

# Geodetic Datums and Coordinate Systems for Surveying and Mapping in Hong Kong

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## This presentation covers the following areas

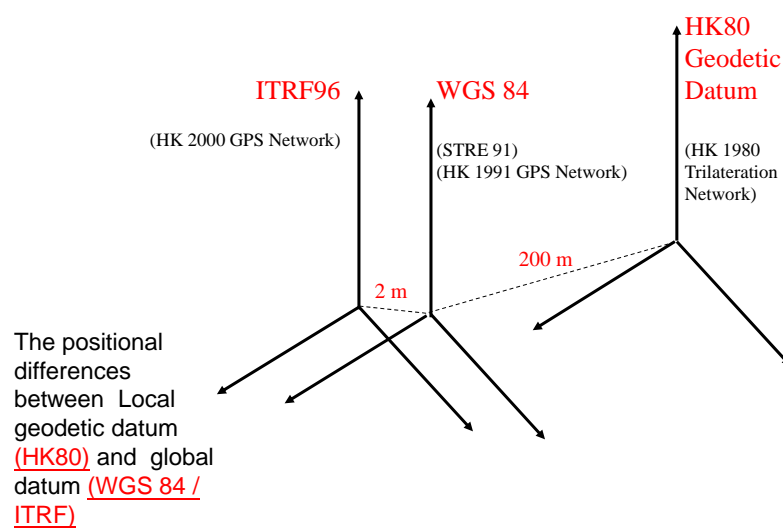
- Explains the coordinate systems used for surveying and mapping in Hong Kong.
- Describes the [Hong Kong 1980 Grid System](#) which is a [plane coordinate system](#) for defining position for land surveying, construction works, land boundaries and matters relating to planning and control of development in the territories.

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- Describes the 1991 and 2000 GPS control survey which established the [global earth-centred coordinate system for Hong Kong](#)
- Explains how the GPS control network and the CORS stations were [connected to the International Terrestrial Reference Frame \(ITRF\)](#).
- Describes the development of the [datum transformation parameters between the ITRF and HK80 geodetic datum](#).

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## Local and Global Reference Frame



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## Description of Position

- place name
- address
- map
  
- plane grid coordinates (Northing, Easting)
- geodetic coordinates (Latitude, Longitude)
- earth-centered cartesian coordinates (X,Y,Z)

Coordinate system is one of the many ways  
to describe position.

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## The Hong Kong 1980 Grid Coordinate System

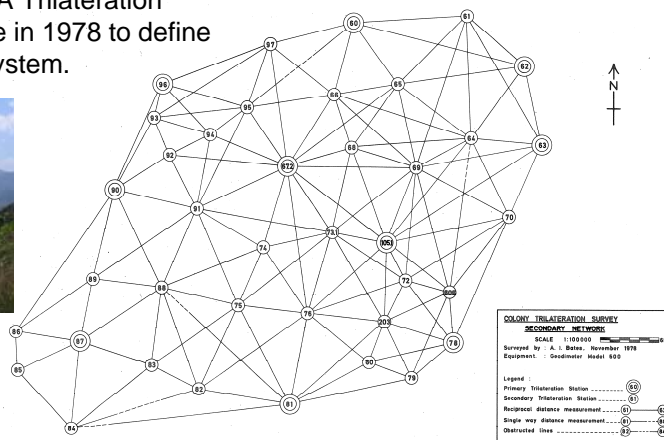
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## The Hong Kong 1980 Grid Coordinate System

- Hong Kong is a small area. Its coverage is about 70km by 45km.
- A plane rectangular coordinate system is most suitable for describing position.
  - it is convenient for plotting a point on a plan.
  - easy to calculate the distance and direction between two points using simple coordinate geometry.
  - it is very accurate because the distortion error caused by map projection is little.

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- The plane coordinate system currently used in Hong Kong for land surveying and mapping is the [Hong Kong 1980 Grid Coordinate System](#).
- It is realized by a network of main control stations. A Trilateration Survey was done in 1978 to define the coordinate system.



