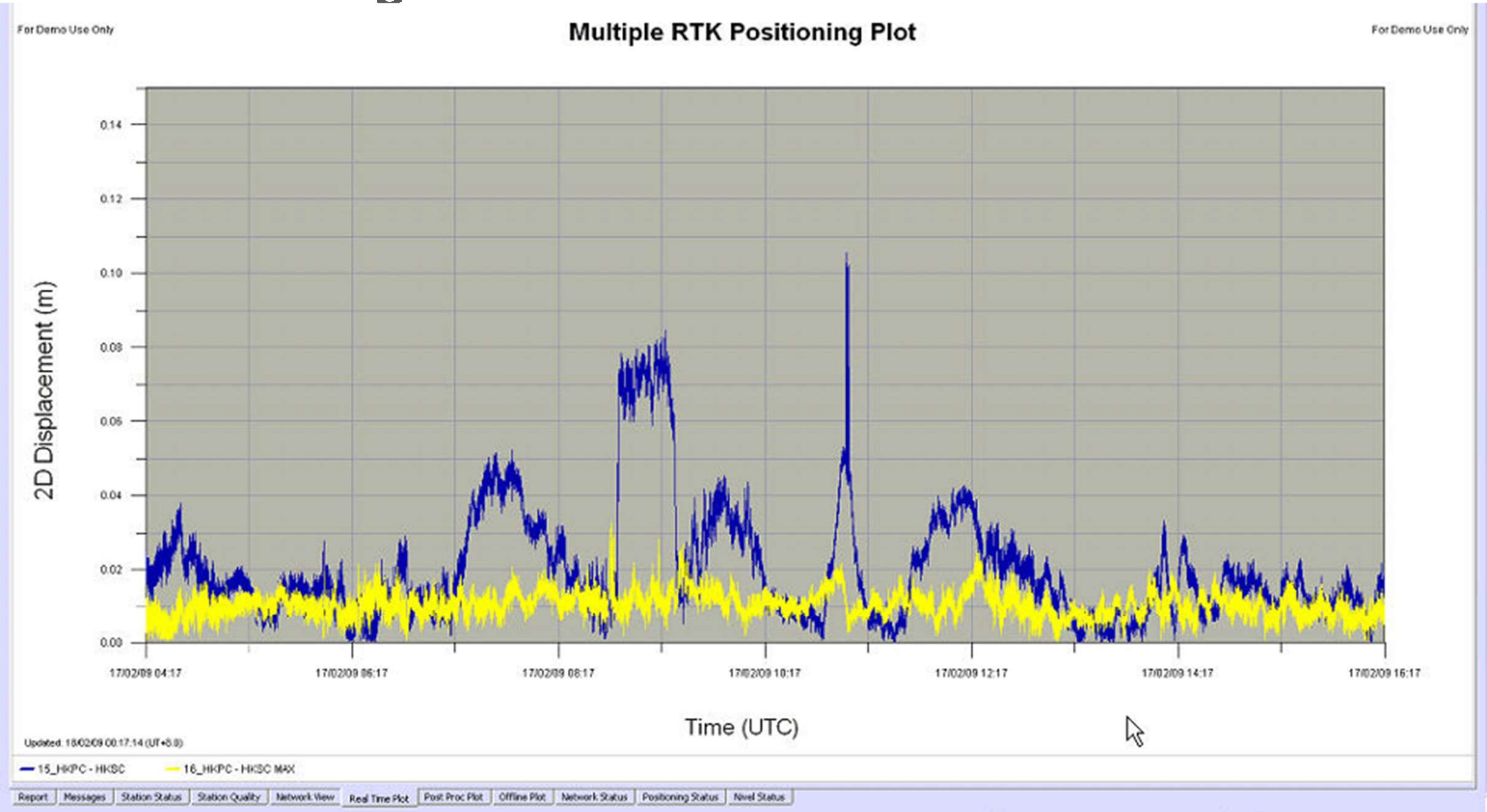
Single GPS RTK vs GPS Network RTK MAX

Processing in Real Time L1 & L2 GPS data



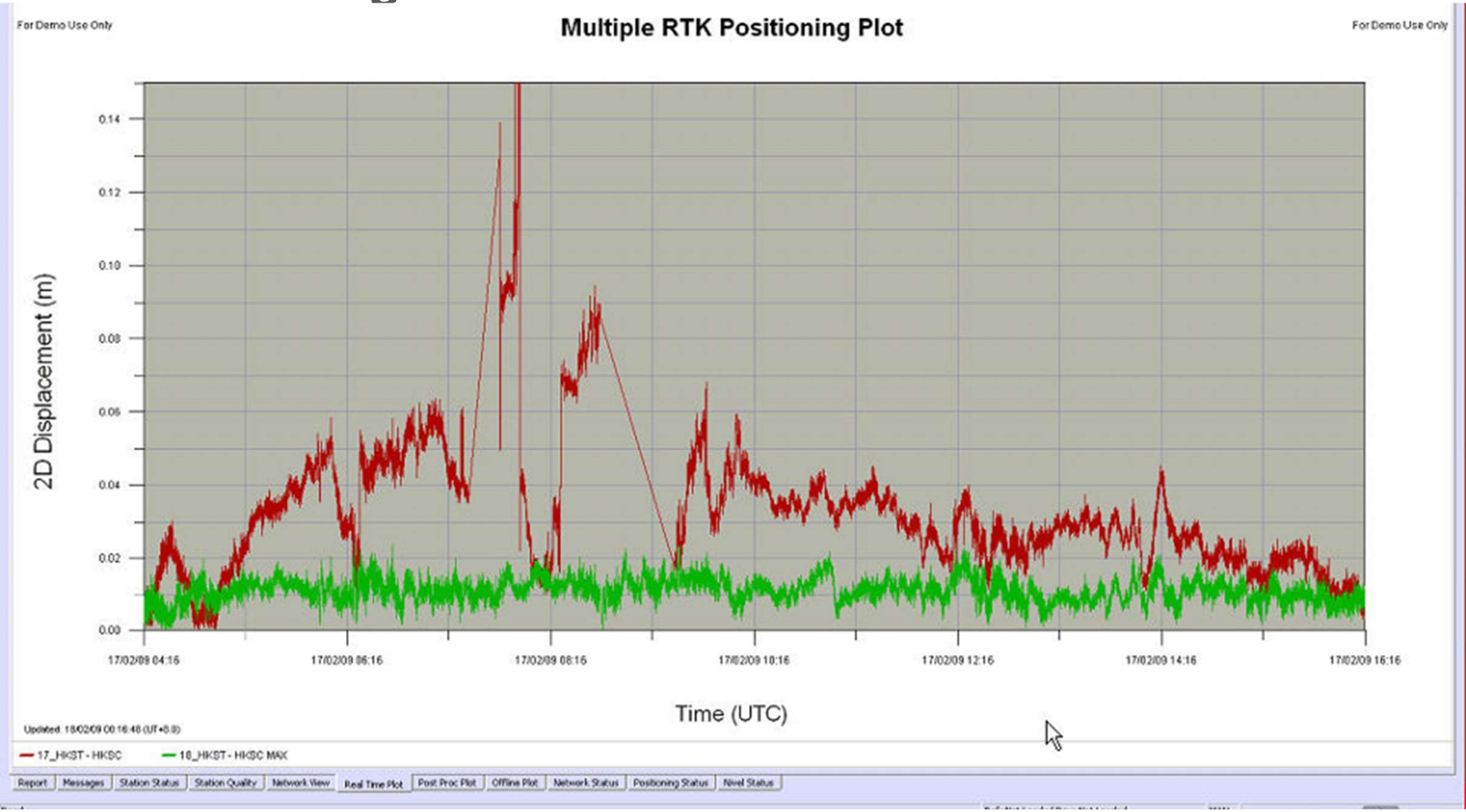
