香港衛星導航技術之應用進展

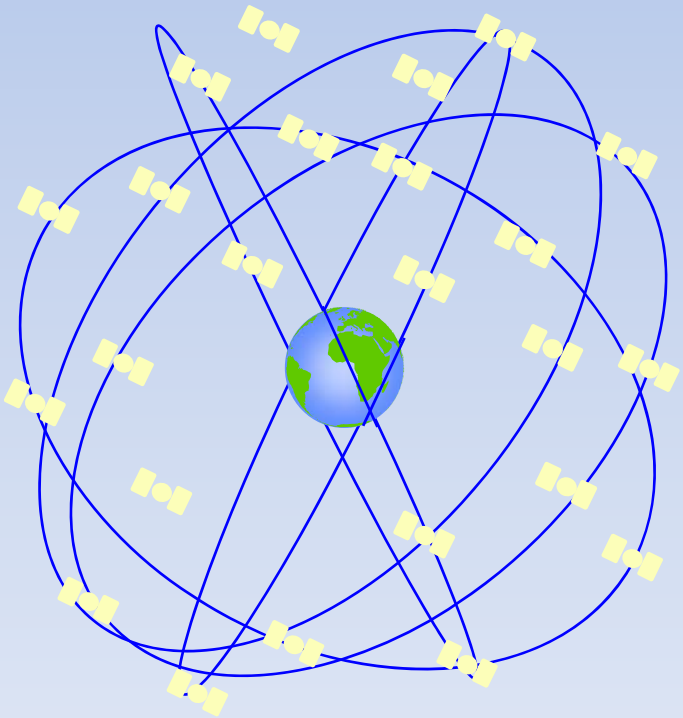
建立香港基於GNSS的定位基礎設施

香港理工大學土地測量及地理資訊學系

陳武

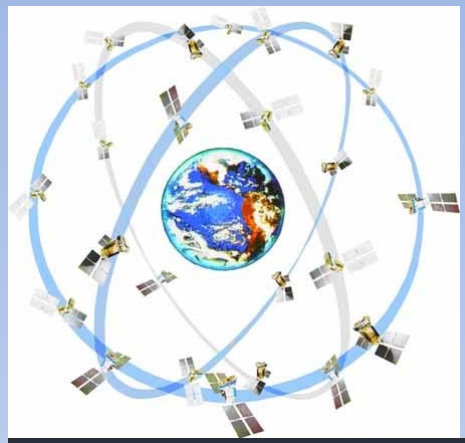
Background

- GPS revolutionize the concepts of positioning/navigation/timing (PNT)
- GPS has become an important infrastructure to support economic development
  - Military
  - Transportation
  - Telecommunication
  - Space Industry
  - Finance
  - Location Based Services
  - Surveying
  - Weather forecasting
  - Scientific researches



Background

- GNSS Based Services
  - Global Services
    - GPS, GLONASS, Beidou (III)
  - Regional Services
    - Beidou (II), IRNSS
    - Satellite Based Augmentation Systems (SBAS)
      - WAAS, EGNOS, MSAS, QZSS, GAGAN, ….
  - Local Services
    - Ground Based Augmentation systems (GBAS)
    - Marine DGPS Services
    - GNSS RTK Network

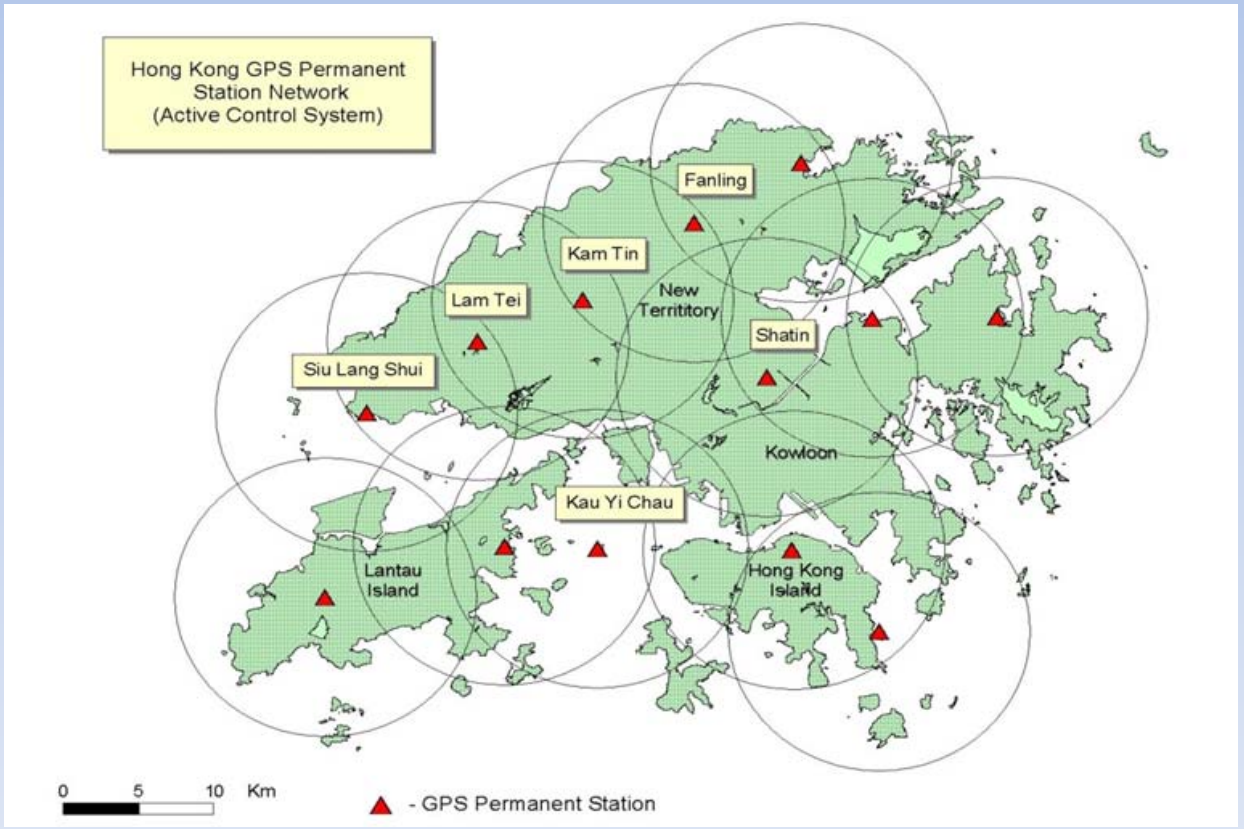


GNSS Local infrastructure Development in Hong Kong

- Lands Department
  - GNSS continuous control network since 2001
  - “SatRef” Network (18 stations)
- Marine Department
  - DGPS system for marine navigation
  - Automatic Identification System (AIS) for port management
- Airport Authority
  - Considering a GBAS system for landing
- Hong Kong Polytechnic University
  - GNSS ionosphere scintillation monitoring network
  - 3 stations

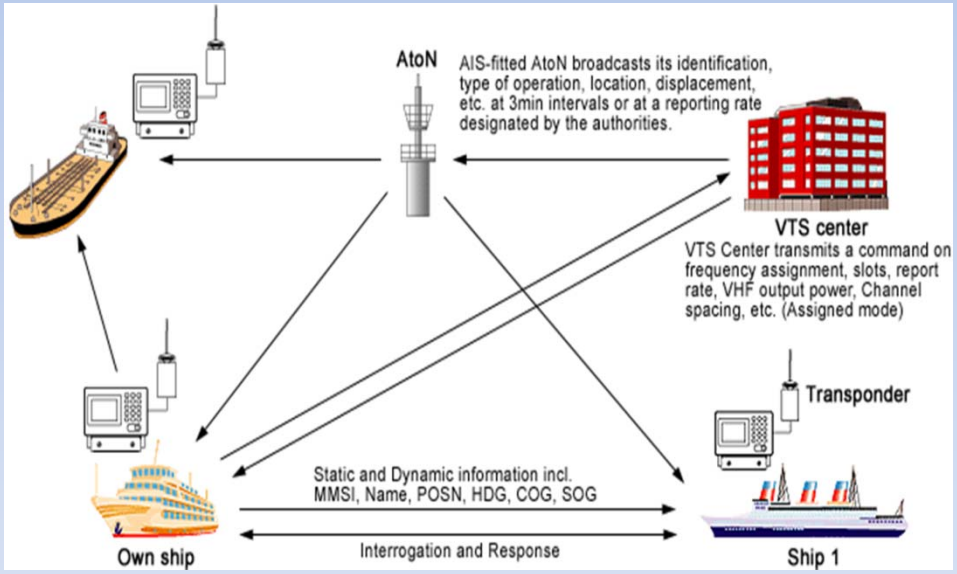
HK GNSS Reference Network (SatRef)

- Provide GNSS RTK in Hong Kong

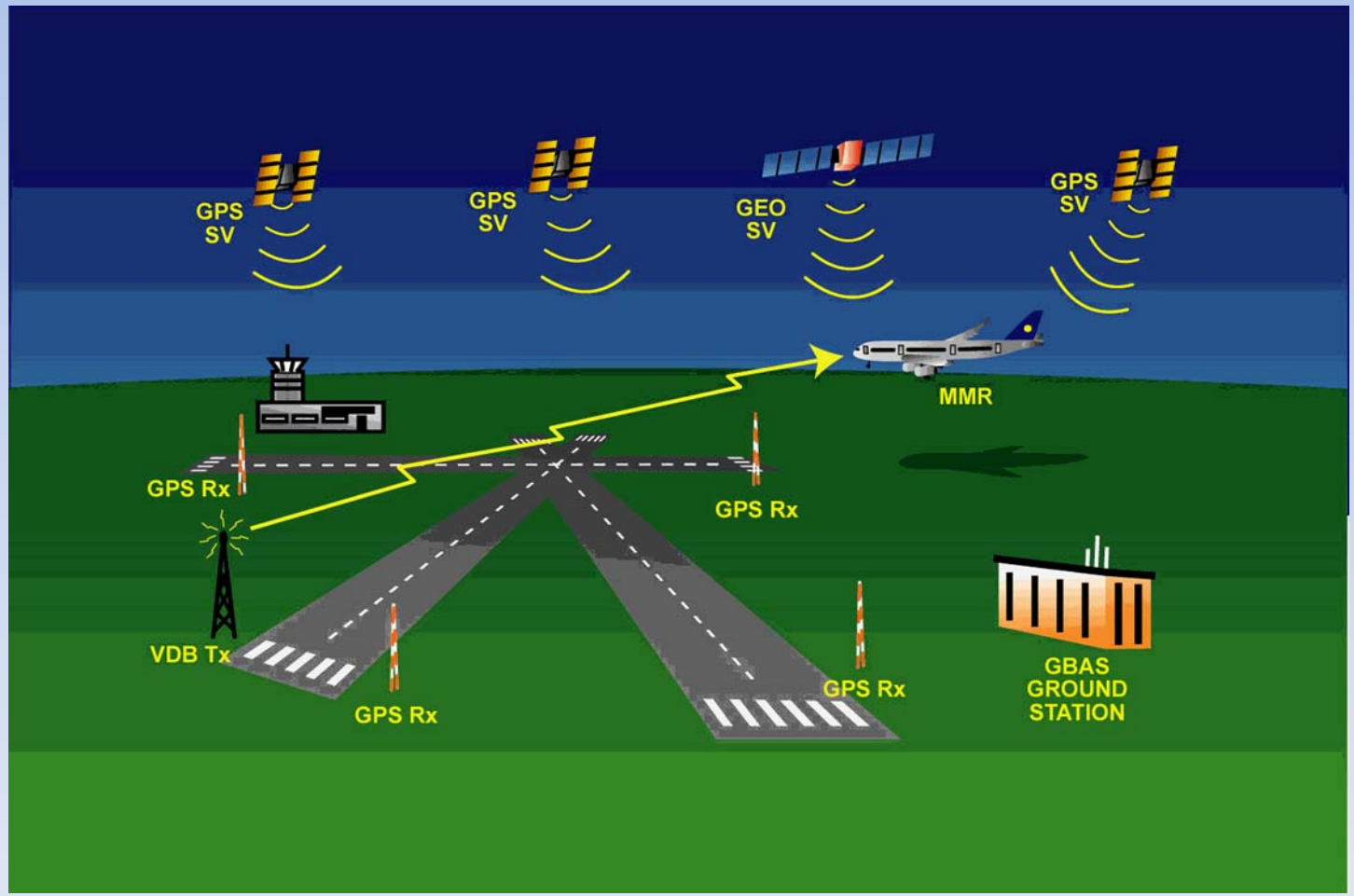


Hong Kong Land-based Automatic Identification system (AIS)

- Established in 2003
- 6 land AIS stations to cover HK water
- Monitoring ships in HK water
- Also
  - A DGPS beacon covers 150 nmi



