Advances in GNSS-RTK for Structural Deformation Monitoring in Regions of High Ionospheric Activity

Chris Rizos, Professor & Head, School of Surveying & Spatial Information Systems UNSW Sydney NSW 2052, AUSTRALIA
Joël van Cranenbroeck, Business Development Manager - Geodetic Monitoring Leica Geosystems AG, Switzerland – Heerbrugg, GSR - EMEA
Vincent Lui, Sales Manager of GNSS, BA Engineering and Taiwan Region Leica Geosystems ltd, Hong Kong SAR

GNSS RTK for Monitoring Applications
Challenges …

However the distance between the GNSS monitoring stations and the GNSS base station must be kept as short as possible for achieving high accuracy. *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.

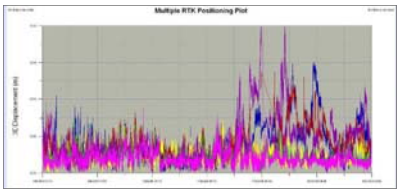
3

GNSS RTK for Monitoring Applications

GNSS technology is being extensively used for monitoring the movement of engineering structures such as bridges, tall buildings, dams, breakwaters, etc. Large structures increasingly have one or more GNSS receivers installed on them, and this trend is expected to continue unabated.

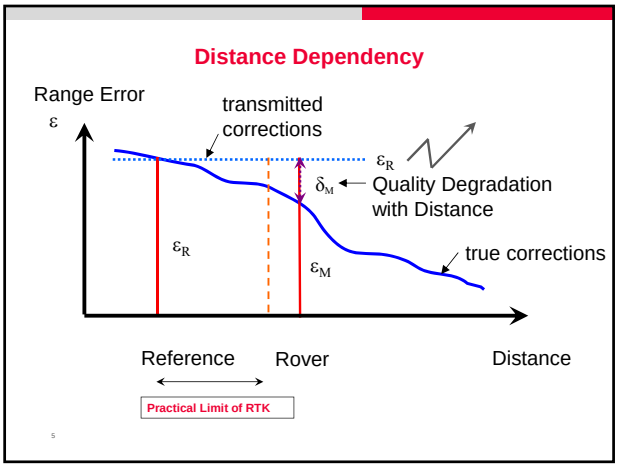
GNSS RTK for Monitoring Applications
Challenges

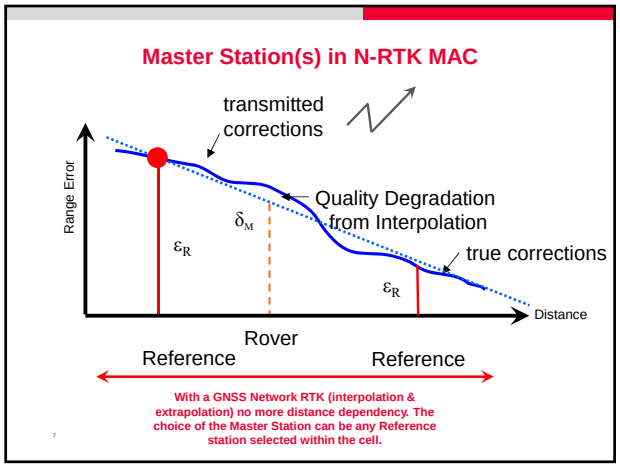
Projects located in the low latitude band can be compromised with high and unpredictable ionosphere turbulences in the afternoon period of time.