Single GPS RTK vs GPS Network RTK MAX

Processing in Real Time L1 & L2 GPS data



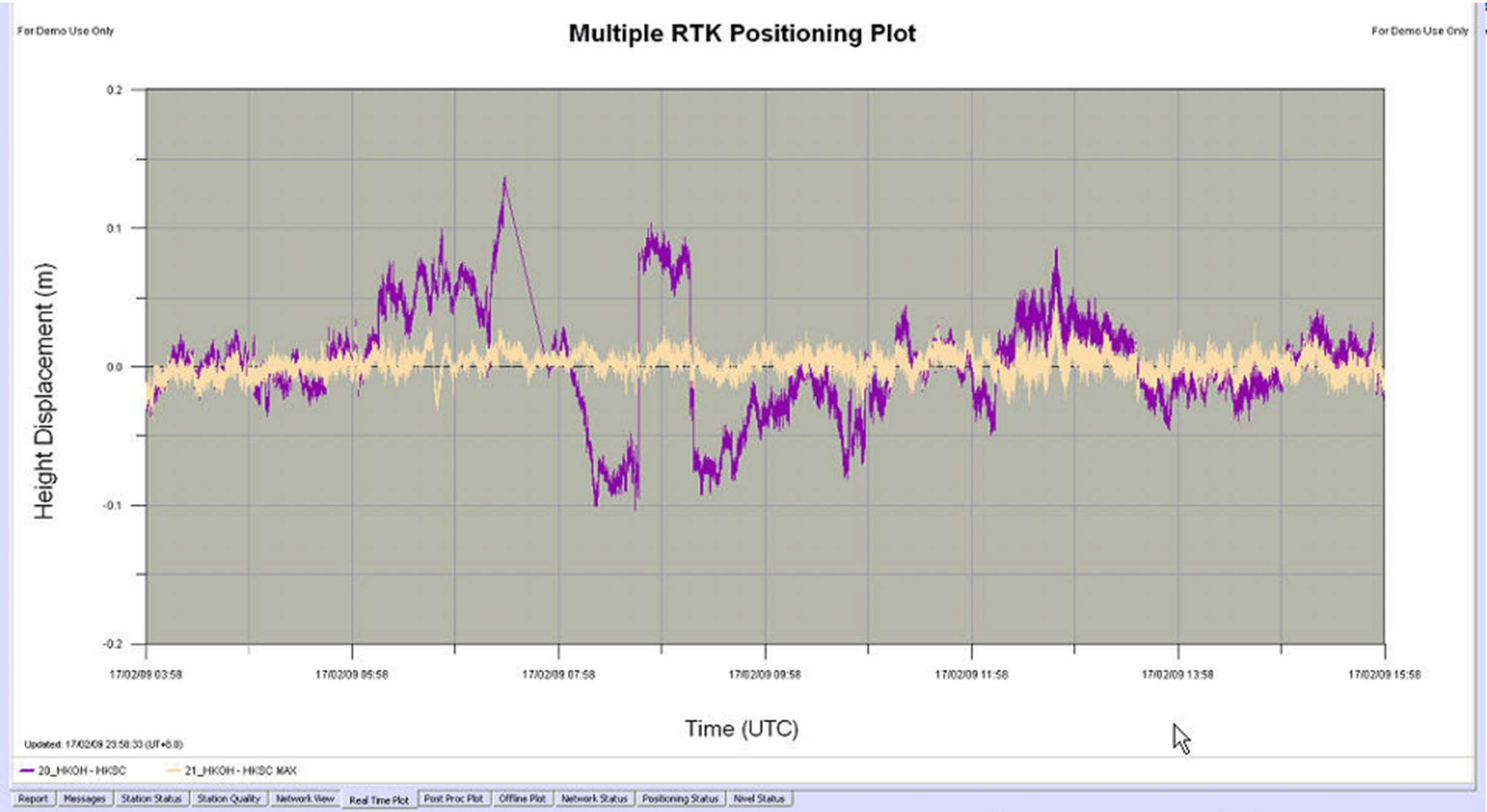
Single GPS RTK vs GPS Network RTK MAX

Processing in Real Time L1 & L2 GPS data