Hong Kong Airport

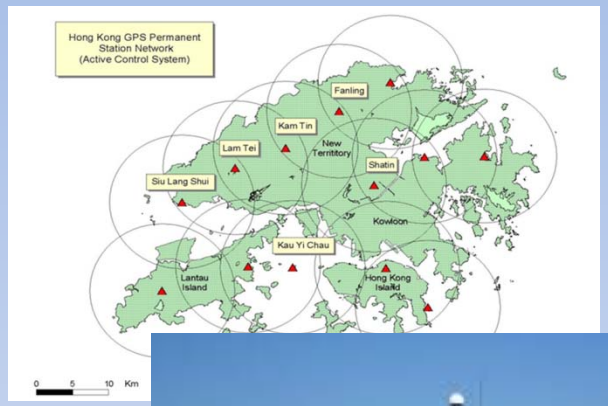


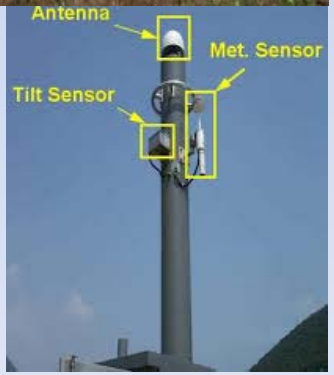
Main Problems for GNSS applications in Hong Kong

- GNSS does not work well in urban environment
  - Multipath
- Hong Kong is located in Low Latitude
  - Large Ionosphere Delay
  - Strong Ionosphere Scintillation
- Hong Kong is surrounded by sea
  - High Humidity

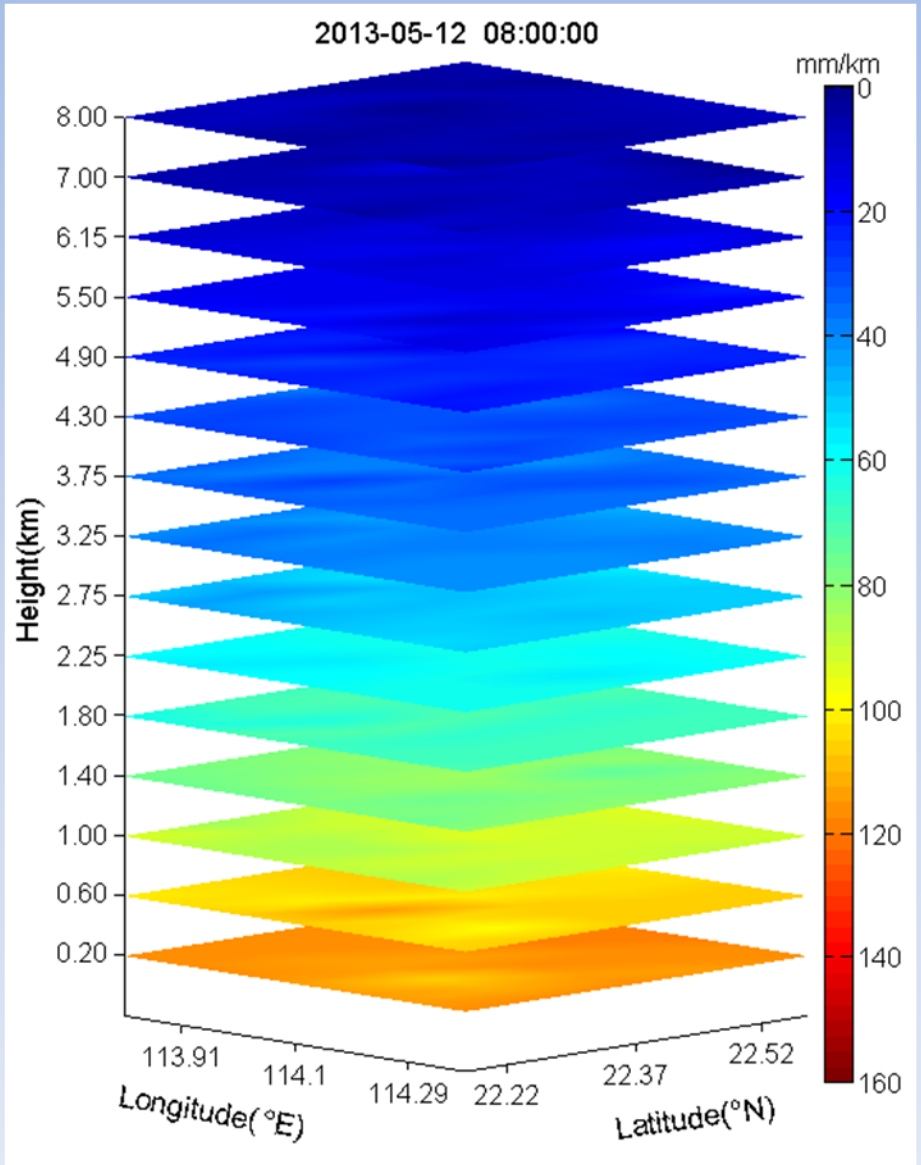
Improving HK SatRef Services

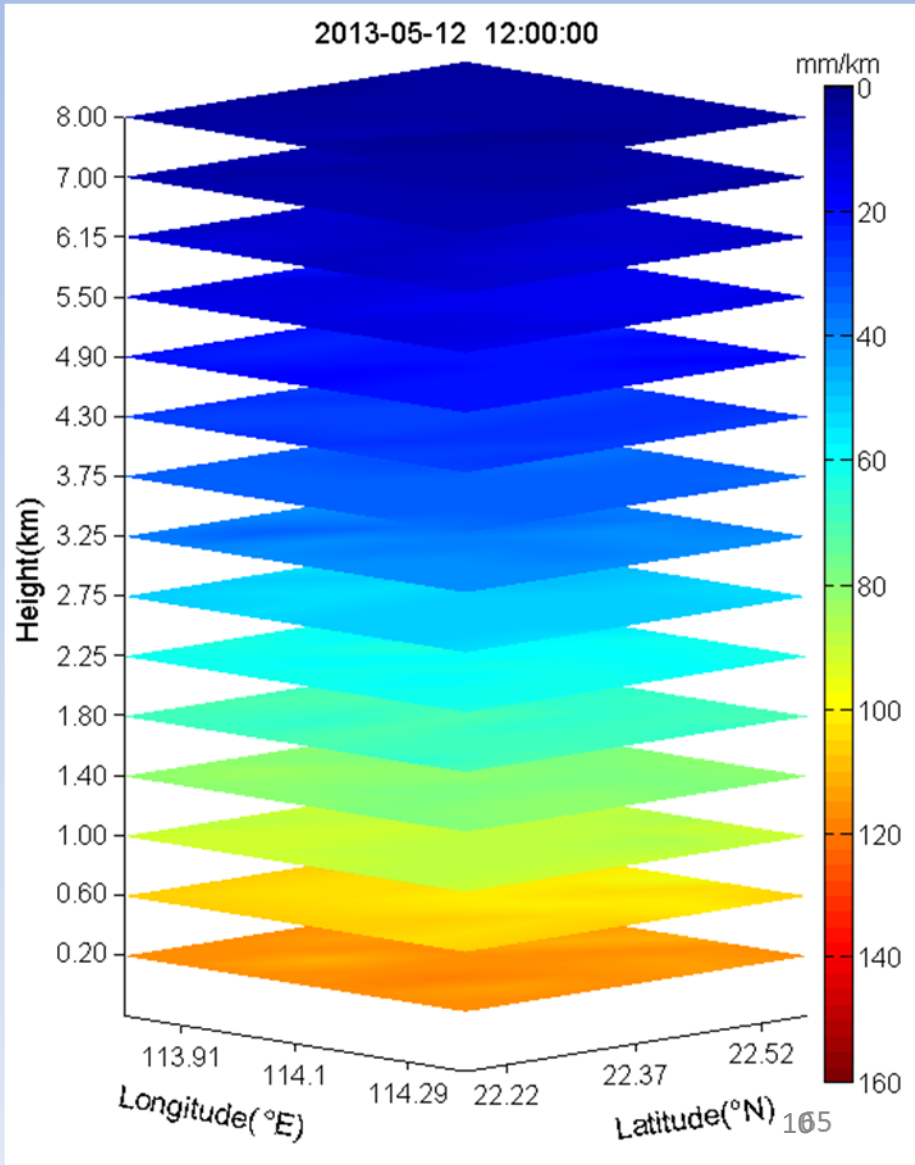
- Receivers for all GNSS constellations (GPS, Beidou, GLONASS, Galileo, QZSS)
  - Improve availability of GNSS RTK positioning
- High Quality Local Geoid
  - 1 cm
  - Provide more reliable 3D cm level RTK Service
- DGNSS platform for mobilephone
- Provide atmosphere remote sensing (troposphere and Ionosphere) service





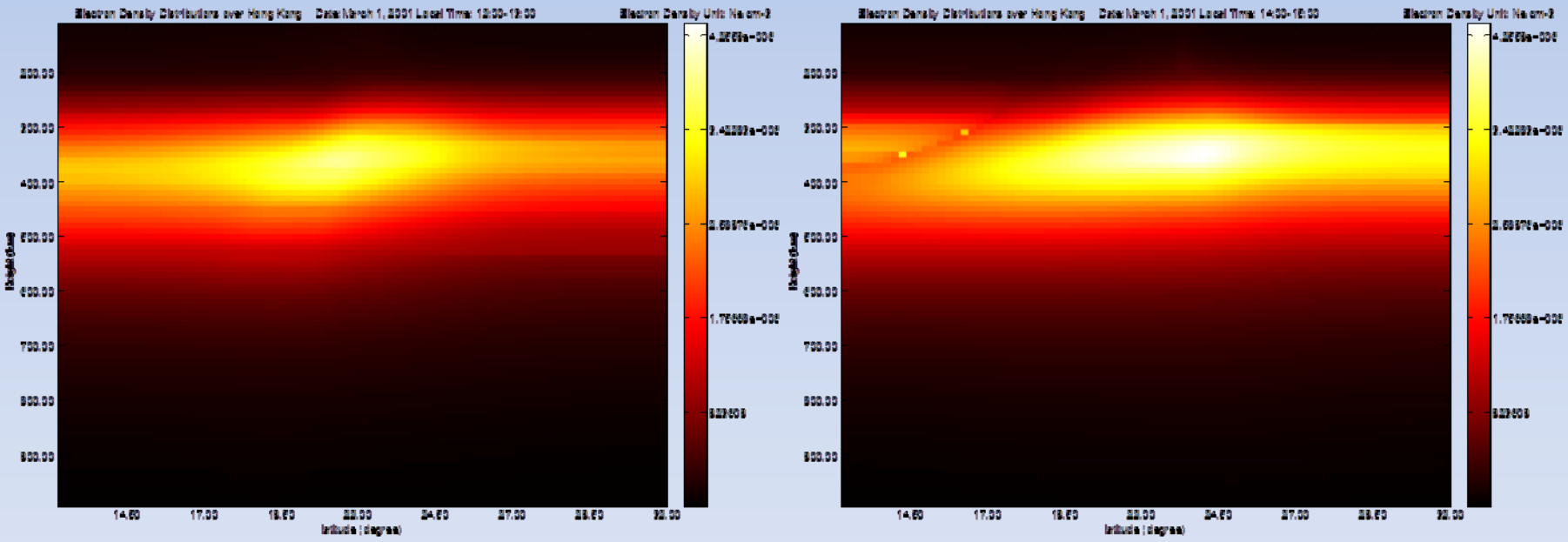
Spatial distribution of water vapor



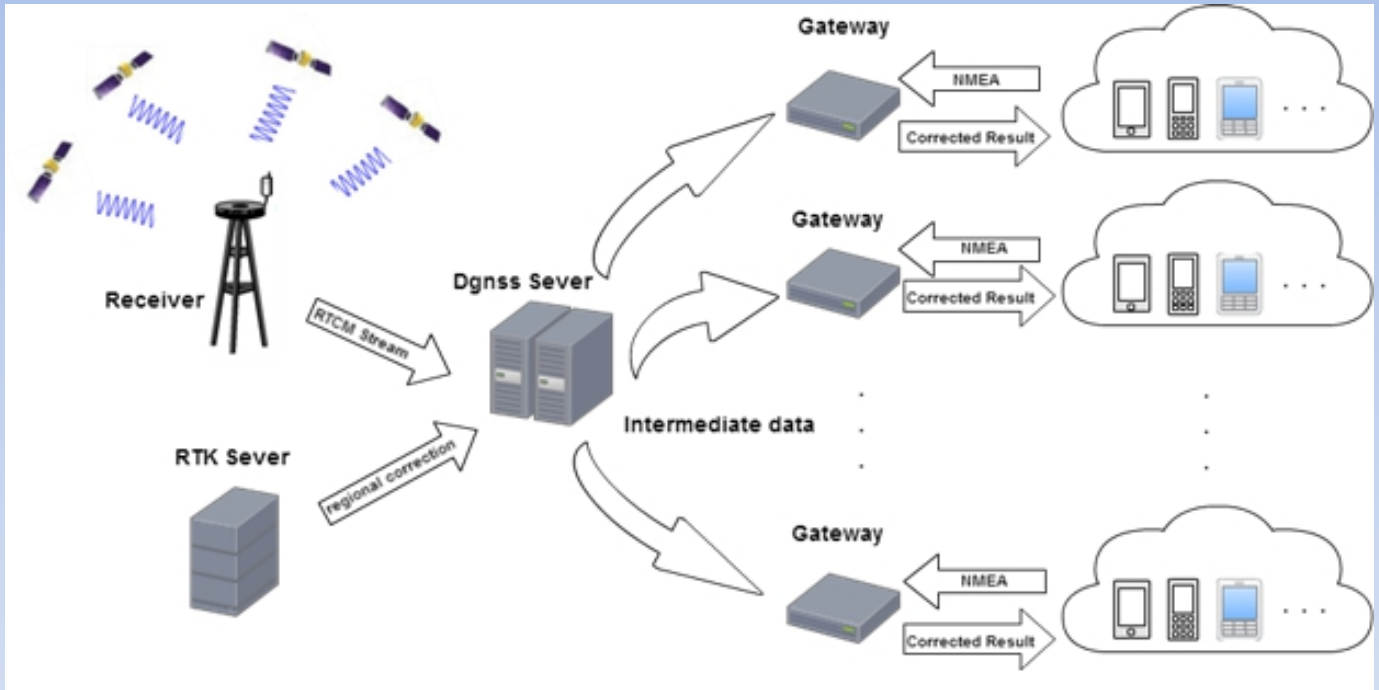


Electron Density Distribution in HK

- Reconstructed electron density distributions on 1 March 2011 (12:00 LT and 14:00 LT)