- The **Main Trilateration Network** consists of 39 stations.
- The distances between the stations were measured by EDM.
- Usual corrections to the **EDM measurements** were applied and then the distances were reduced to the surface of the reference ellipsoid by making slope, sea level and chord to arc corrections.
- Scale factor correction was applied to each distances based on the **Transverse Mercator Projection** with central meridian passing through old trigonometrical station "Patridge Hill".
- The **scale factor** at the central meridian is **one**.

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- In the network adjustment computation, the plane rectangular coordinate value of trigonometrical station 67.2 (Tai Mo Shan) determined in 1976 was assigned as the **origin (fixed) point**
- the azimuth from station 67.2 to station 94 (Au Tau) was kept fixed in order to define **orientation of the network** and hence the orientation of the axes of the coordinate system.
- the fixed azimuth was based on the results of the 1963 Main Triangulation.
- the network adjustment results produce the coordinate values of all the 39 main trilateration stations.
- **the accuracy of the adjusted distances is 2-3 ppm and the maximum residual is 28mm.**



- The Hong Kong 1980 Grid Coordinates System is widely used in Hong Kong for describing position of land boundaries, map features, civil engineering works, buildings, town planning zones, etc.

(N, E) = 1980 Grid Coordinates (Lat, Long) = ITRF 96 Geodetic Coordinates SUBJECT LOT COORDINATES & DIMENSIONS:					
Boundary Point	Bearing	Distance	N	E	
SUBJECT LOT NO. - TPTL2323					
A			832585.713	838826.049	
B	79°53'20"	109.302	832604.902	838933.653	
C	119°32'44"	14.362	832597.820	838946.148	
D	159°04'00"	94.185	832509.851	838979.799	
E	ch188°15'07"	ch70.864	832439.720	838969.628	
F	217°26'14"	26.888	832418.371	838953.283	
G	266°10'35"	17.290	832417.218	838936.031	
H	315°26'37"	127.018	832507.726	838846.914	
J	326°58'05"	60.171	832558.172	838814.114	
A	ch23°25'43"	ch30.016	832585.713	838826.049	
BOUNDARY CURVE DATA:					
Arc	Arc Len.	Radius	Incl.Angle	N (Centre)	E
D-E	74.024	72.661	58°22'14"	832483.890	838911.933
J-A	35.487	18.006	112°55'15"	832567.987	838829.210
GPS Survey Control Station:					
Station			Lat	Long	
HKSS			22°25'51.84451"	114°16'09.45642"	
HKFN			22°29'40.87008"	114°08'17.40609"	
HKSC			22°19'19.81950"	114°08'28.27647"	

- It is the reference system to support social and economic activities in Hong Kong.

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The Hong Kong 1991  
GPS Control Network  
Reference Frame : WGS84

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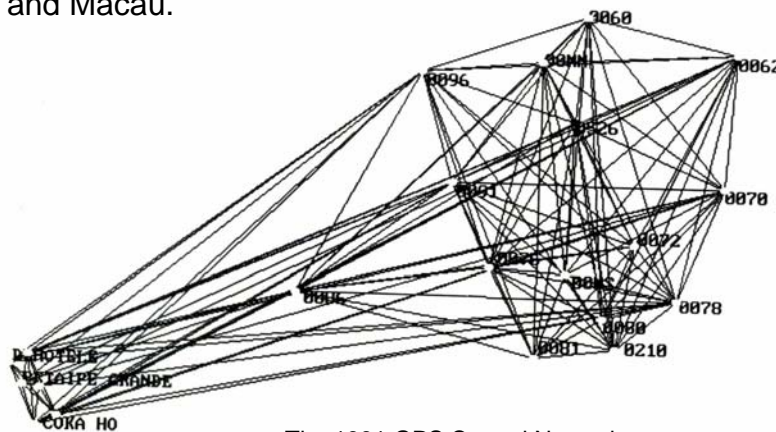
# The Hong Kong 1991 GPS Control Network

Purpose for establishing the **GPS Control Network**

- GPS survey need control point in the reference system of the Positioning Satellite
- Need to **transform the GPS survey results from WGS84 Geodetic Coordinates to HK80 Grid Coordinates.**

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- Special Team Royal Engineers (STRE) carried out GPS survey to build a GPS Control Network in Hong Kong and Macau.