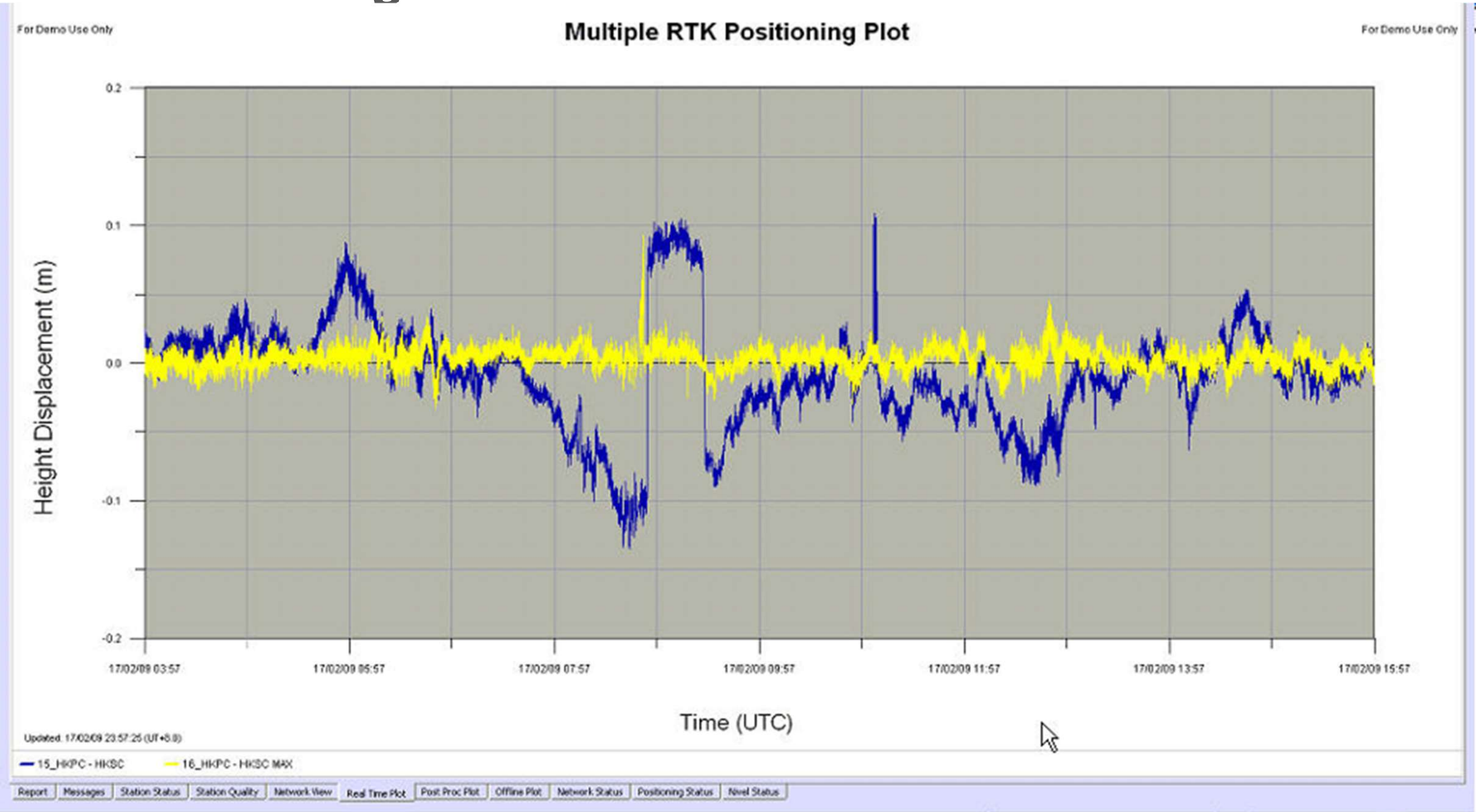
Single GPS RTK vs GPS Network RTK MAX

Processing in Real Time L1 & L2 GPS data



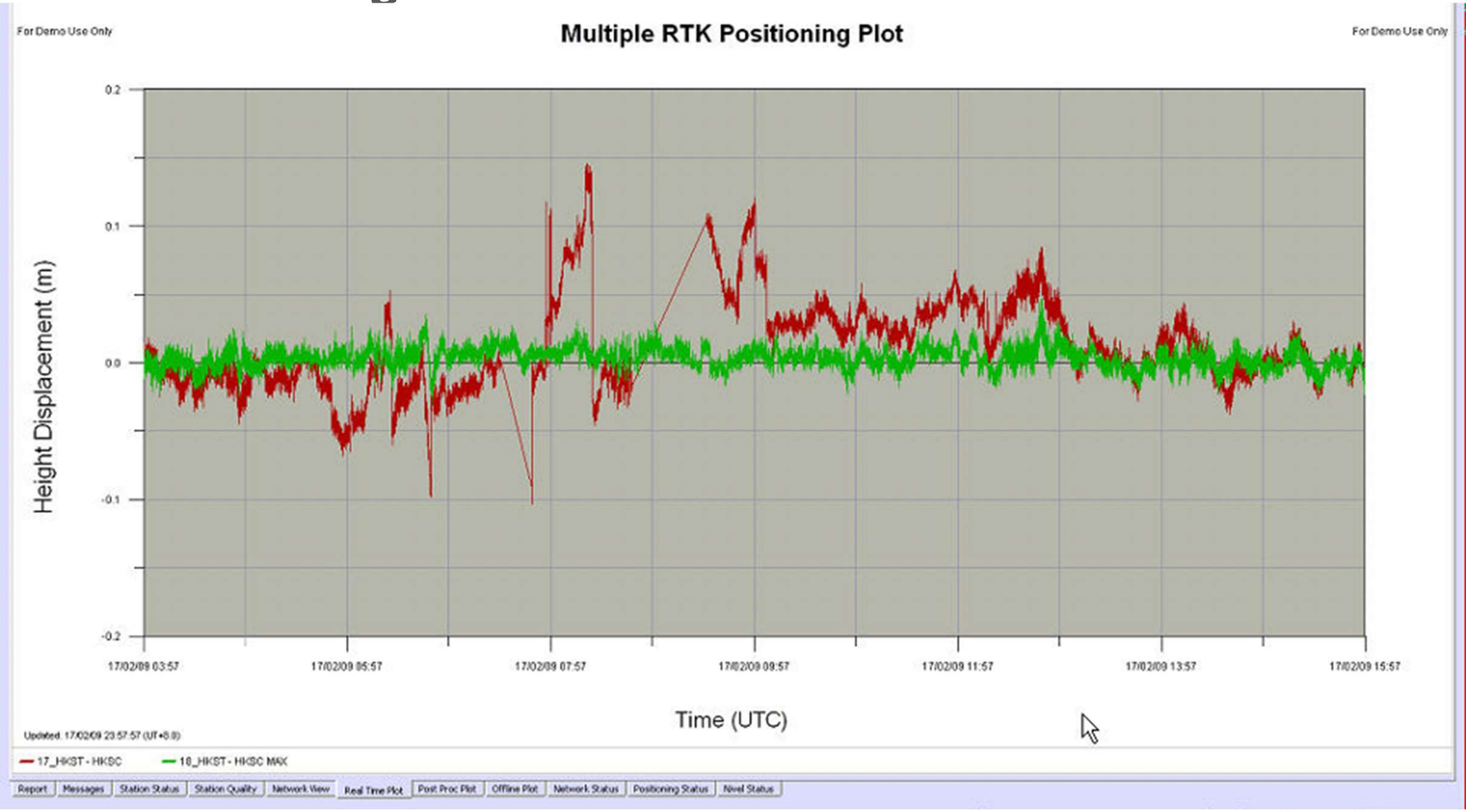