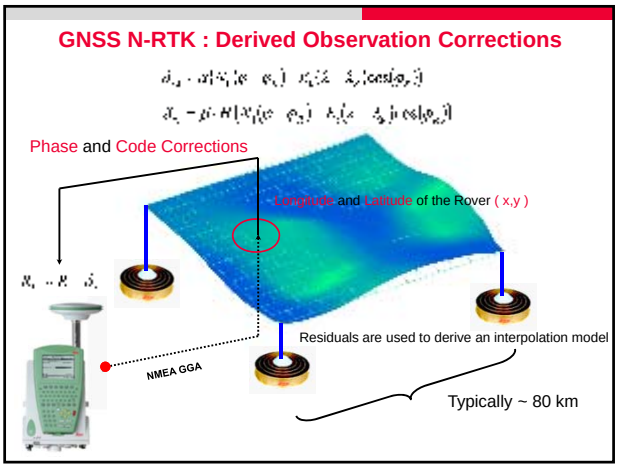


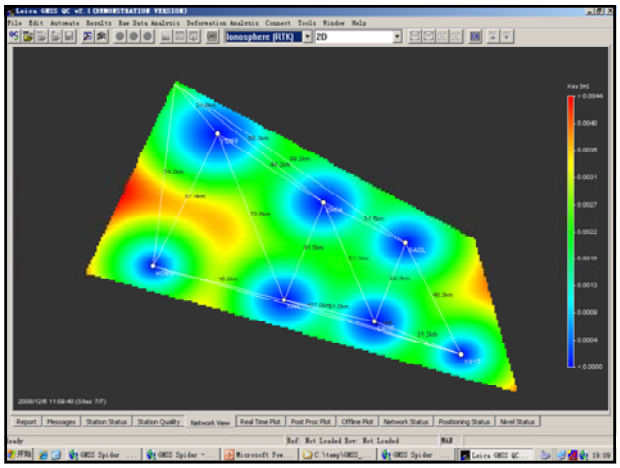
In that case the time series are difficult to be correctly interpreted. Is that a noise or a signal ?

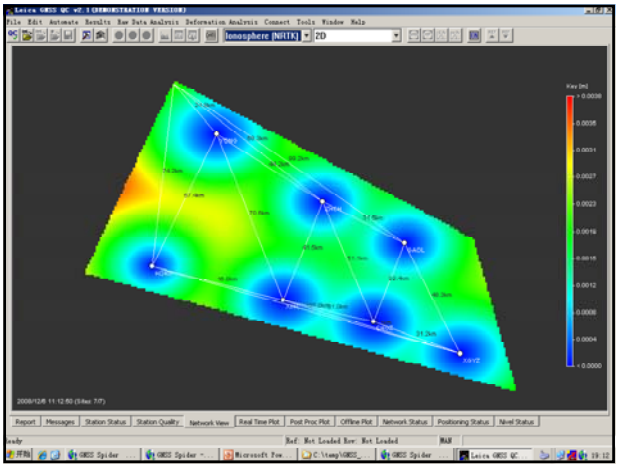
4

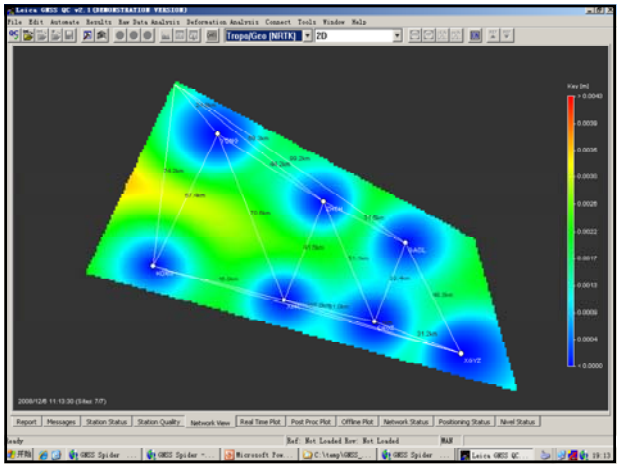

Distance Dependency
Range Error
ε
transmitted
corrections
εR
δM
Quality Degradation
with Distance
εR
εM
true corrections
Reference
Rover
Distance
Practical Limit of RTK