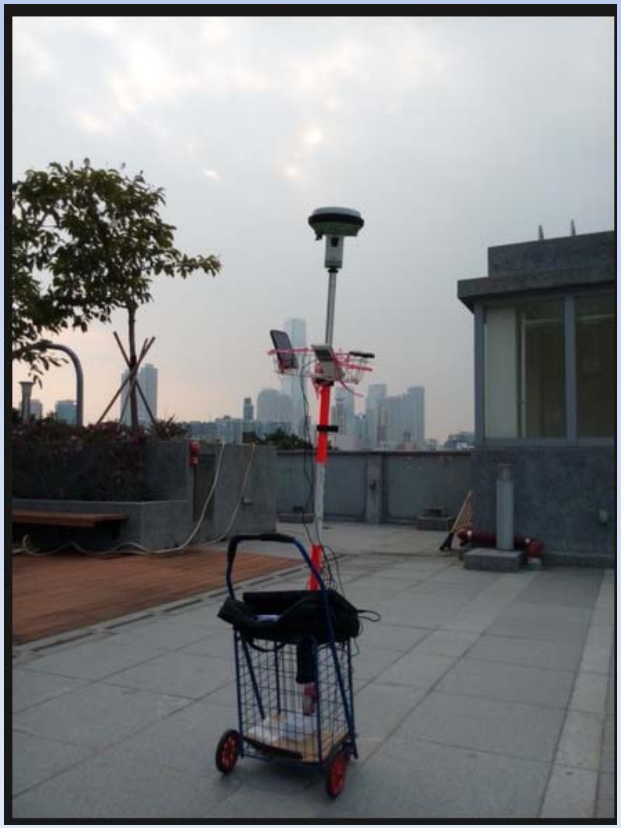
DGNSS server platform for mobilephones

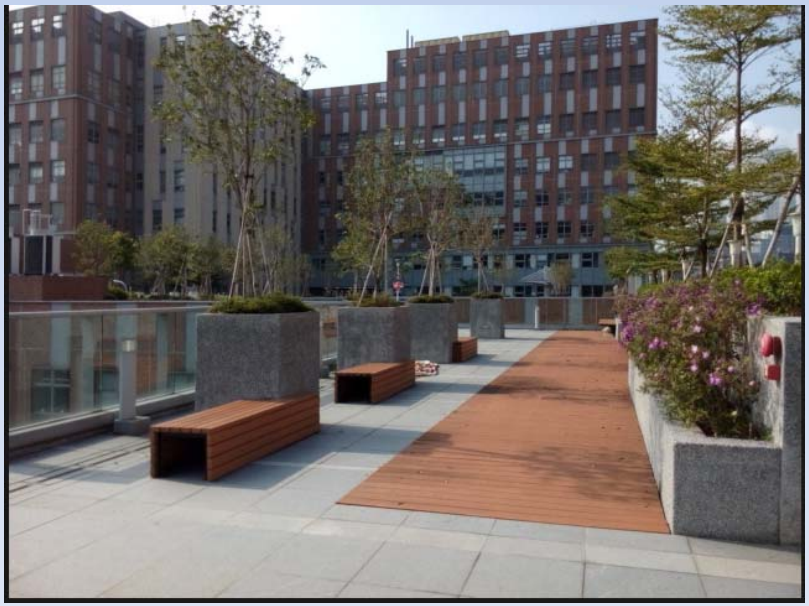


Polyu test

Dec.4,2015 PolyU

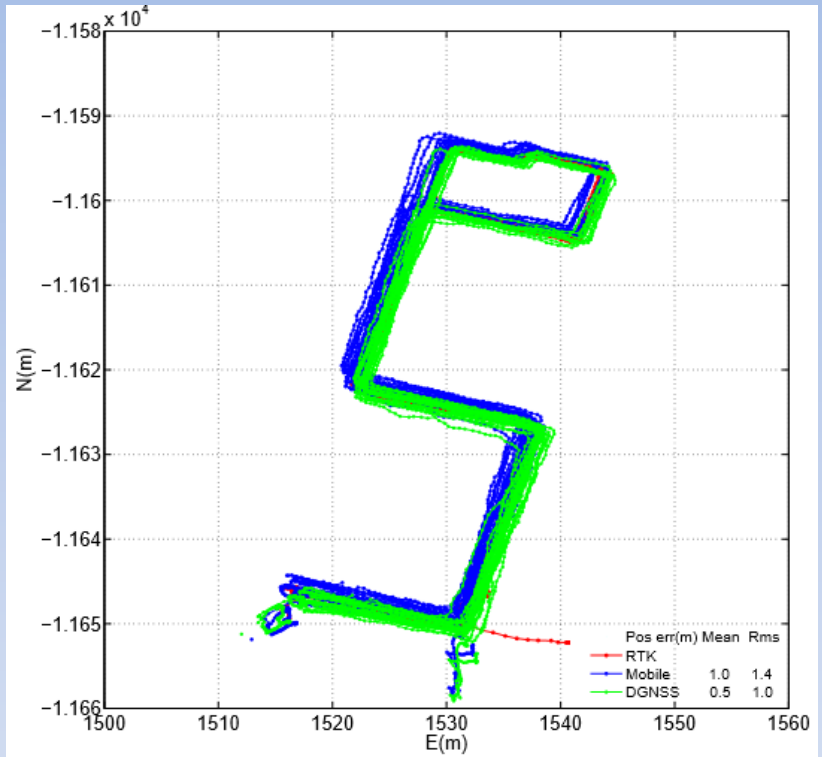
UniStrong E7737

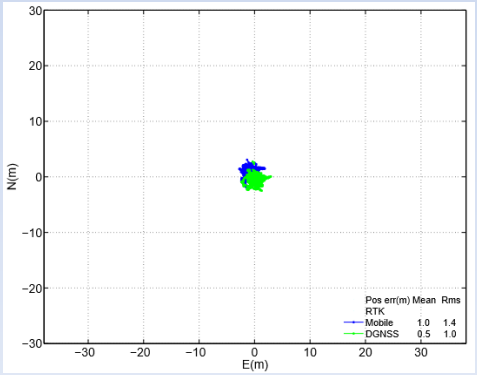




4 - 12 - 2015

10:00-11:00





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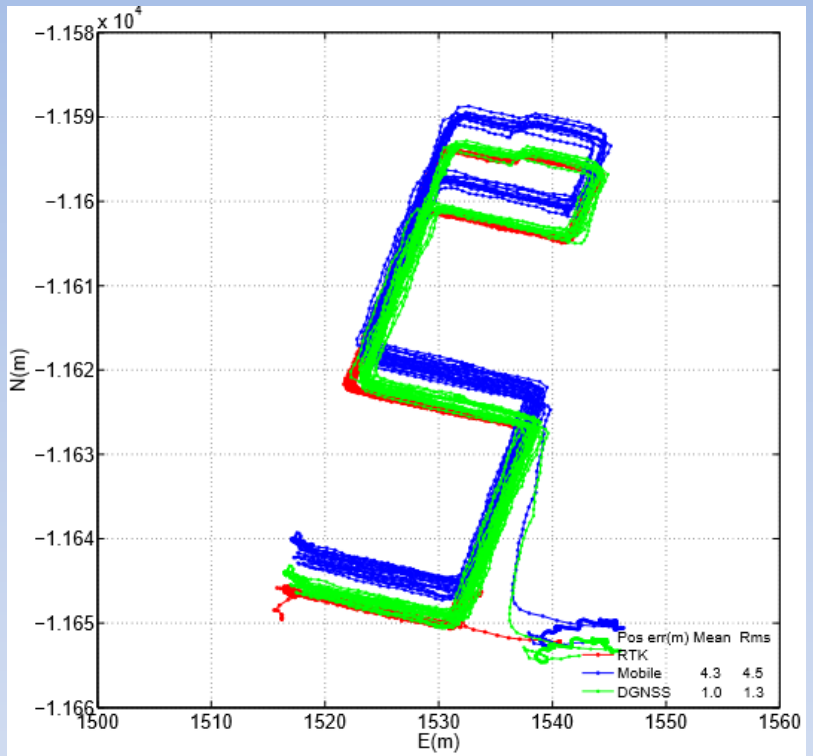
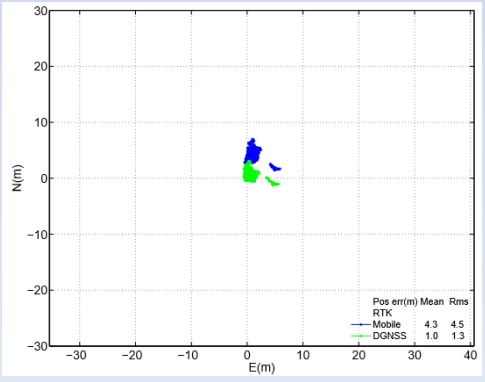
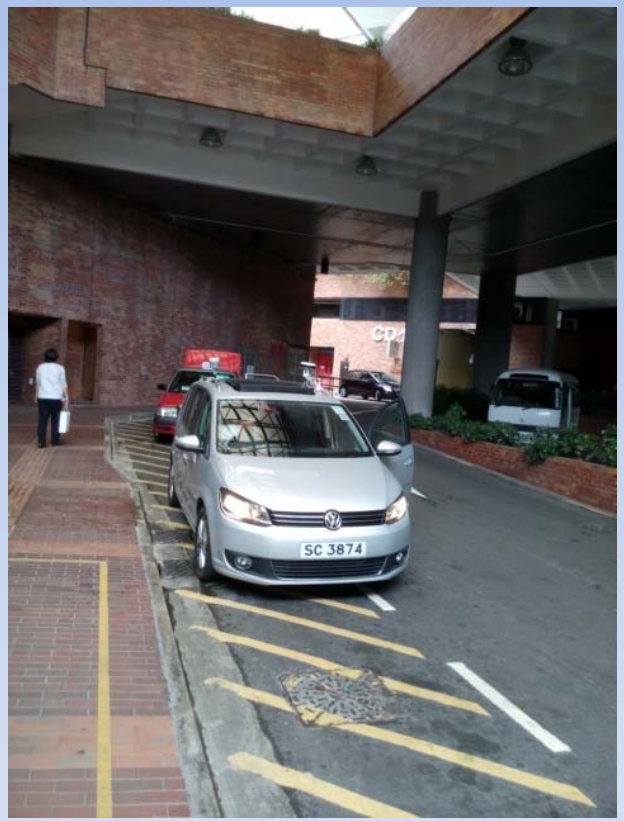
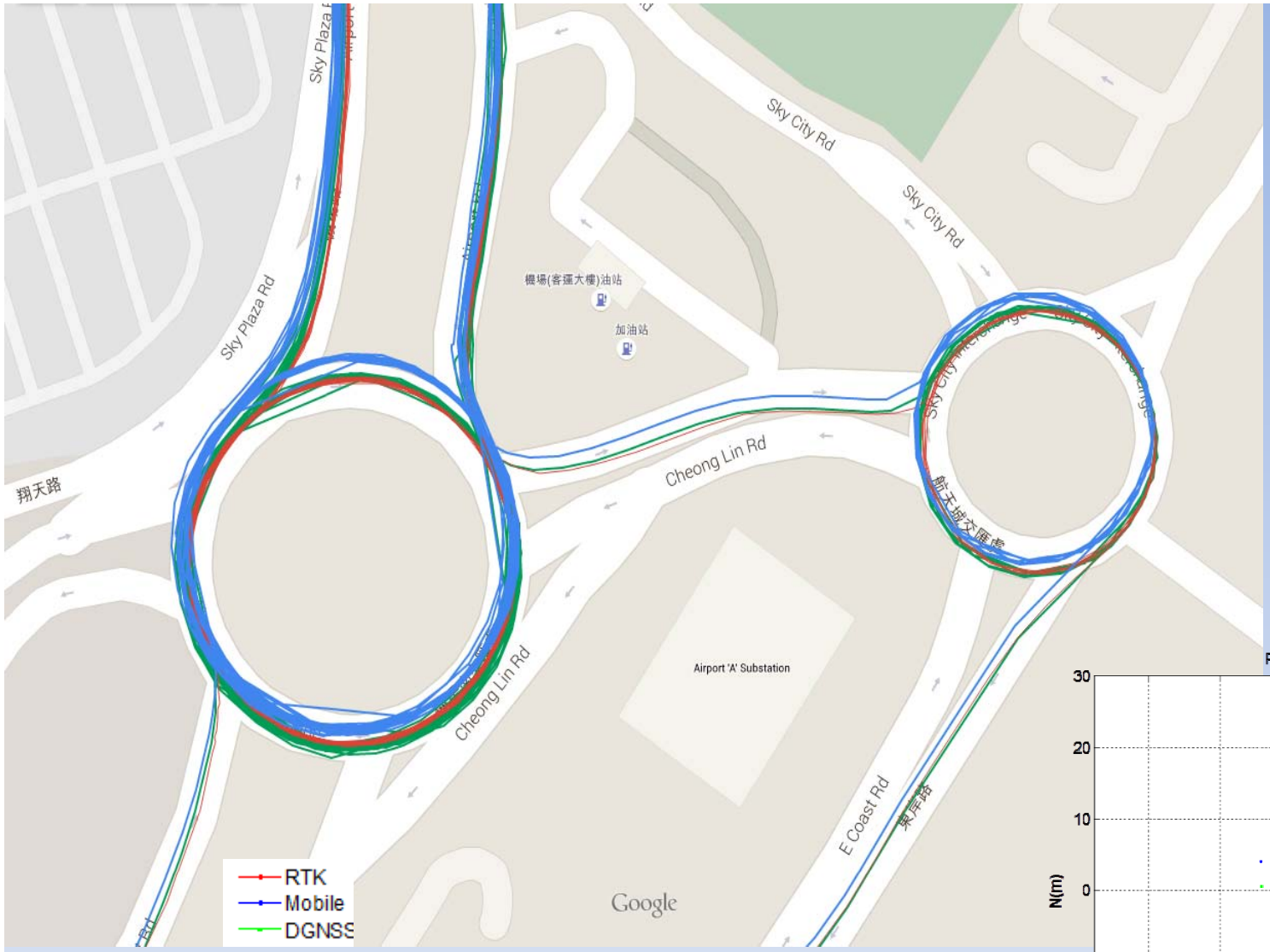
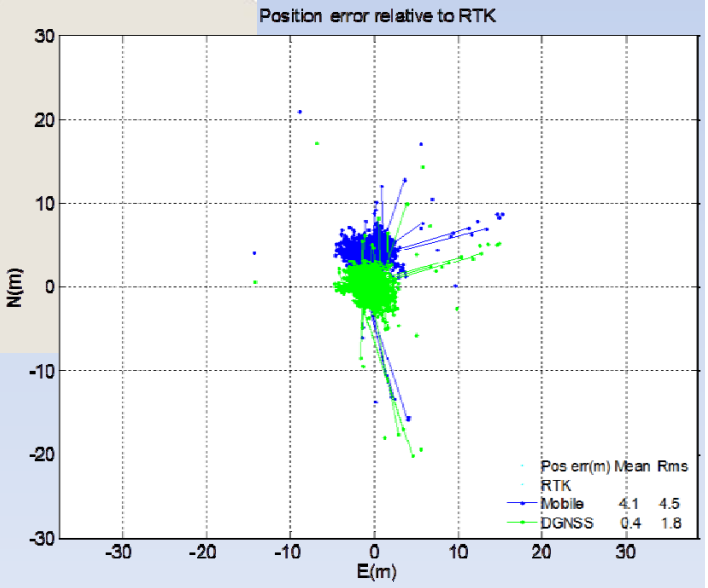