The 1991 GPS Control Network

10000m

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- Adjustment of the 1991 GPS Control Network
  - keep 1 point fixed (Trigonometrical station 526)
  - Absolute accuracy of the fixed point (Doppler survey results) is about 0.5m (latitude, longitude) and 1m (ellipsoidal height)
  - Reference Frame : WGS 84
  - Residual of the baseline length =  
about 1- 2 cm (average), 7cm.(Maximum)
  - Residual of the ellipsoidal height =  
about 3- 4 cm (average), 8cm.(Maximum)

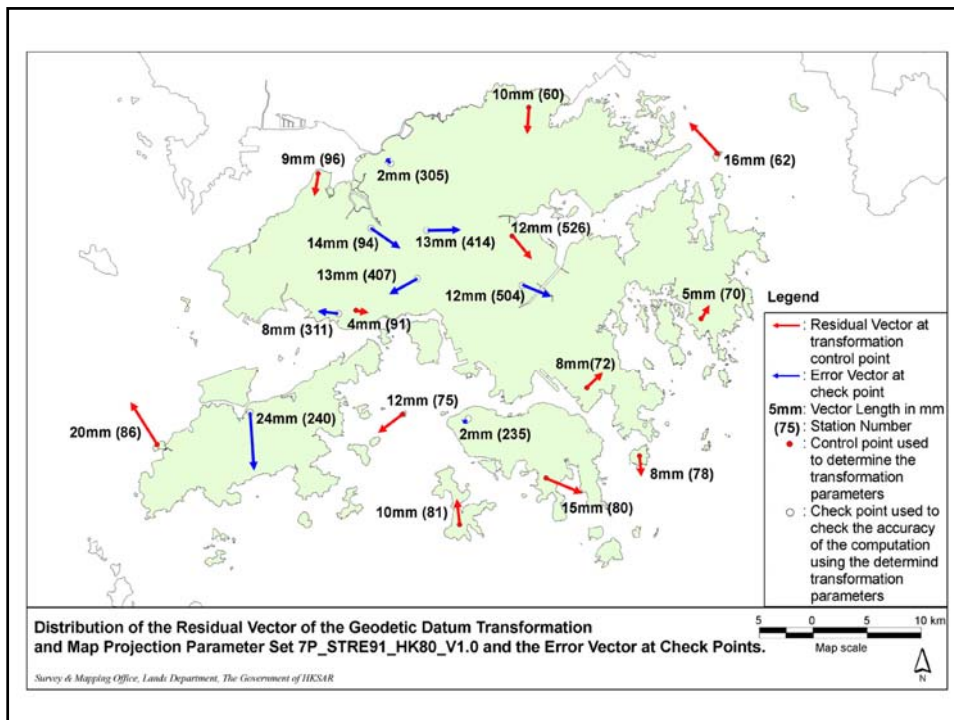
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## Methodology for transforming WGS84 Geodetic Coordinates to HK1980 Grid Coordinates

- 7 parameters transformation  
(WGS 84 datum to HK80 datum)
- Transverse Mercator Map Projection. (Latitude, Longitude) to (HK80 Grid)
  - Use 12 Control Points (11 Main Trilateration Station and 1 Doppler Station) to compute the Transformation parameters.
  - All points have high quality WGS84 Geodetic Coordinates and HK1980 Grid Coordinates.
  - Residual of the Transformation computation:  
1cm (average), 2cm (maximum)

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The Hong Kong 2000  
GPS Control Network