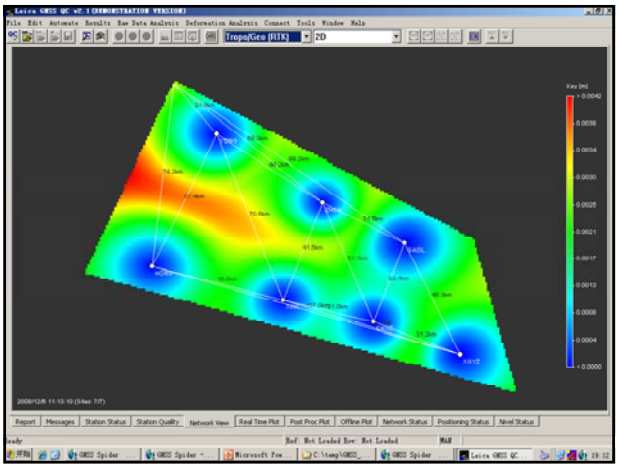

Master Station(s) in N-RTK MAC
transmitted
corrections
Range Error
Quality Degradation
from Interpolation
δM
εR
true corrections
εR
Distance
Rover
Reference
Reference
With a GNSS Network RTK (interpolation & extrapolation) no more distance dependency. The choice of the Master Station can be any Reference station selected within the cell.

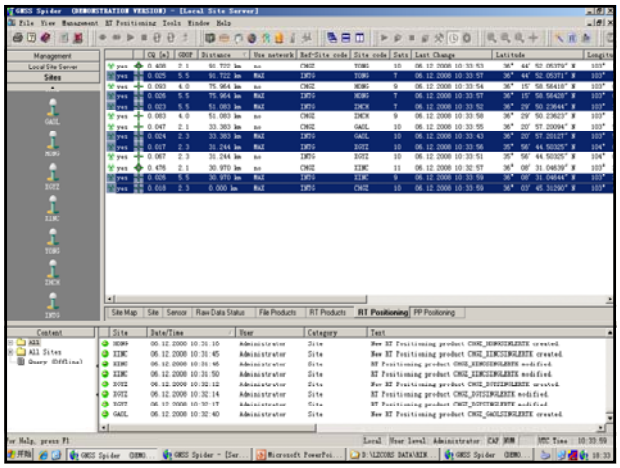

GNSS N-RTK : Derived Observation Corrections
Phase and Code Corrections
Longitude and Latitude of the Rover (x,y)
Residuals are used to derive an interpolation model
NMEA GGA
Typically ~ 80 km

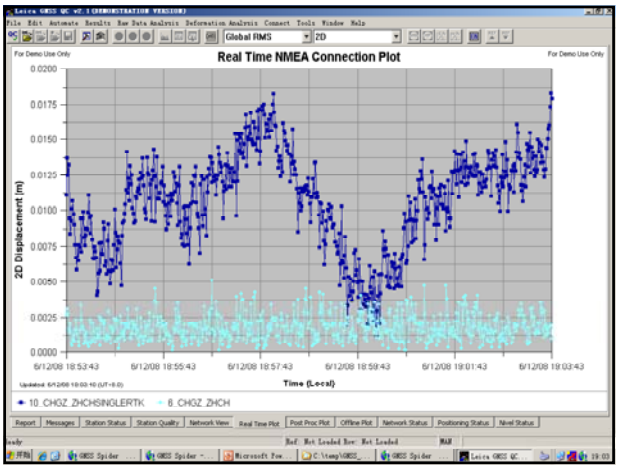


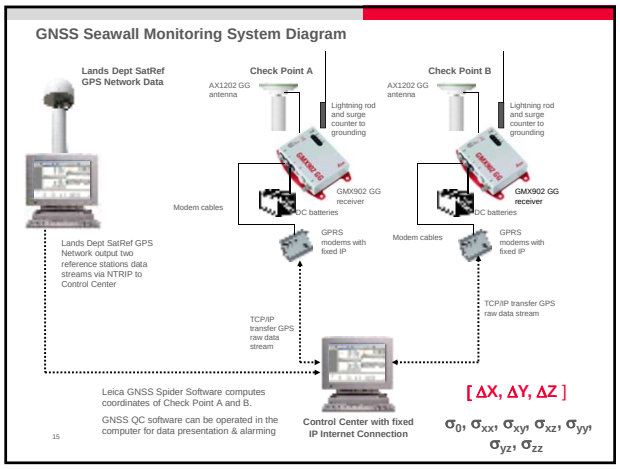












Practical trial in Hong Kong, PR China

Seawall Monitoring, CEDD Ports Work

Objectives :