Airport car driving test
15:09 -17: 06 , 2015-08-13

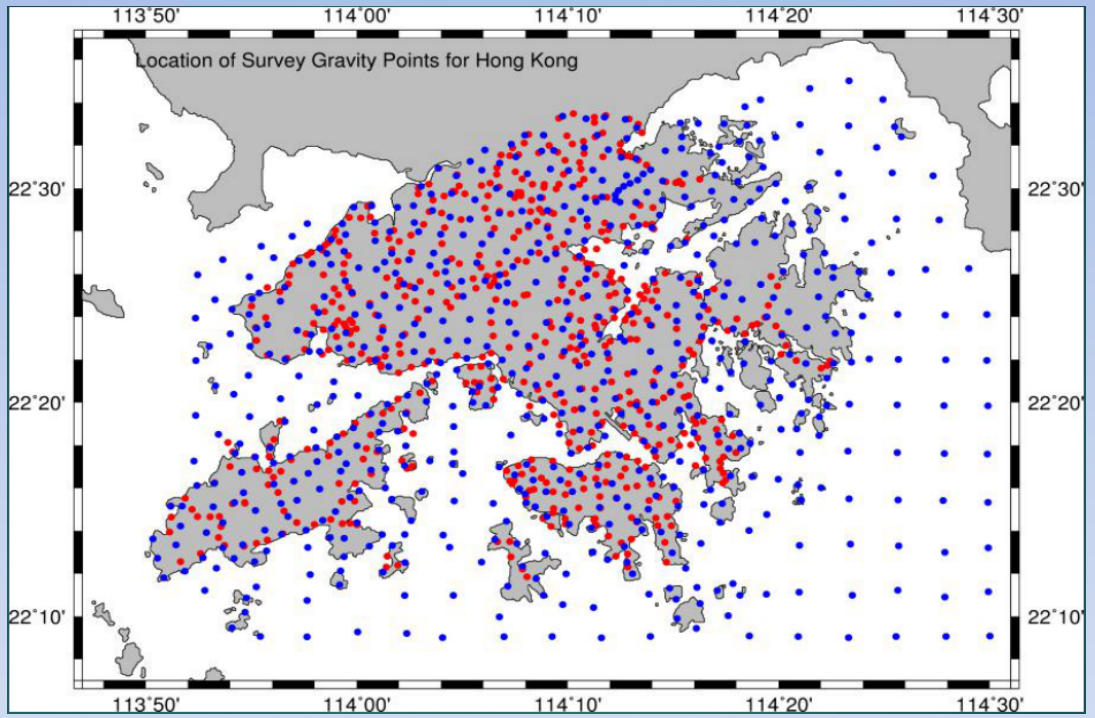



Sky Plaza Rd
Sky City Rd
Sky City Rd
機場(客運大樓)油站
加油站
Cheong Lin Rd
翔天路
Cheong Lin Rd
Airport 'A' Substation
E Coast Rd
東岸路
RTK
Mobile
DGNSS
Google


Position error relative to RTK
30
20
10
0
-10
-20
-30
N(m)
-30
-20
-10
0
10
20
30
E(m)
Pos err(m) Mean Rms
RTK
Mobile 4.1 4.5
DGNSS 0.4 1.8

Hong Kong High Precision Geoid Model

Gravity Data



blue-old
red- new

- New Gravity survey
  - To establish high quality gravity network
  - Establish absolute gravity points
  - Evaluated old gravity survey quality