Single GPS RTK vs GPS Network RTK MAX

Processing in Real Time L1 & L2 GPS data

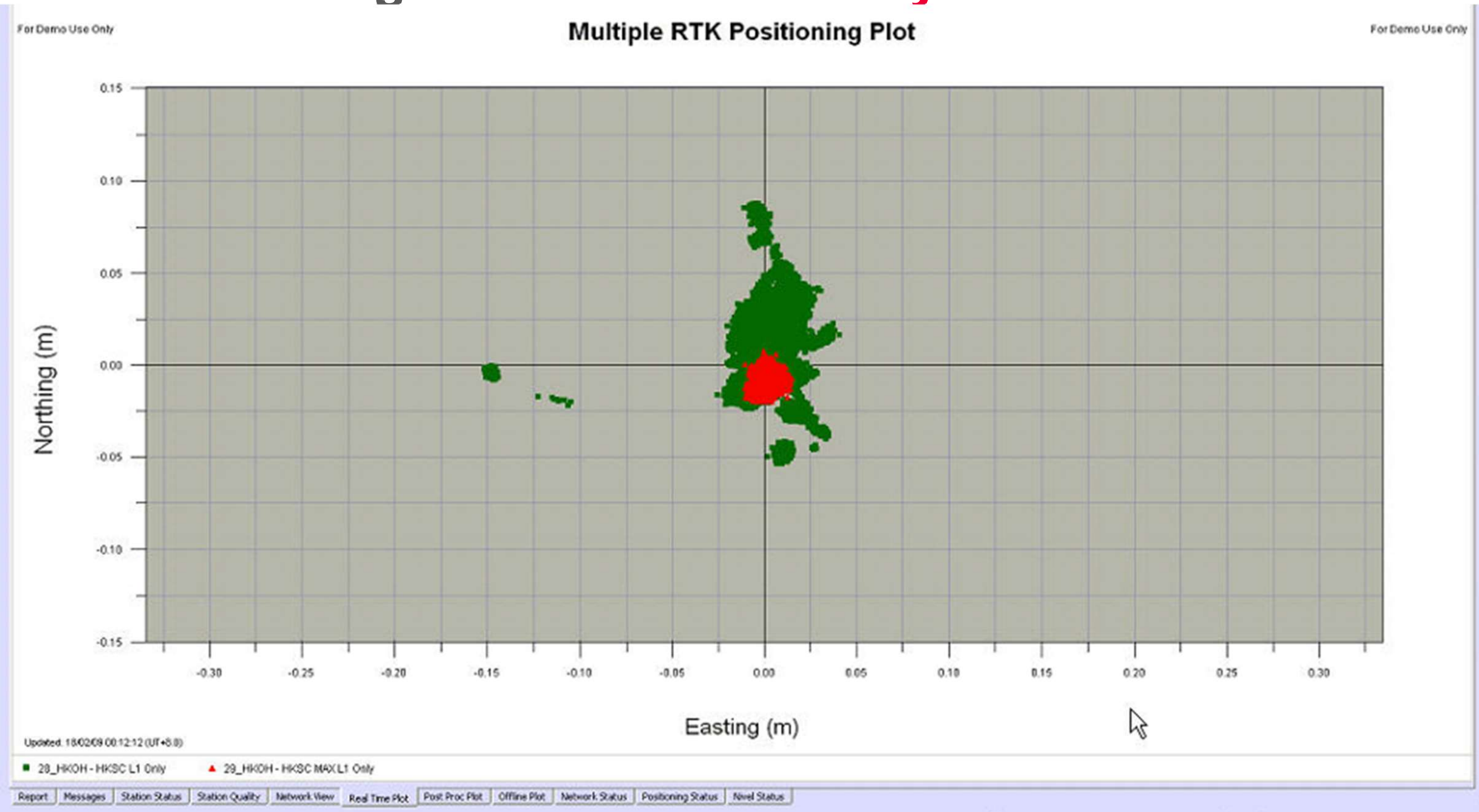


Single GPS RTK vs GPS Network RTK MAX