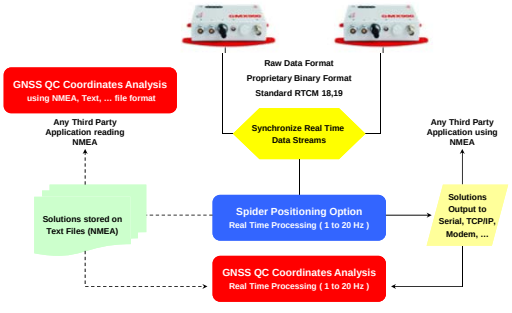
- Ensure safety of seawalls in HK
- Total 120km seawalls in HK
- Monitoring by traditional manual methods are time consuming and manpower involved with human life risk in typhoon periods.
- Real-time displacement presentation
- Multiple levels auto alert
- Fully automatic, day and night, 24/7

Seawall infrastructure in Hong Kong, PR China

14

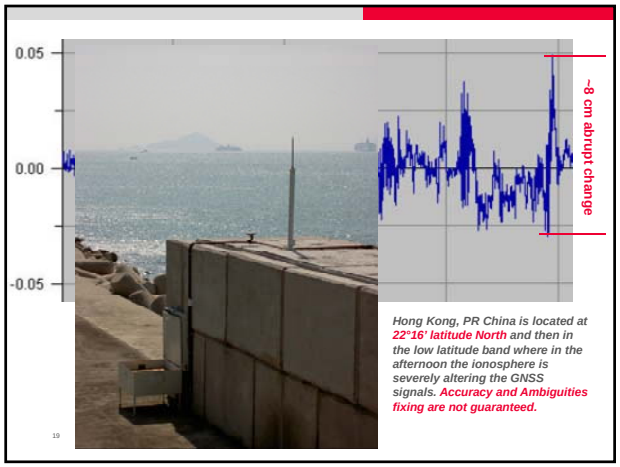
Centralized GNSS Processing Strategies

Real Time from 1Hz up to 20Hz



16

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



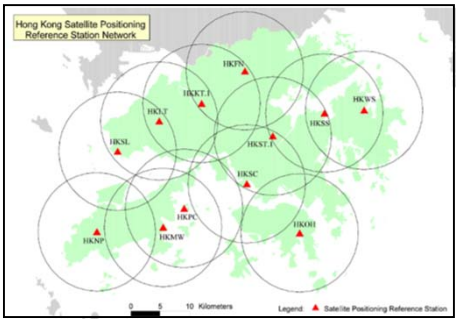
*Hong Kong, PR China is located at **22°16' latitude North** and then in the low latitude band where in the afternoon the ionosphere is severely altering the GNSS signals. **Accuracy and Ambiguities fixing are not guaranteed.***

19

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

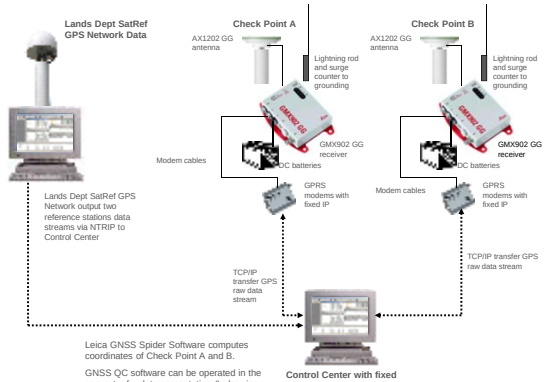
Reference Station Data from HK SatRef Network