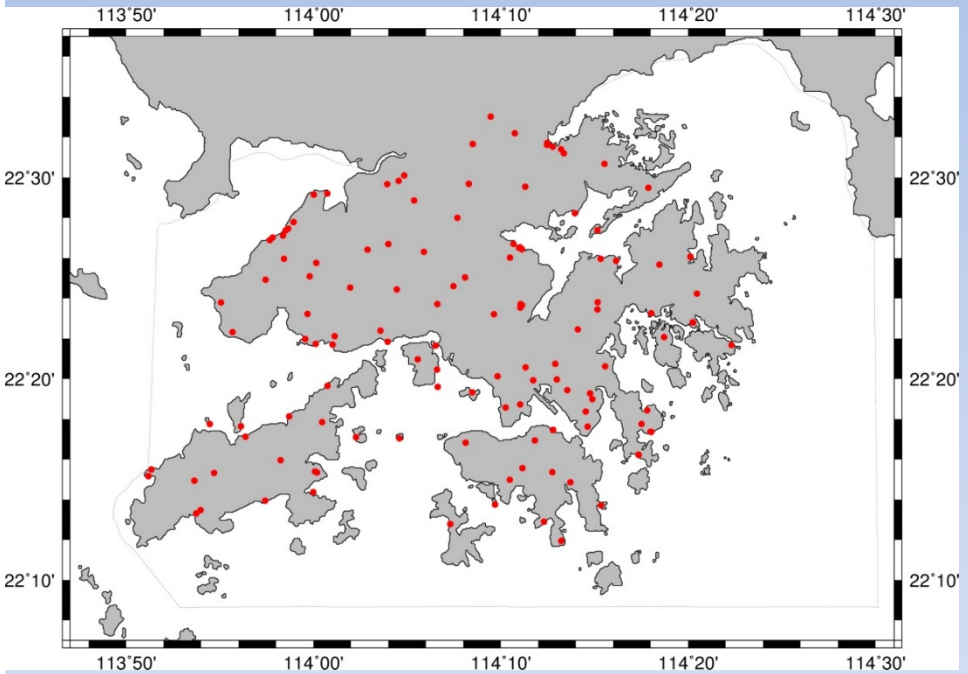
Data Description

Gravity Data

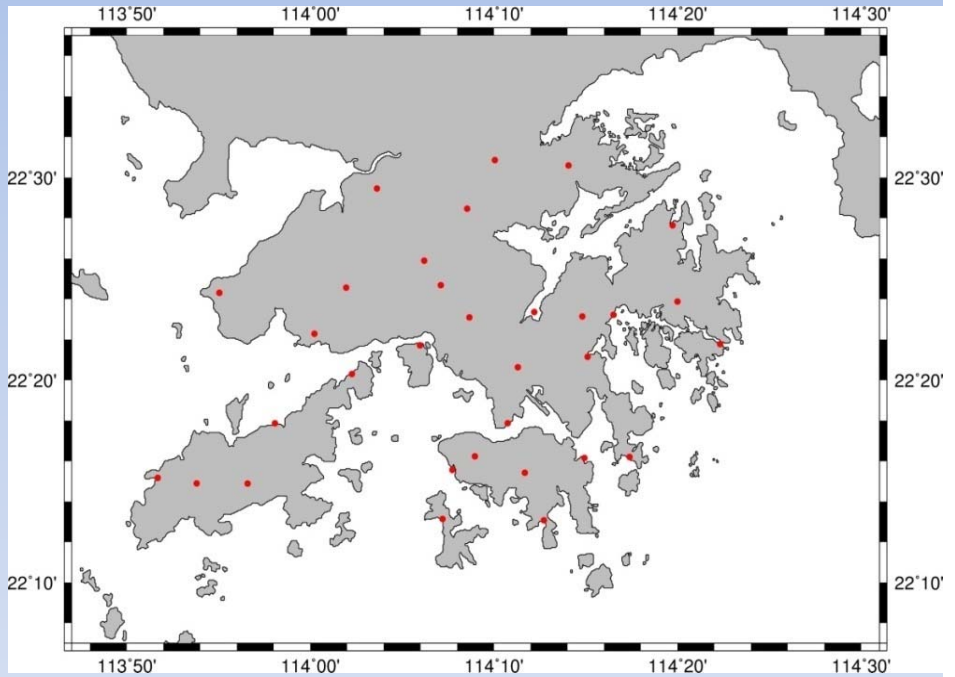
① Gravity measurements

GNSS/Leveling surveying

GPS/leveling data

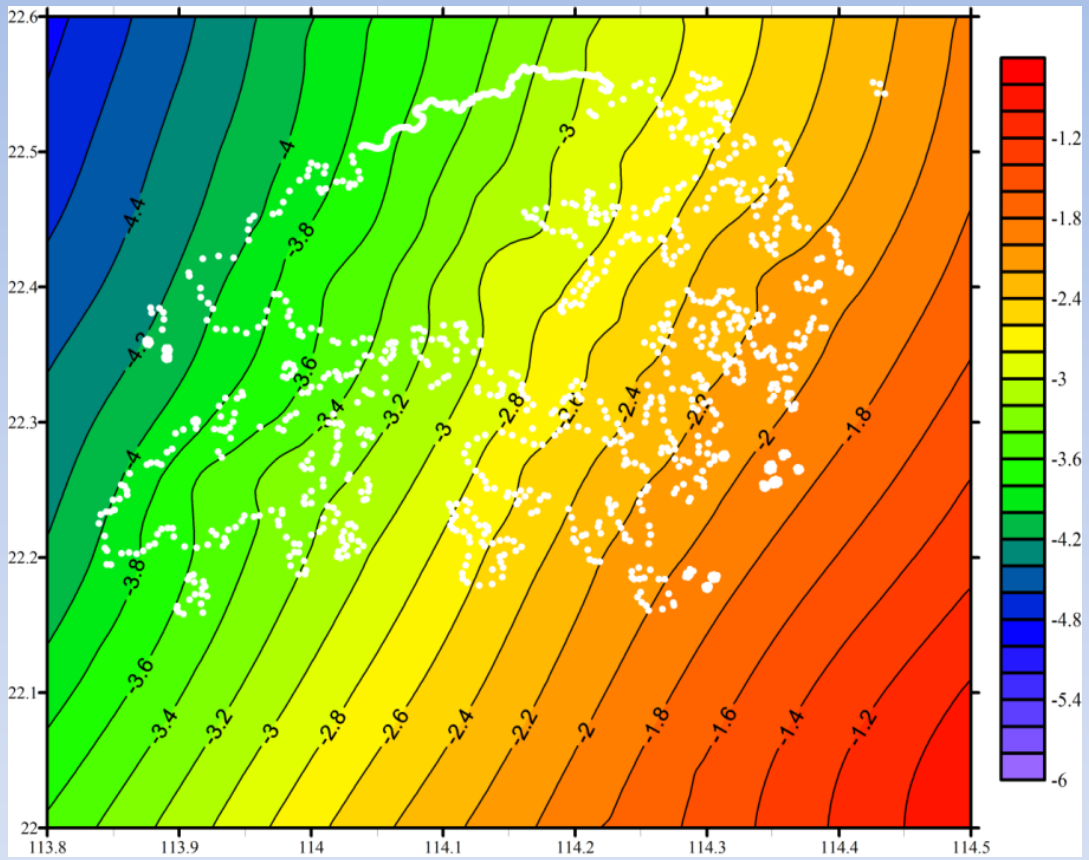


133 GPS benchmarks



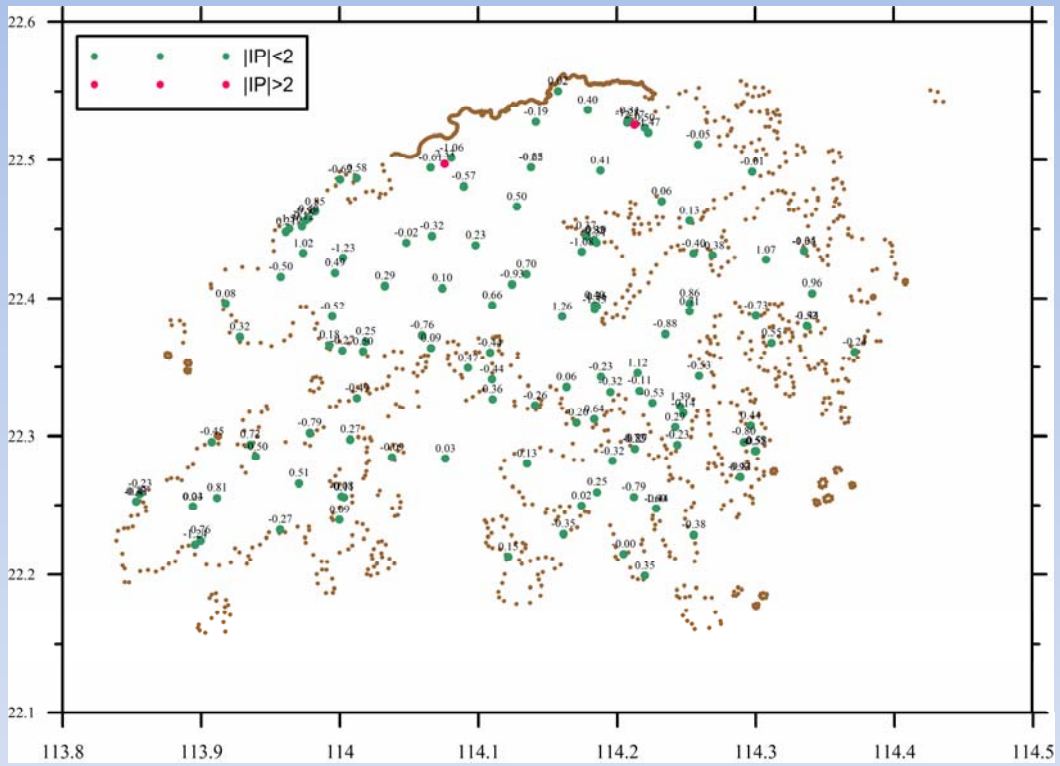
34 GPS/leveling stations

Geoid Models and Accuracy Evaluation



Geoid Models and Accuracy Evaluation

(Internal Precision: check with 133 points)

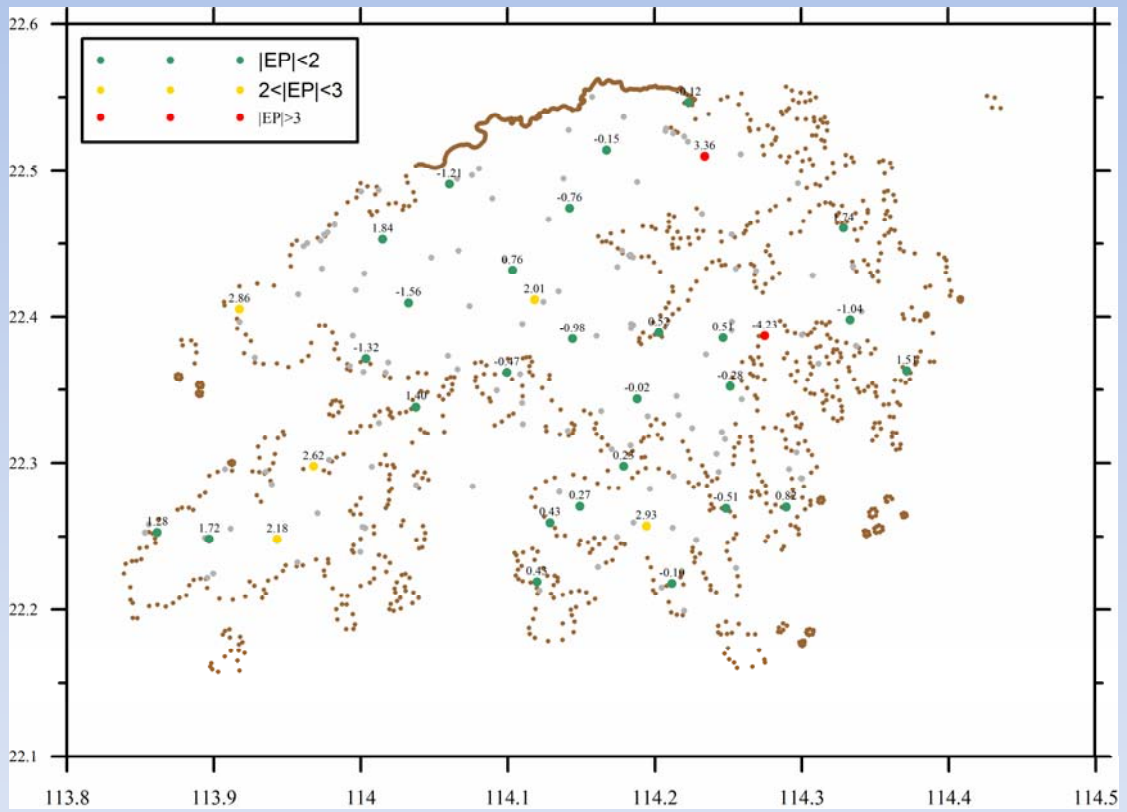


The internal precision of quasi-geoid model II (unit: cm)

Model II	Min	Max	mean	STD
Internal precision	-1.47	2.33	0.00	0.69

Geoid Models and Accuracy Evaluation

Accuracy evaluation - external accuracy, check with 34 points not used for geoid computation



The external precision of quasi-geoid model II (unit: cm)

$|EP| \leq 2$ (27 points)

$2 < |EP| < 3$ (5 points)

$|EP| \geq 3$ (2 points):

No.	*EP*
230047G	3.36
Wong Nai Chung	2.93
230211	2.86
Pak Mong	2.62
Tung Chung Road	2.18
30925G	2.01
220073G	-4.23

Geoid Models and Accuracy Evaluation

Accuracy evaluation - external precision

The external precision (all 34 points) of quasi-geoid model II (unit: cm)

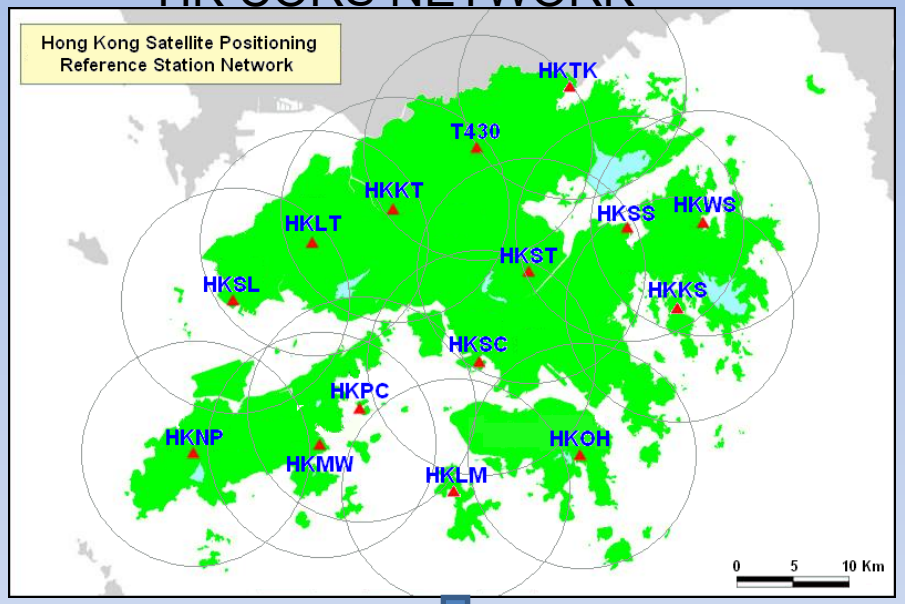
Model II	Min	Max	mean	STD
External precision	-4.24	3.36	0.44	1.54

The external precision (exclude 2 points >3cm) of quasi-geoid model II (unit: cm)

Model I	Min	Max	mean	STD
External precision	-1.56	2.93	0.54	1.26

GNSS RTK Services (GPS/GLONASS/Beidou)