Reference Frame : ITRF 96

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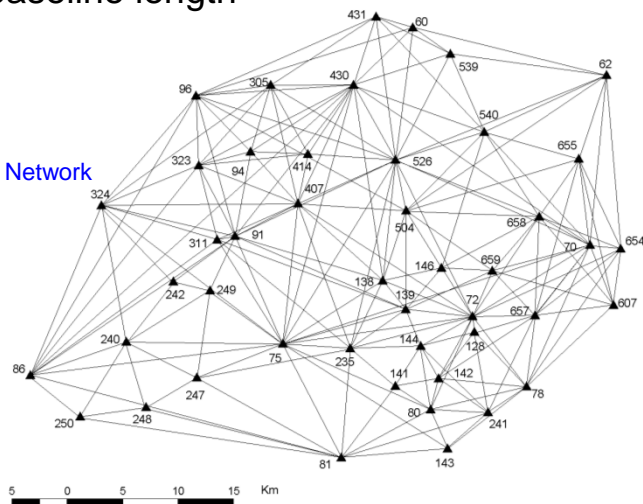
## The Hong Kong 2000 GPS Control Network

- the 1991 GPS Control Stations located on the top of mountains. It is difficult to access.
- the purpose of the **establishing the 2000 GPS Control Network** is to **reduce the logistic cost**.
  - Add GPS control point to **more easily accessible** areas.

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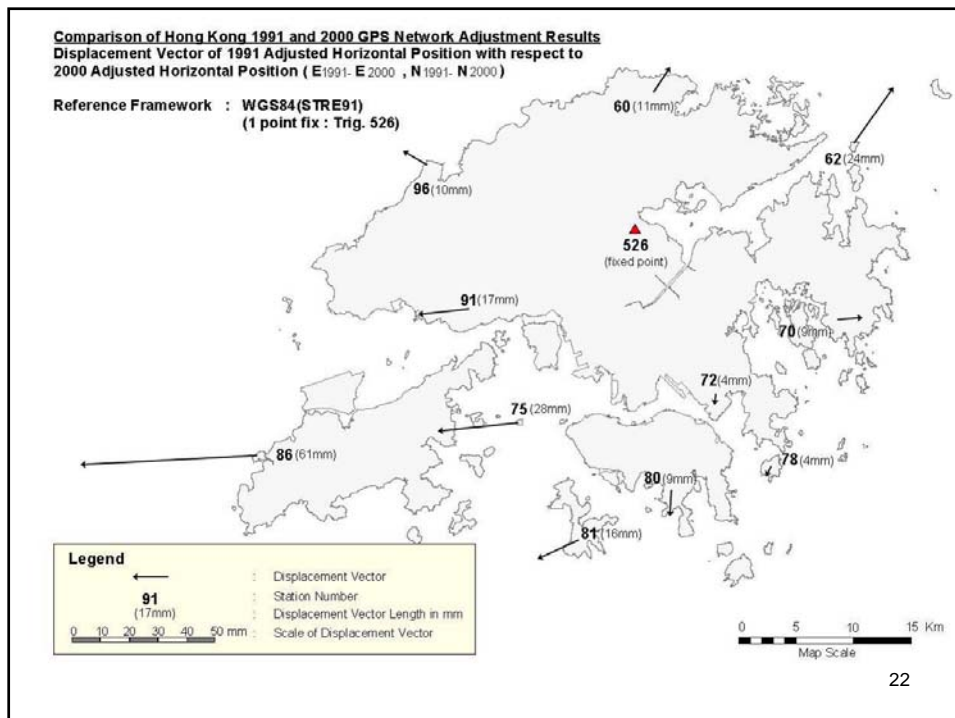
- 46 stations.
- Relative accuracy:  $((3\text{mm})^2 + (1\text{ppm} \times L)^2)^{1/2}$   
where L = baseline length