Own by the HK Lands Dept



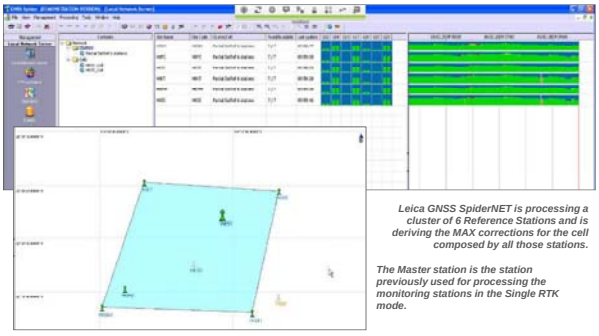
20

From GNSS Single RTK Seawall Monitoring System Diagram to …



21

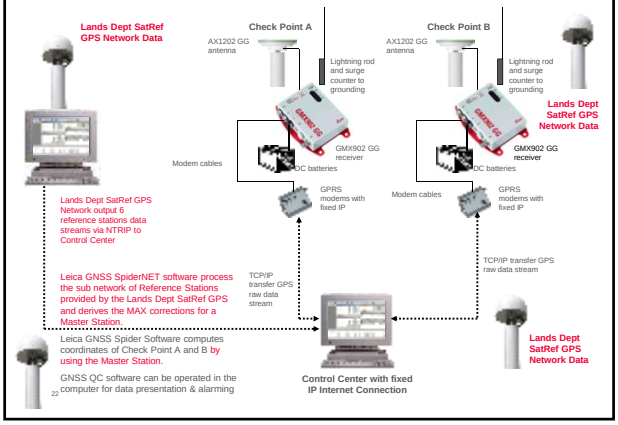
Leica GNSS SpiderNET for Network RTK
Processing in Real Time L1 & L2 GPS data



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.

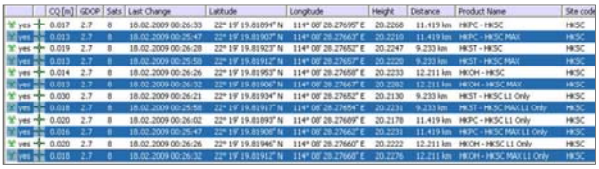
The Master station is the station previously used for processing the monitoring stations in the Single RTK mode.

GNSS Network RTK aided Seawall Monitoring System Diagram



22

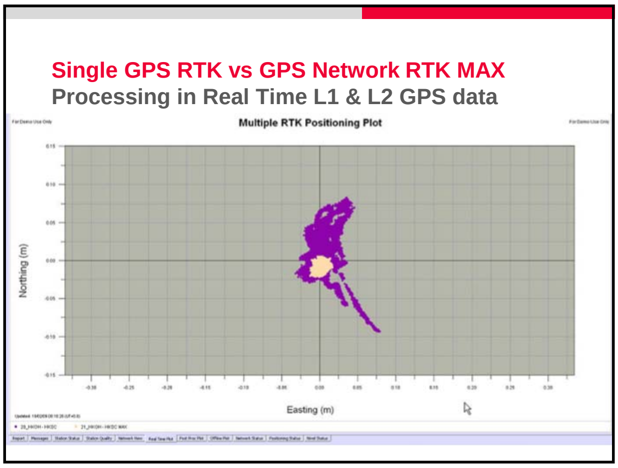
Leica GNSS Spider Site Server Positioning option
Processing in Real Time L1 & L2 , L1 only GPS data



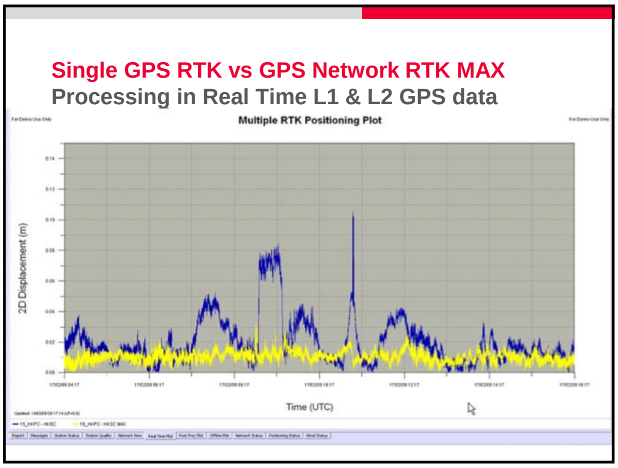
Leica GNSS Spider Site Server with the Positioning option allows the operator to process any combination of baselines between the reference stations and the monitoring stations by using L1 & L2 or L1 only and by using different strategies to solved the ambiguities in real time.