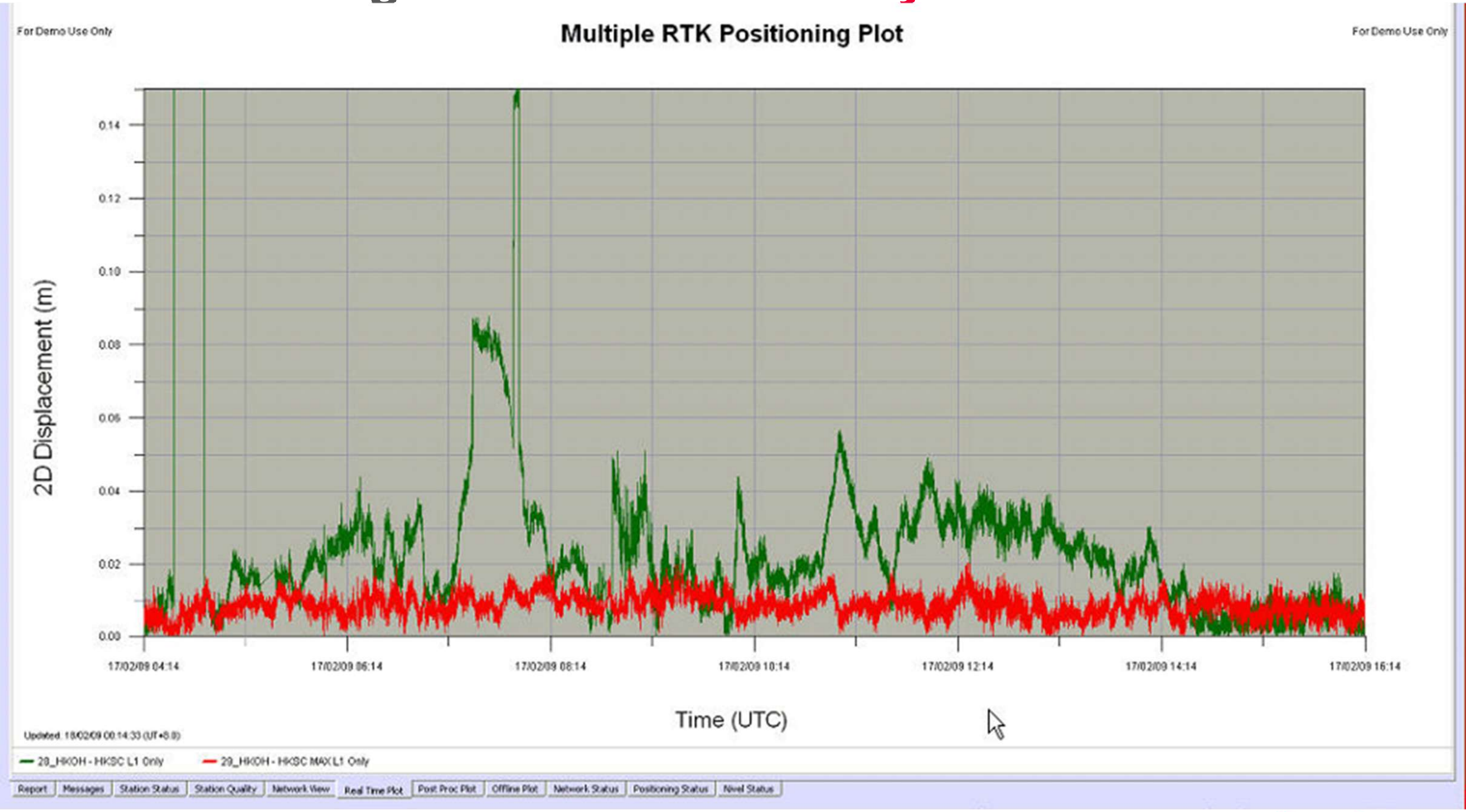
Processing in Real Time L1 & L2 GPS data



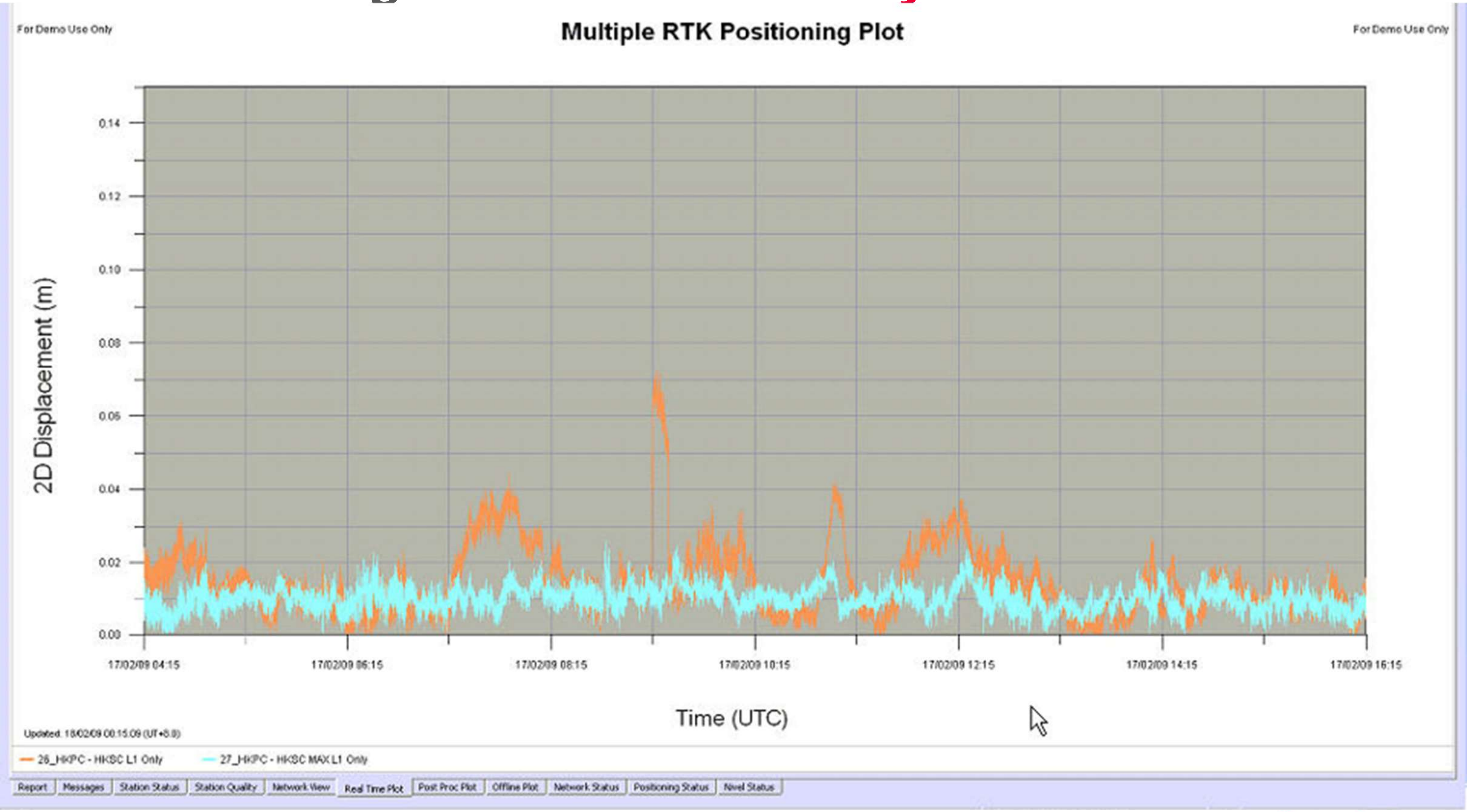
Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 only GPS data



Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 only GPS data

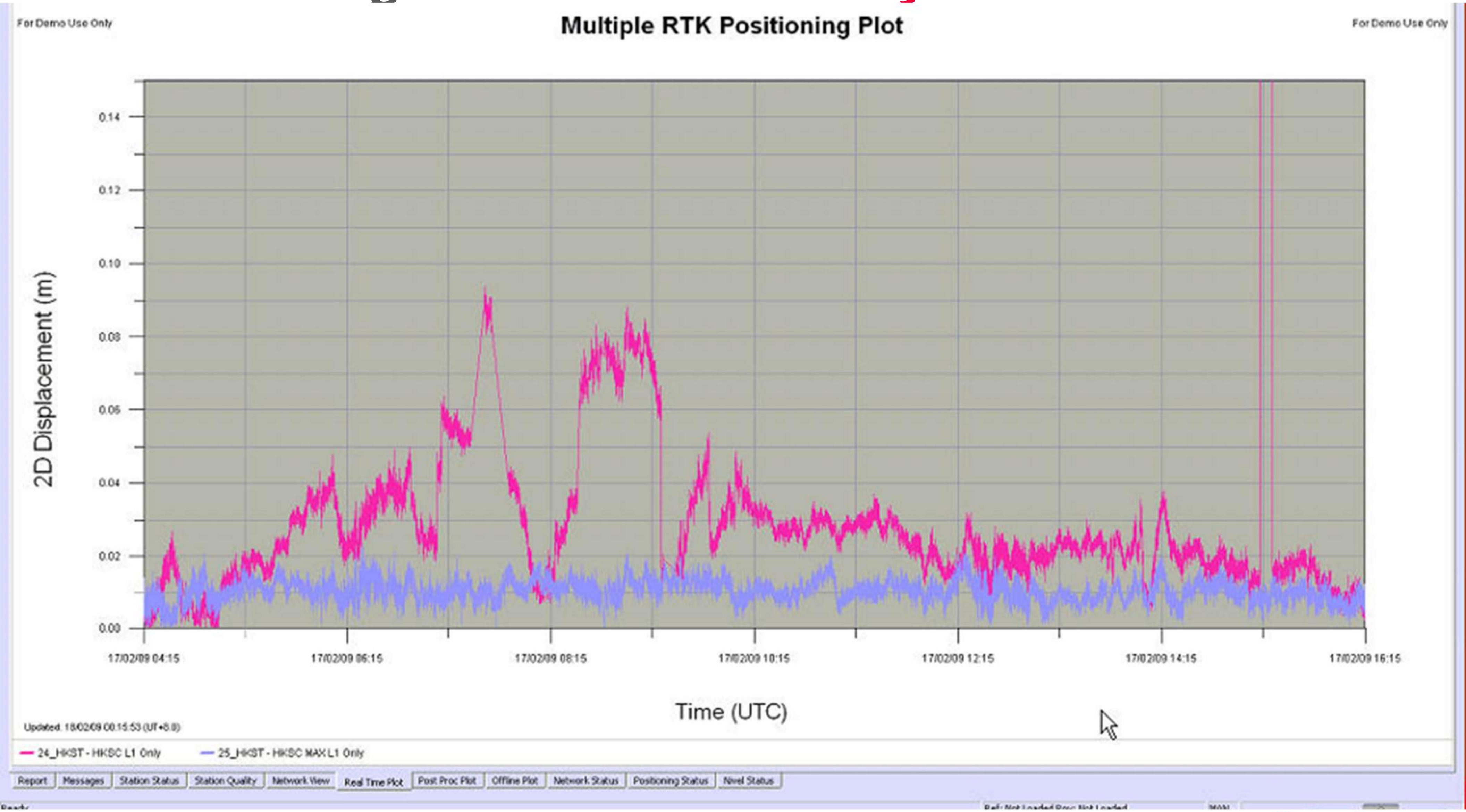


Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 only GPS data

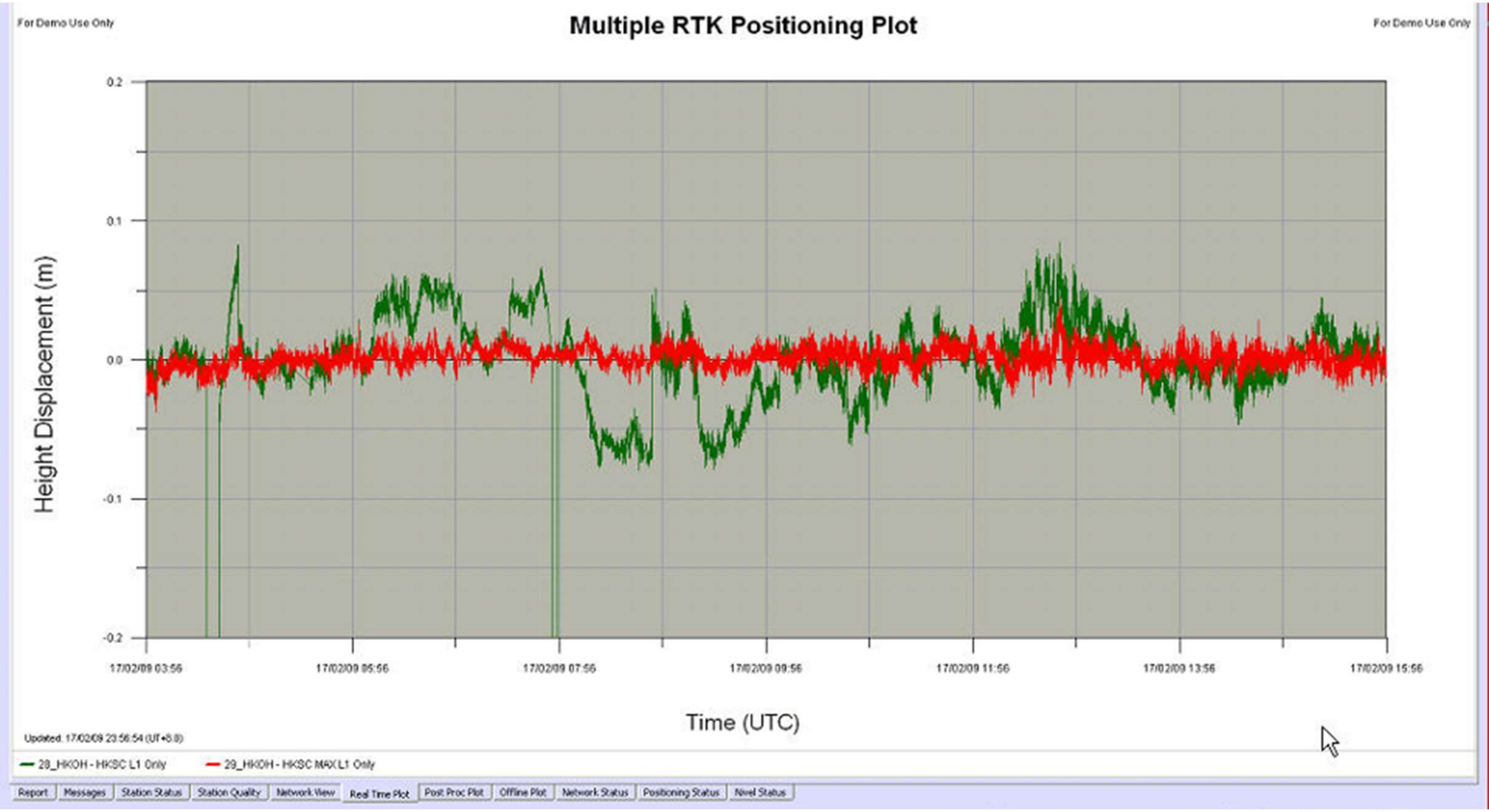


Single GPS RTK vs GPS Network RTK MAX