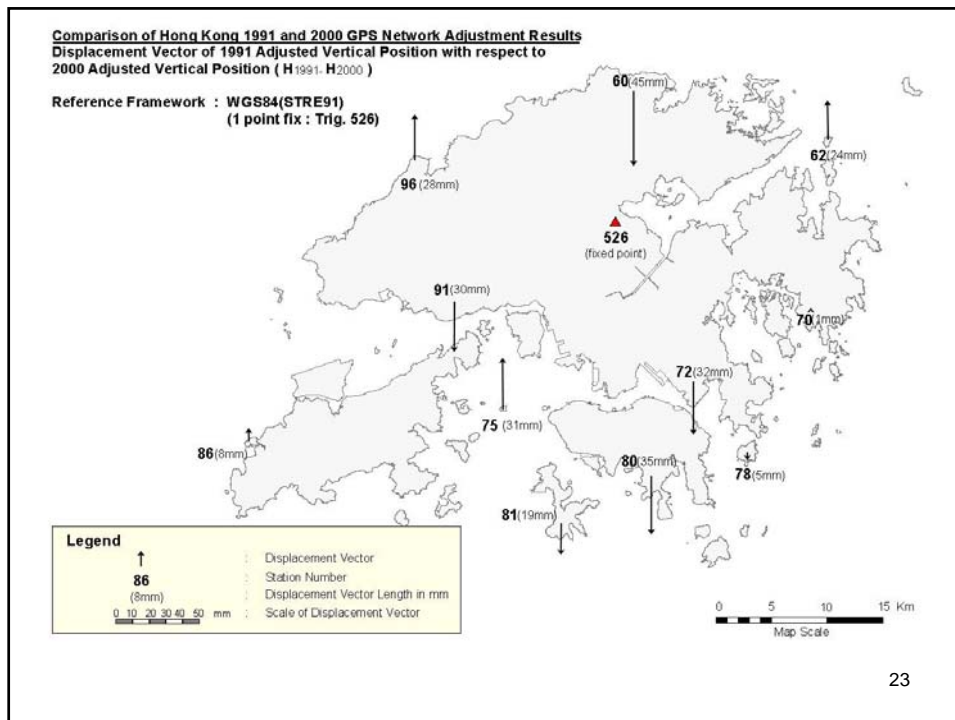
The 2000 GPS Control Network



- Compare the 1991 GPS Control Network against the 2000 GPS Control Network
  - Finding : There is 1 ppm scale error in the 1991 GPS Control Network
  - Maximum difference at the edge of the network (6 cm)
  - Reason : the 1991 GPS Control Network Adjustment has baseline residuals up to 6-7cm
  
- Conclusion : 2000 GPS Control Network Adjustment results is more accurate and shall be used.

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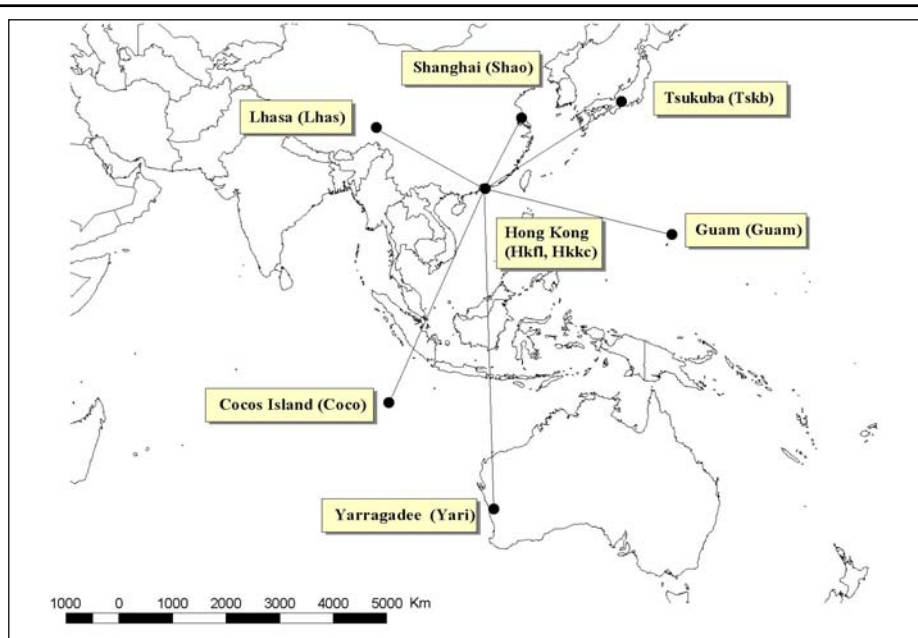


- The 2000 GPS Control Network need to be tied to a [global reference system](#).
  - The [WSG 84](#) Geodetic Coordinates of the fixed point (526) used in the [1991 GPS survey](#) has low absolute accuracy in relation to the center of the earth. (about 1m) .
  - Positioning of Precise Satellite Orbits are based on [International Terrestrial Reference Frame \(ITRF 96\)](#) which have cm-level absolute accuracy.