The different baselines are processing using the Single RTK mode and the MAXMoM mode (MAX corrections issues of the SpiderNET Server)

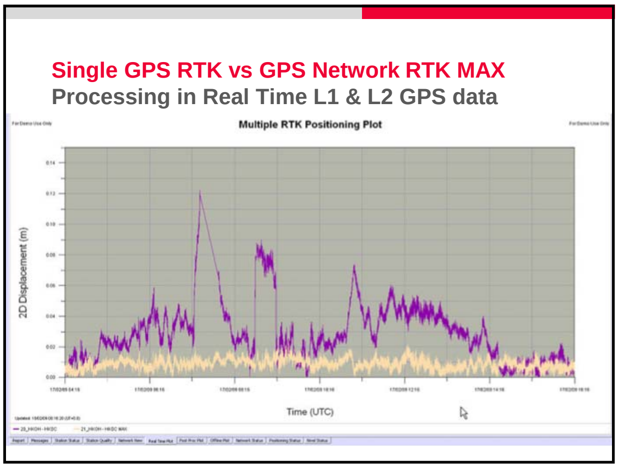
24



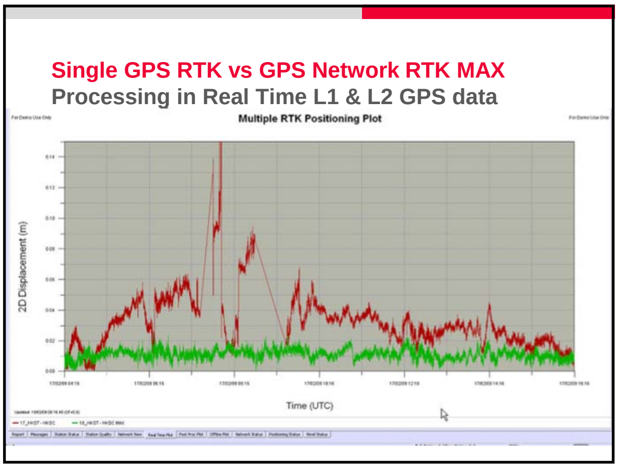
Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 & L2 GPS data
Multiple RTK Positioning Plot
Northing (m)
Easting (m)



Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 & L2 GPS data
Multiple RTK Positioning Plot
2D Displacement (m)
Time (UTC)

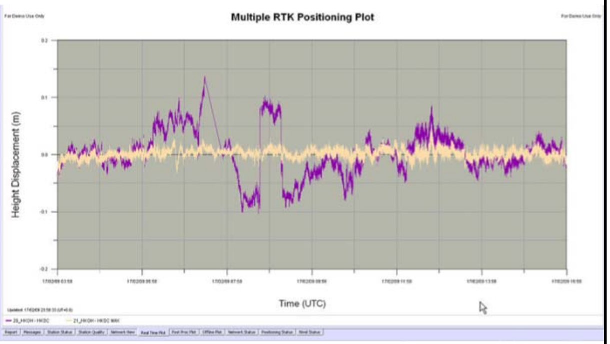


Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 & L2 GPS data
Multiple RTK Positioning Plot
2D Displacement (m)
Time (UTC)