Processing in Real Time L1 only GPS data



Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 only GPS data



Geosystems

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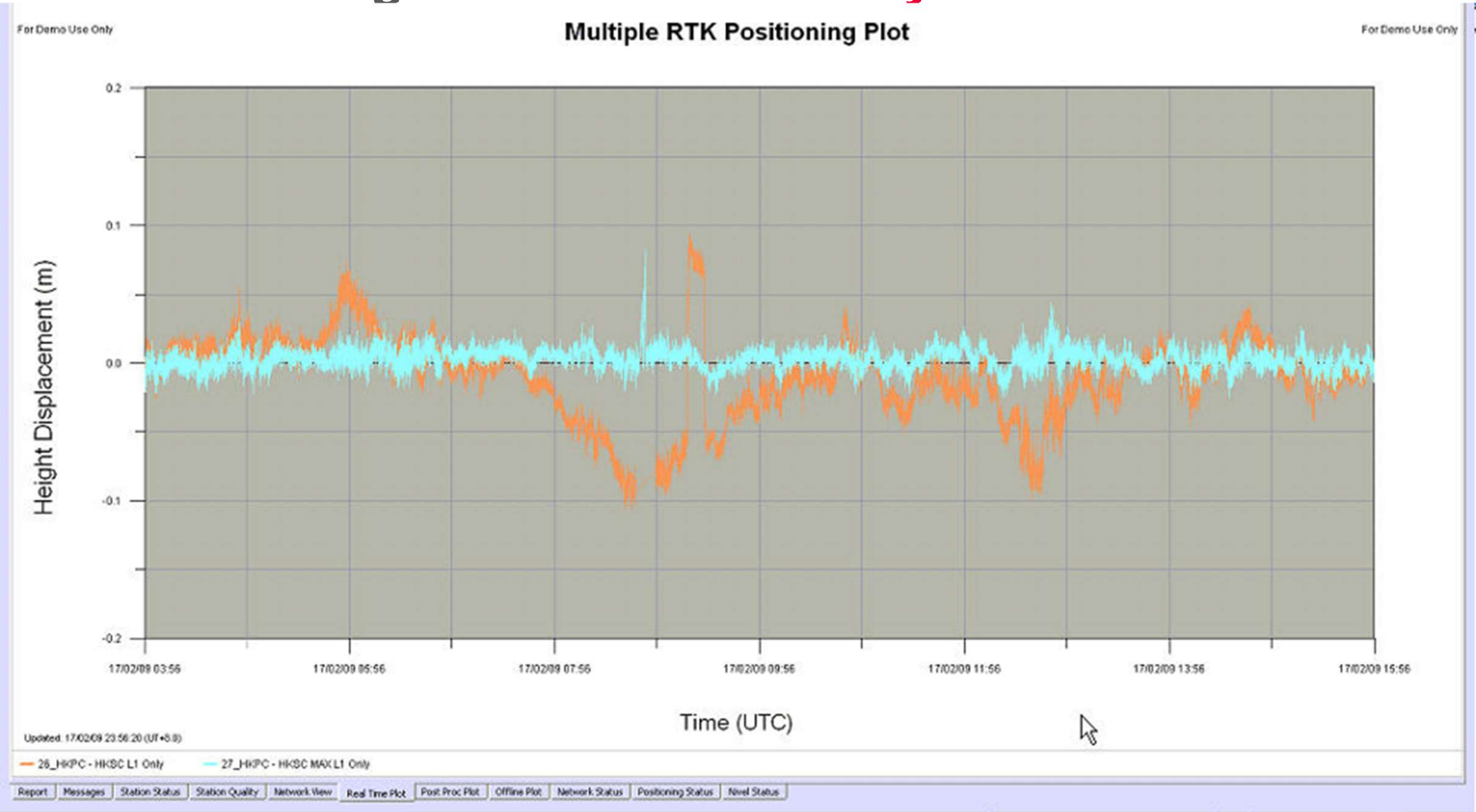
Processing in Real Time L1 only GPS data