HK CORS NETWORK



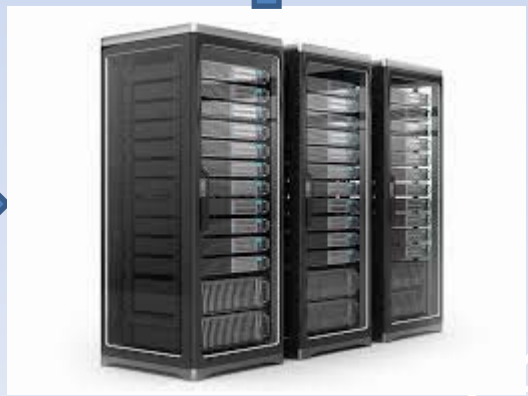
USER

NTRIP

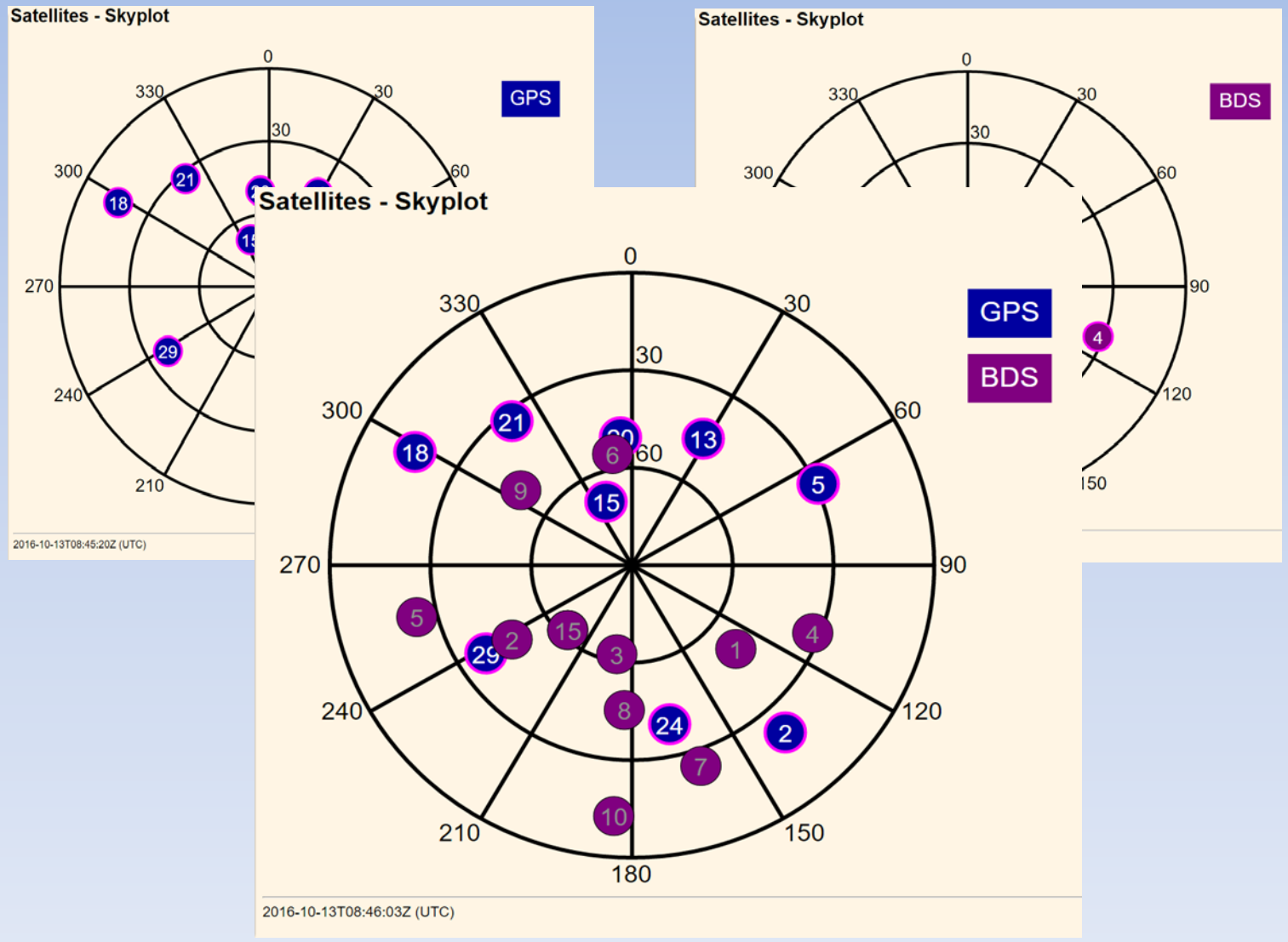
NTRIP

SERVER

LSGI
NETWORK RTK
SERVICE

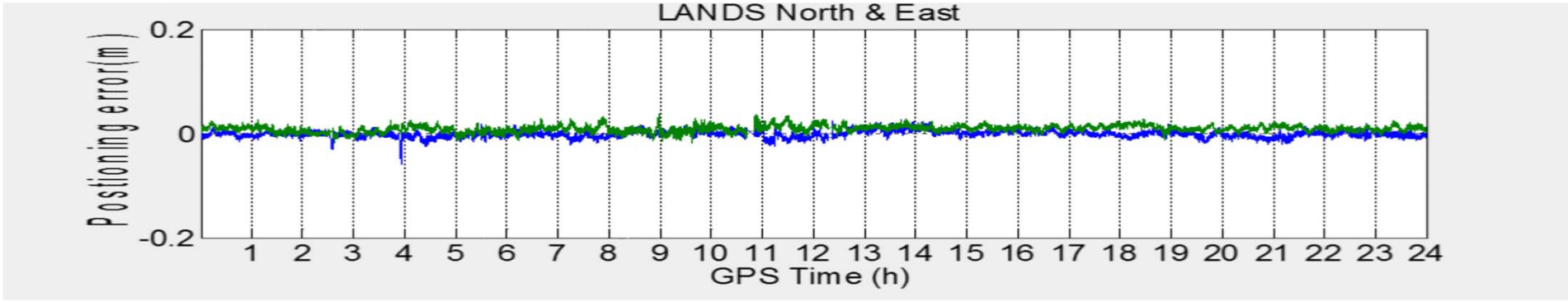


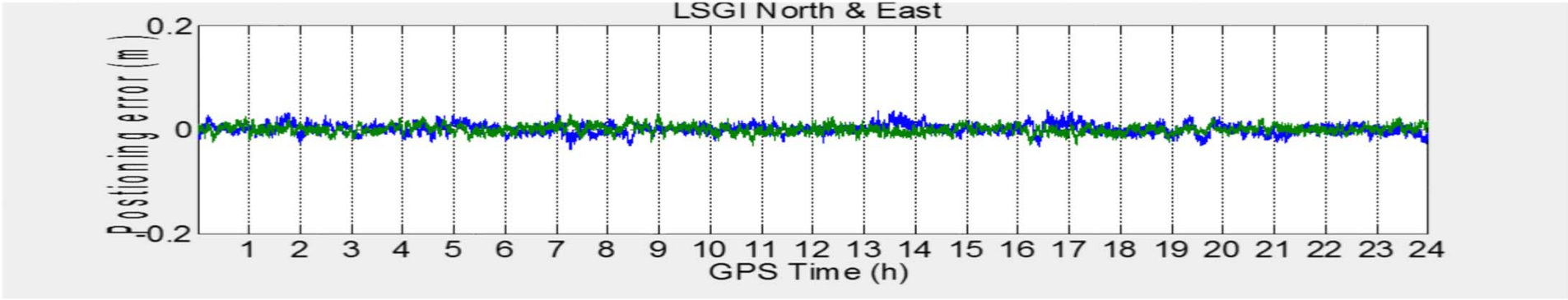
Satellite Skyplot



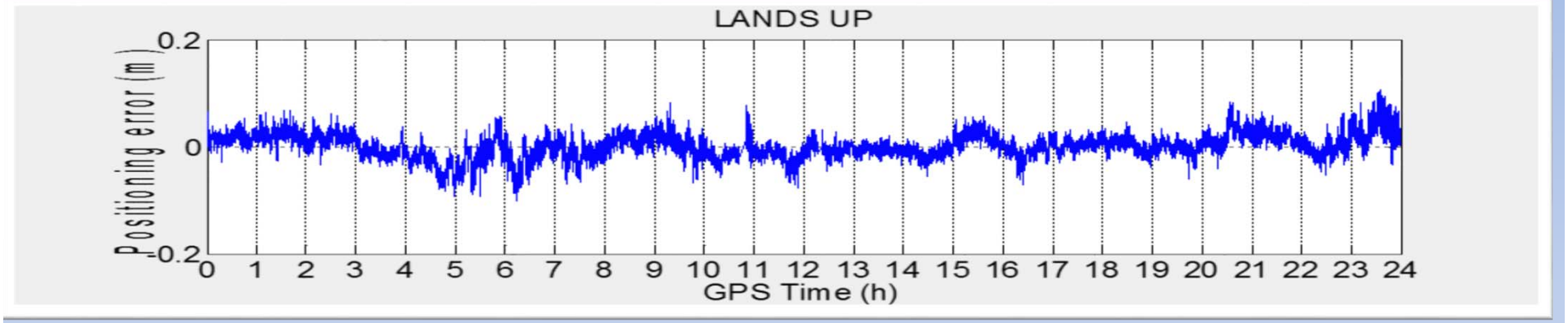
Static Test

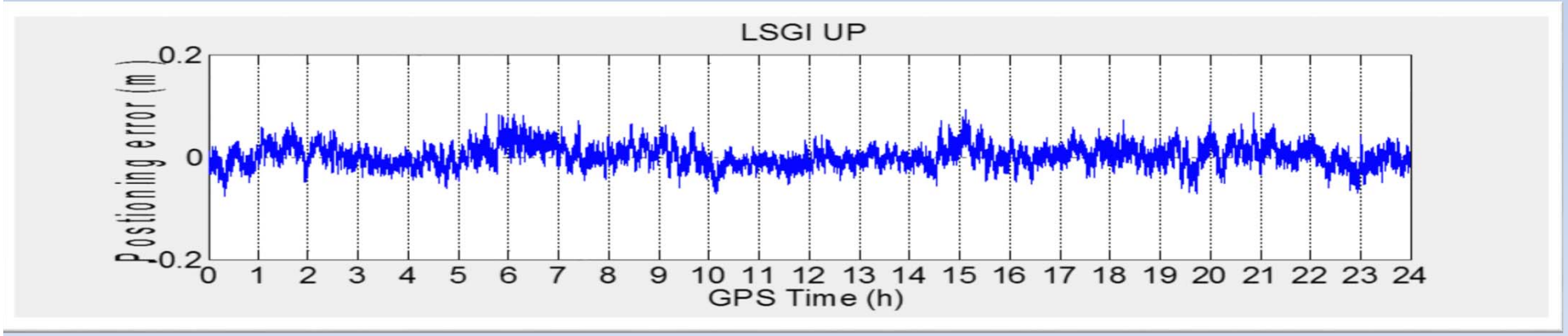
Test Result—N&E





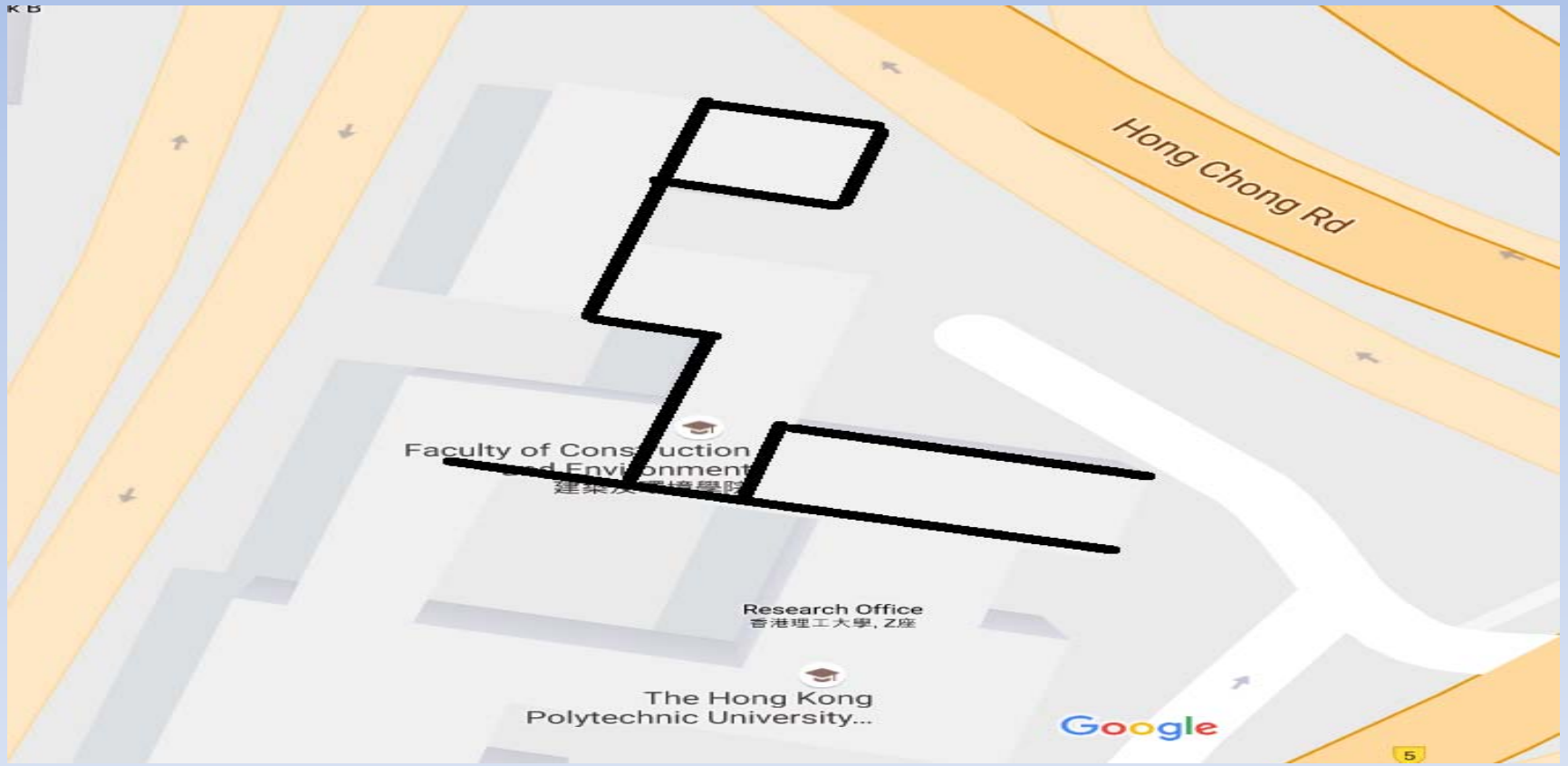
Test Result—U





	SYSTEM	ALL	NON-FIX	NON-FIX	FIX/ALL	STD		
						N	E	U
LANDS	GPS	85575	531	0.62%	99.38%	0.006	0.006	0.023
LSGI	GPS/BDS	86264	0	0.00%	100.00%	0.009	0.008	0.021