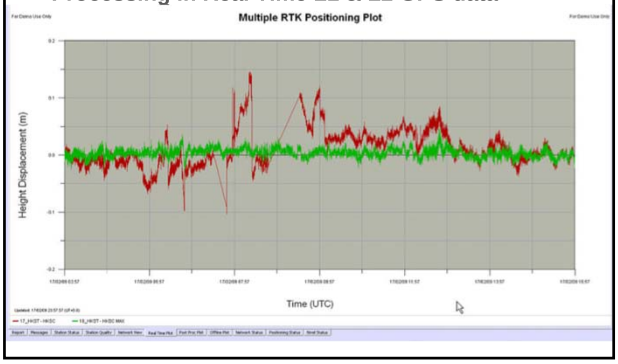


Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 & L2 GPS data
Multiple RTK Positioning Plot
2D Displacement (m)
Time (UTC)

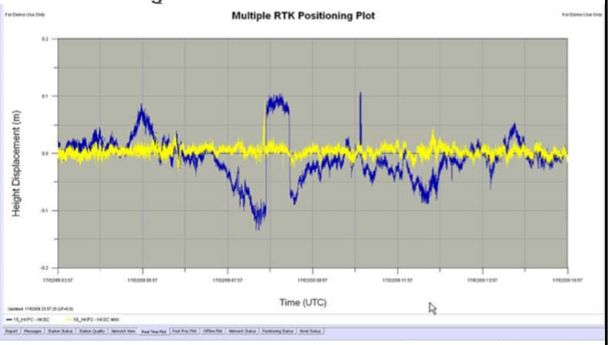
Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 & L2 GPS data



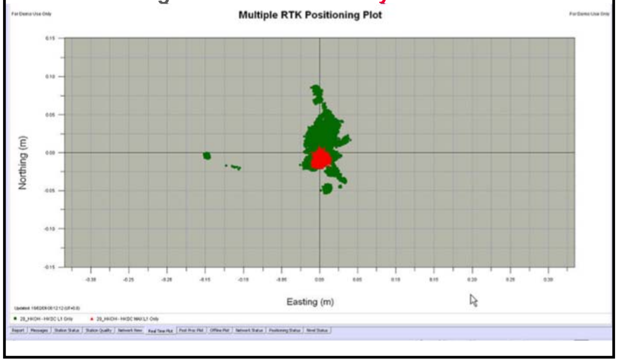
Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 & L2 GPS data



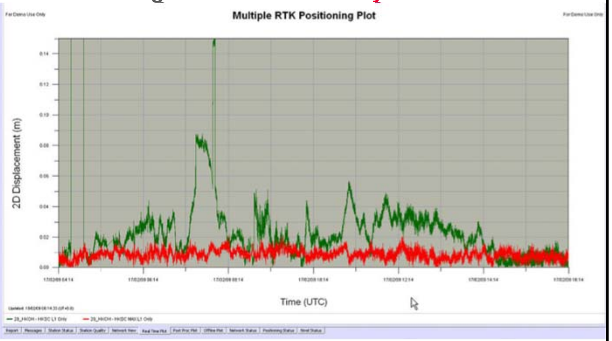
Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 & L2 GPS data



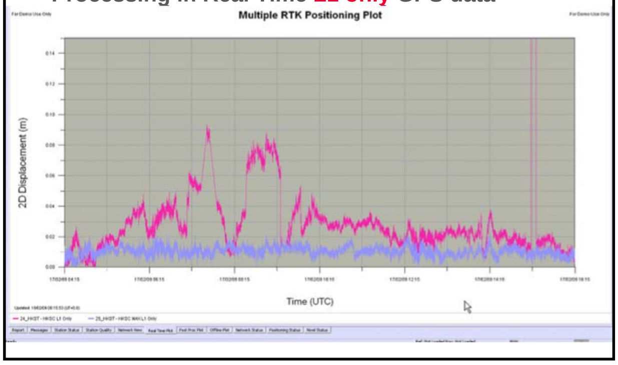
Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 only GPS data