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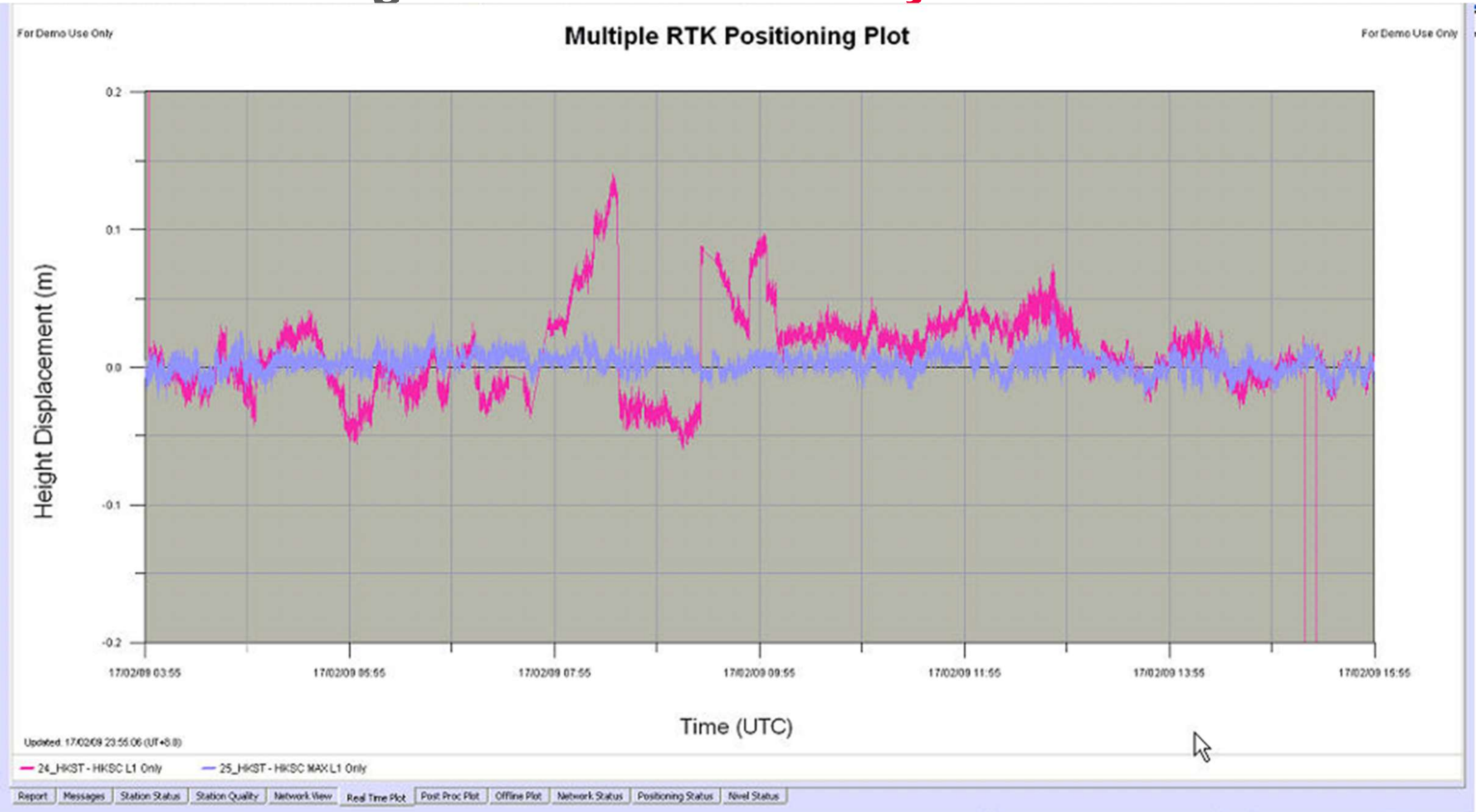

Conclusions and Prospective

The practical results are demonstrating that the combination of GNSS Network RTK resources within a GNSS Monitoring projects have outstanding advantages :

- Maximum (unbiased) accuracy and reliability with effective quality indicators that allow the responsible of a monitoring project to better control the operations and the results.
- The lonely solution for projects located in the low latitude band where the ionosphere turbulences are affecting severely the signals processing.
- Possibility to mix dual frequency receivers (GNSS Network) with affordable single frequency receivers for slow motion operations.
- No need of networked baselines adjustment.
- No need to establish single base station in urban area (obstructions) for high rise building monitoring and bridge monitoring projects e.g.
- The authors are working on other projects that will be reported in FIG Sydney …

Many thanks for your attention …

Càm on rât nhiêu …

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Hanoi, October 2009