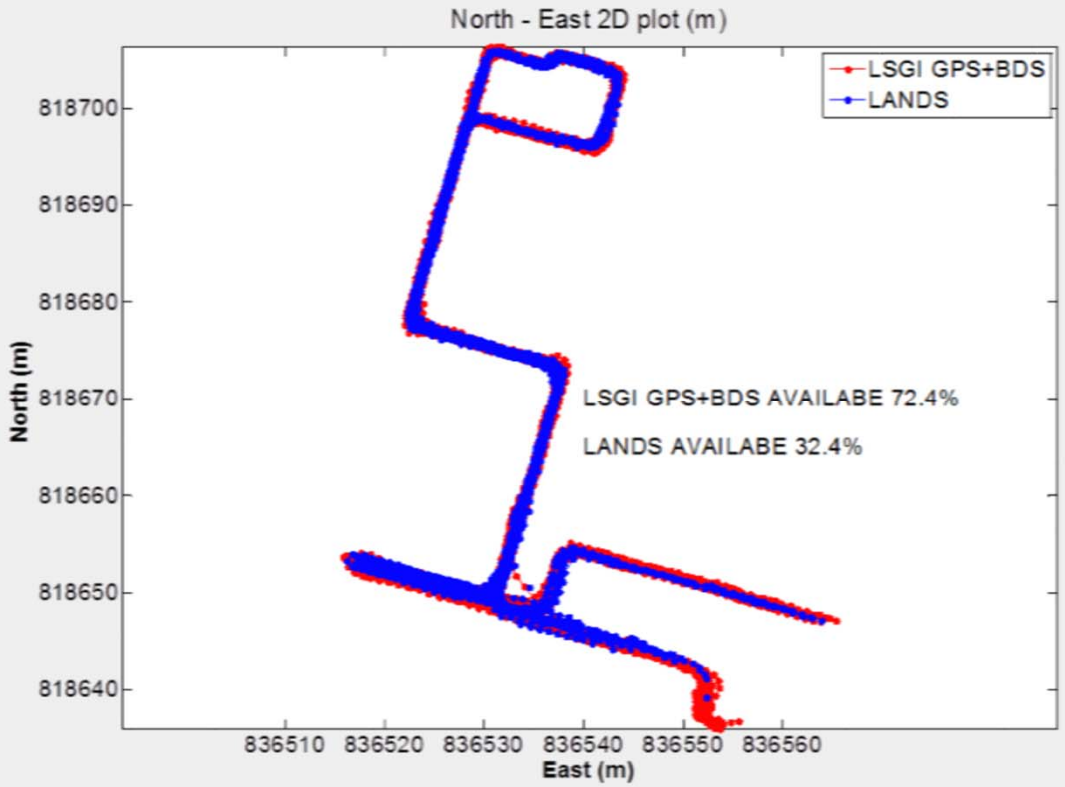
RTK Test in PolyU



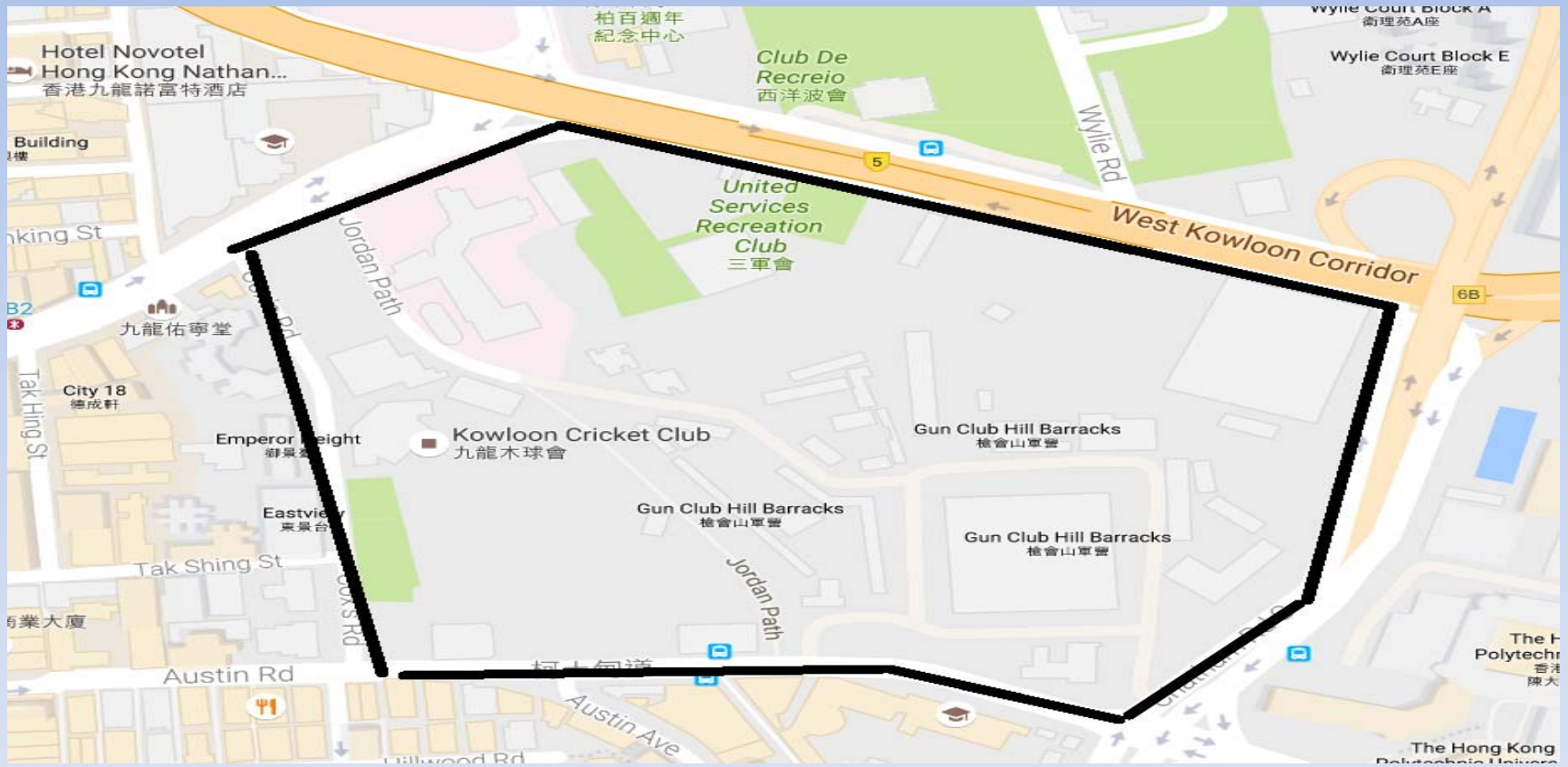
Test Environment

Test Result

July 20th

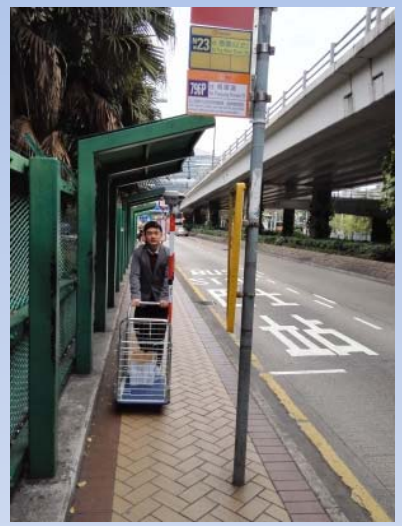


RTK Test in Jordan

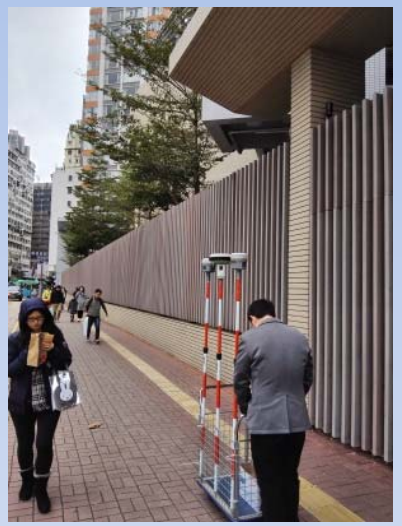


Test Environment

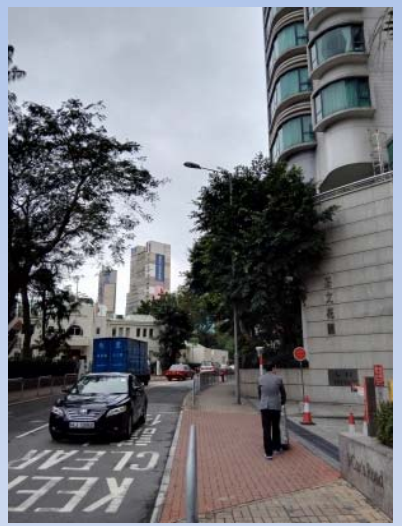
tree



bus station



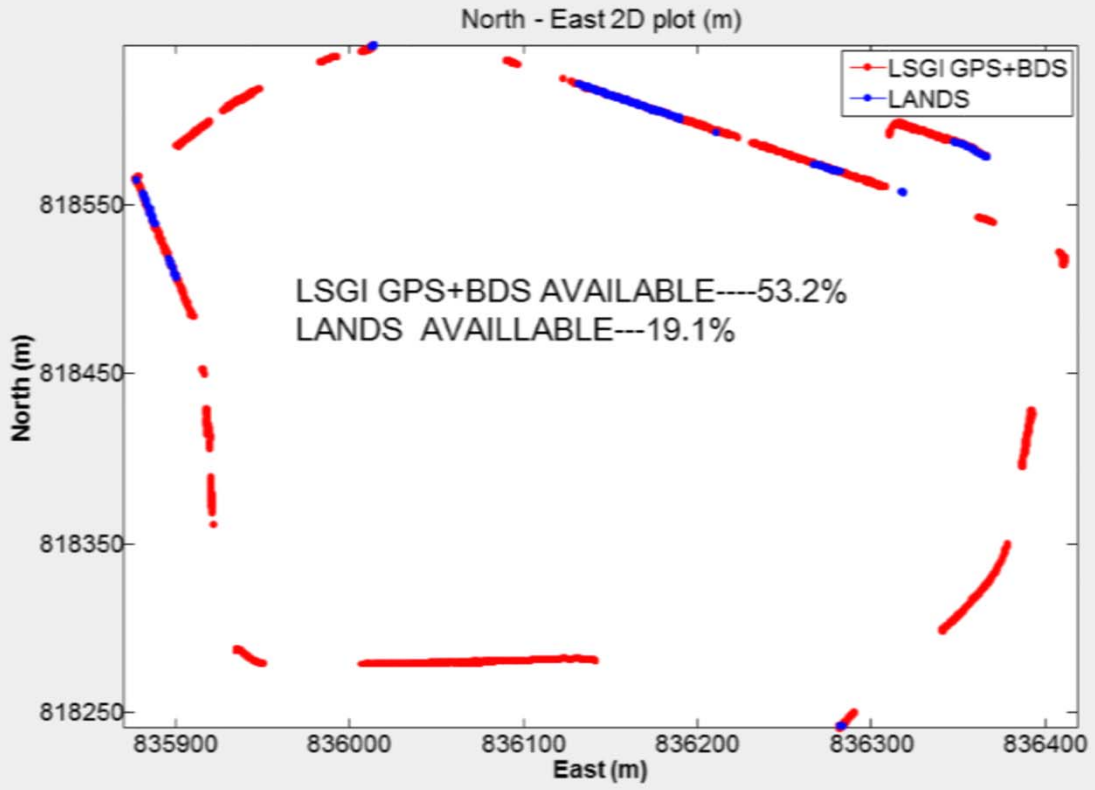
wall



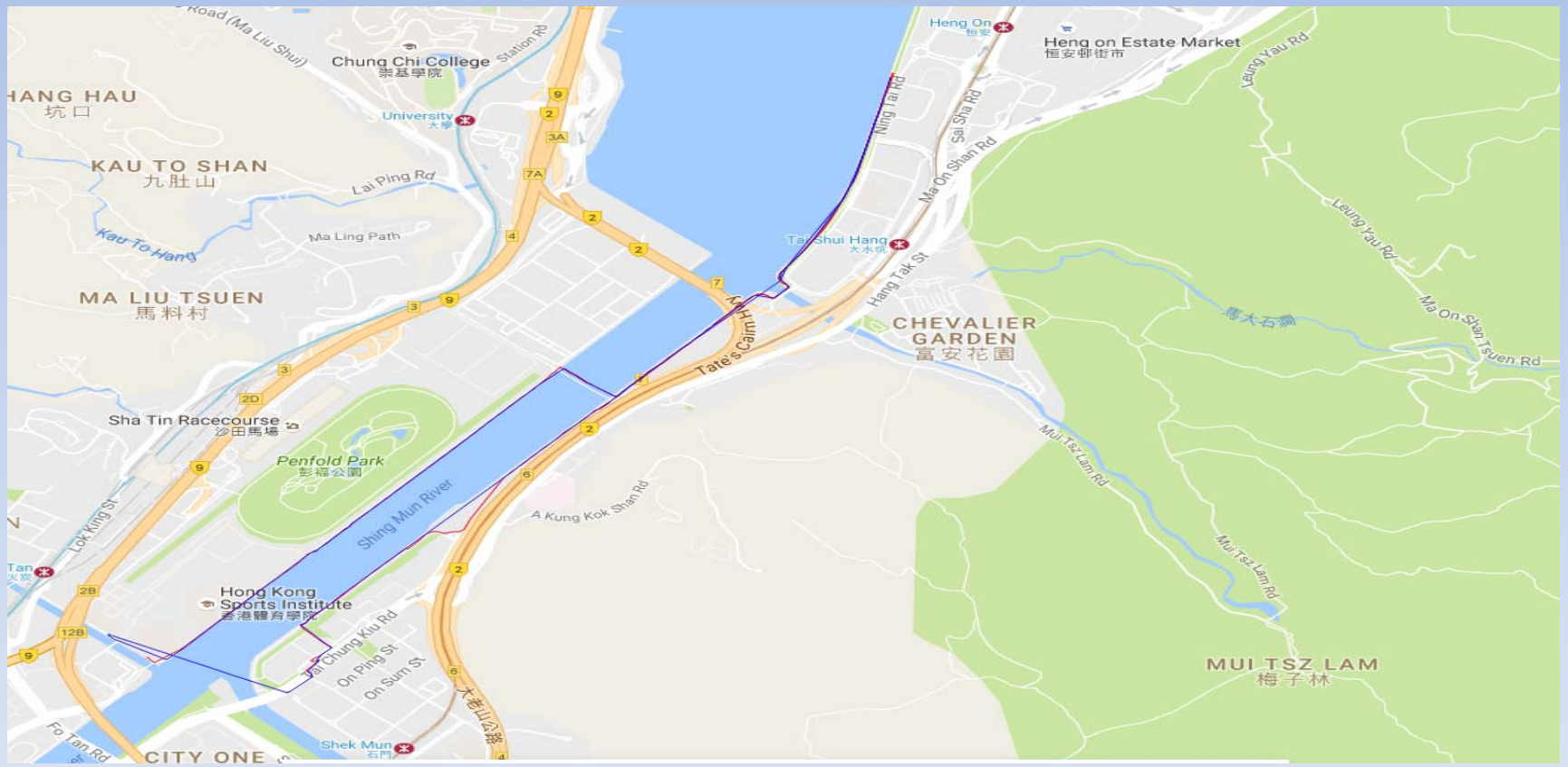
tall building

Test Result

July 19th

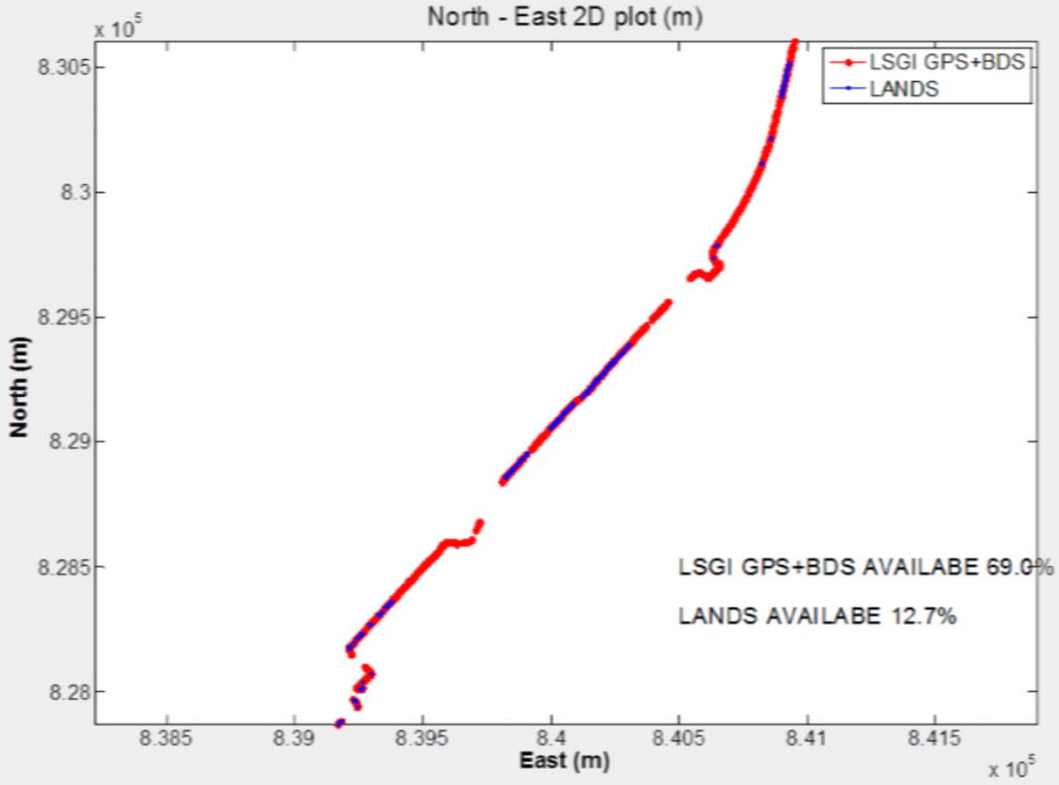


Test in Sha Tin

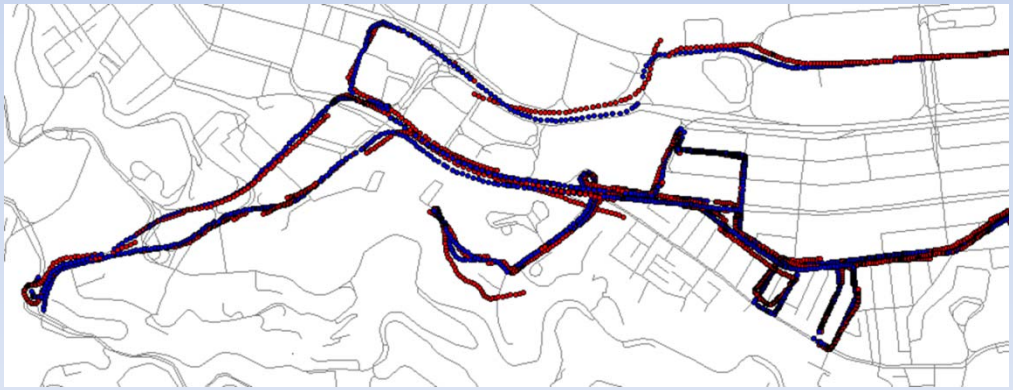


Test Result

July 26th



Vehicle Navigation (GPS+DR+Map Matching)