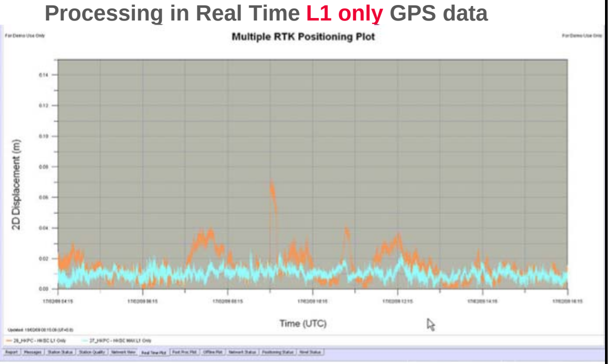
Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 only GPS data



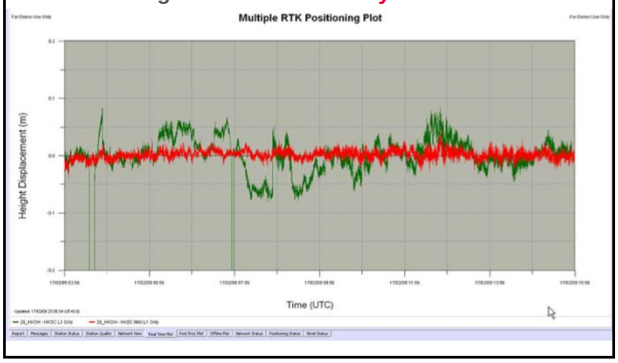
Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 only GPS data



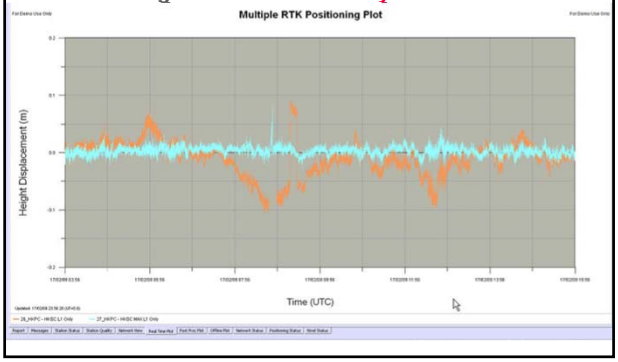
Single GPS RTK vs GPS Network RTK MAX
Processing in Real Time L1 only GPS data



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



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



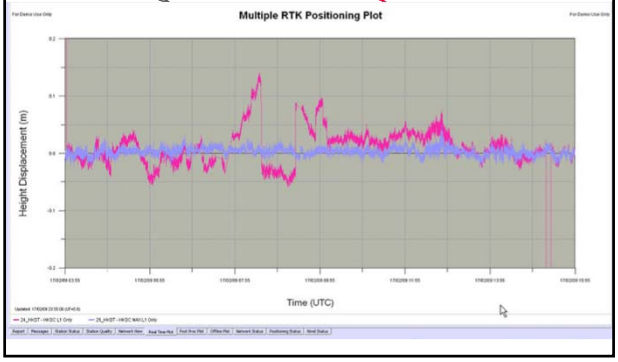
The combination of GNSS Network RTK resources delivers outstanding advantages …

Maximum (unbiased) accuracy and reliability !

- Better control over the operations and the results by taking advantage of installed CORS infrastructure.
- Reliable time series solutions for projects located in low latitude regions where the ionospheric turbulences severely affect signal and data processing.
- The possibility to mix dual-frequency receivers (GNSS CORS) with affordable single-frequency receivers for slow deformation motion monitoring.
- No need for subsequent networked baselines adjustment.
- No need to establish single CORS in urban areas (obstructions) for high rise building or long bridge monitoring projects.

39

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



Only for low latitude regions ?
The return of high solar cycle activity will strike …

Although implemented for a trial in Hong Kong, the authors believe that with the return of high solar cycle activity the proposed mixed-mode solution strategy could find application in many other places than only those currently exposed to severe ionospheric disturbances (i.e. low latitude regions).

40

Many thanks for your attention

Chris Rizos ,
Joël van Cranenbroeck
and
Vincent Lui
Sydney, April 2010