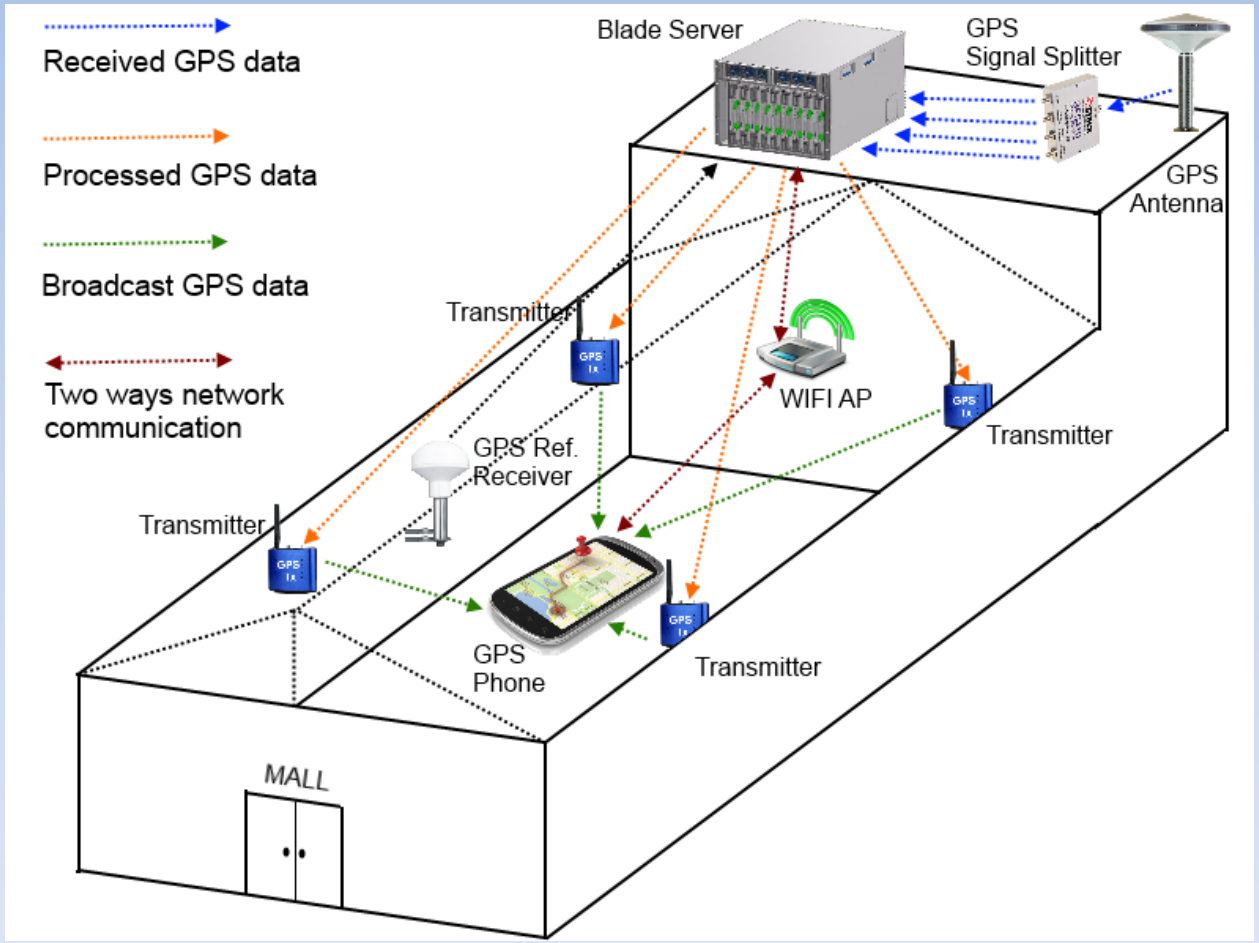


Field Tests and Analysis (5000 km in Hong Kong Roads, 10m accuracy)

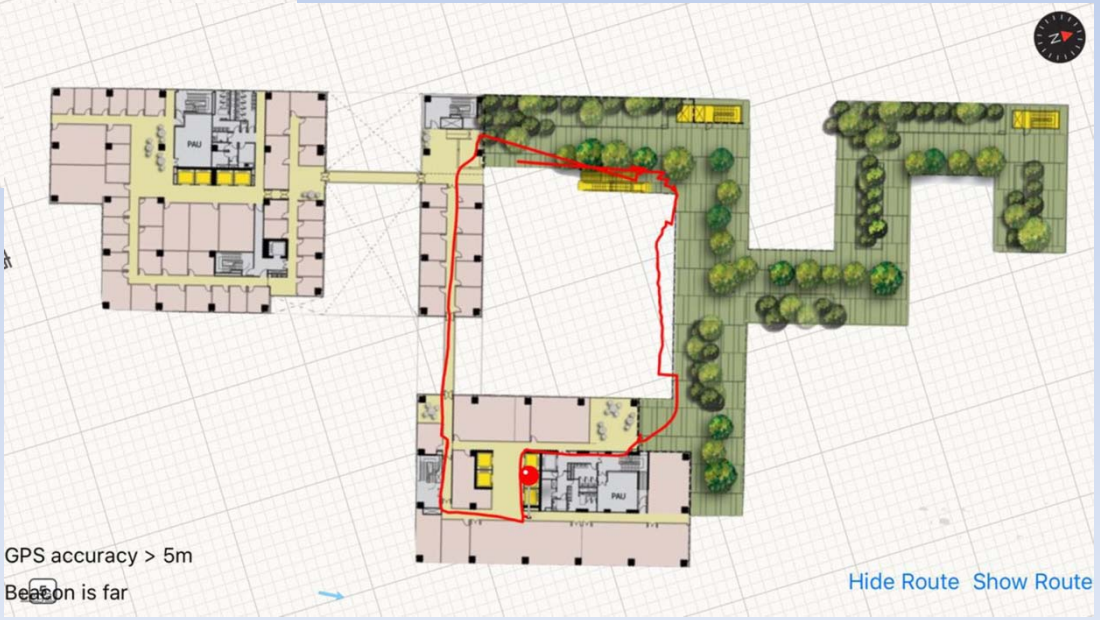
GPS	GPS/DR	GPS/DR/MM (without MM feedback	GPS/DR/MM (with MM feedback)
50%	64%	90%	96%

Multipath Improvement

Indoor GPS system - Concept



Indoor Positioning with mobilephone (Integrating sensors in mobilephone)



Future Development

- Integrate GNSS, Digital Map, Other positioning sensors
- Significant Reduce Multipath Effects
- Improving indoor positioning
- To develop Hong Kong Positioning Infrastructure to Support Economic development

Thank you