## Tie the Hong Kong reference system to the ITRF

- Connect two Hong Kong Reference Stations (Fanling and Kau Yi Chau) to 6 International GNSS Services for Geodynamic Stations (IGS stations)
  - Cocos Island
  - Guam
  - Lhasa
  - Shanghai
  - Tsukuba
  - Yarragadee
- The connection of Hong Kong GPS network to ITRF96 was established using two months continuous GPS observation (April and May 1998).
- Baseline length 1200km to 5000km

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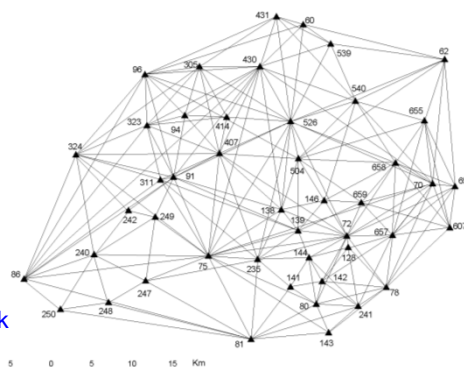
Tie the Hong Kong reference system to the ITRF

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- Computation strategy :
  - **Fix station** Tsukuba (TSKB) in Japan because it is most stable.
  - **Tightly constrain** GUAM station (velocity of a few mm/year) and YAR1 station (velocity below 5cm/year)
  - **Loosely constrain** LHAS, SHAO and COCO for the evaluation of the final results
  
- Evaluate the accuracy of the final results:
  - Evaluate the **repeatability** of the computed coordinates and **baseline vectors**.
  - **Compare** the coordinates of COCO, LHAS and SHAO with the **IGS published coordinates**.
  - The **absolute accuracy ITRF96 geodetic coordinates** of the two Hong Kong Reference Stations is better than **2 cm**.

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- **Constrained Adjustment of the 2000 GPS Control Network**
  - Fixed the ITRF96 coordinates of Station 75 (Kau Yi Chau) in the final adjustment.
  - The ITRF96 geodetic coordinates of all the GPS Control Points were computed.



The 2000 GPS Control Network

- transforming ITRF96 Geodetic Coordinates to HK1980 Grid Coordinates

- 7 parameters conformal transformation

- ( ITRF96 geodetic coordinates  $(x,y,z)_{ITRF\ 96}$  to HK80 geodetic coordinates  $(x,y,z)_{HK\ 80}$  )

- then use Transverse Mercator Map Projection

- (Latitude, Longitude)<sub>HK80</sub> to (Northing, Easting)<sub>HK80</sub> )

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- Use the same 12 Control Points to compute the Transformation parameters.

- All points have high quality ITRF96 Geodetic Coordinates and HK1980 Grid Coordinates.

- Residual of the Transformation computation:

- average 1cm,
    - maximum 2cm

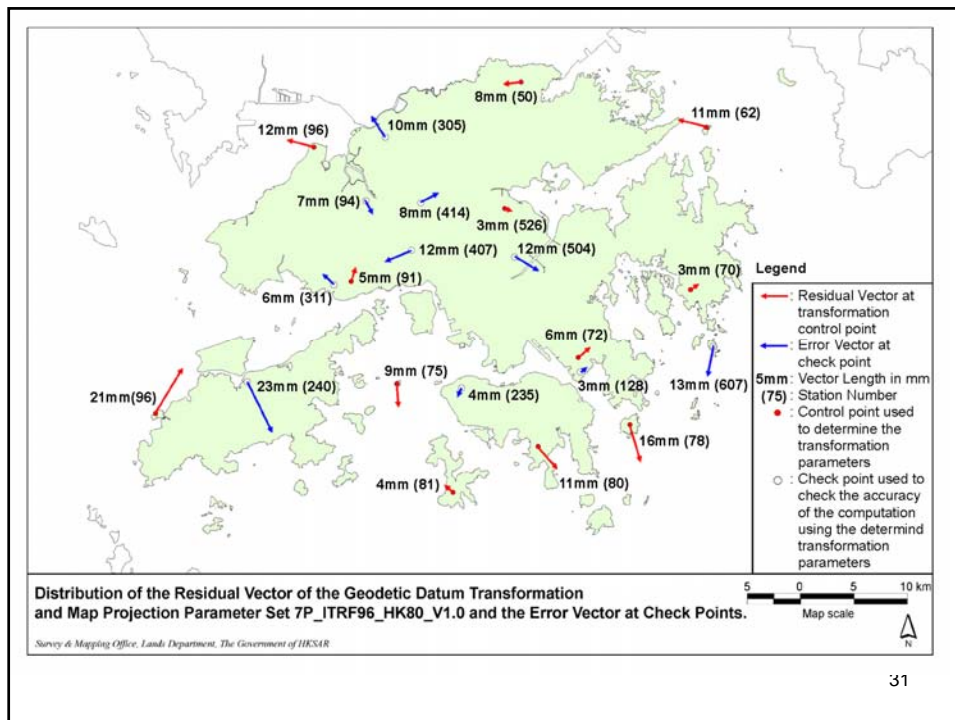
- Use 10 Trigonometrial Station as check point to check the accuracy of the transformation.

- Difference at check points :

- average 1cm,
    - maximum 2.3cm

- GPS survey results in ITRF96 geodetic coordinates can be transformed to HK1980 grid coordinates with average 1cm accuracy and maximum accuracy 2cm which is similar to the accuracy of the Hong Kong 1980 Main Trilateration Network.

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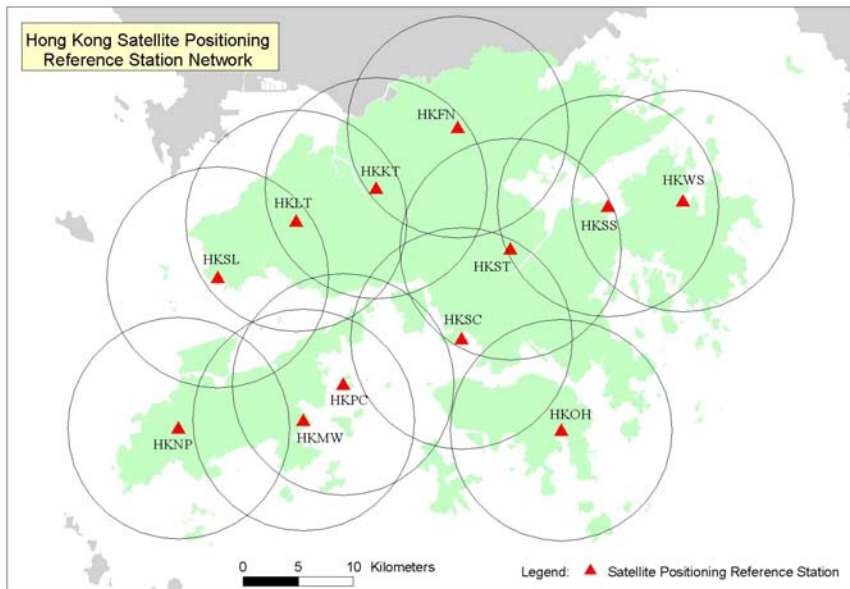
- Comparing the 1991 and 200 GPS network,
  - the 2000 GPS Network has :
    - higher absolute accuracy because of its [connection with ITRF](#)
    - high relative accuracy because of its [better measurement quality](#).
- The [2000 GPS control network](#) are used for GPS survey in Hong Kong.
- The [Geodetic Datum Transformation and Map Projection Parameter Set \(7P\\_ITRF96\\_HK80\\_v1.0\)](#) are used for transforming the GPS survey results in ITRF96 geodetic coordinates to HK1980 grid coordinates.

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# The Hong Kong Satellite Positioning Reference Station Network

Reference Frame : ITRF 96



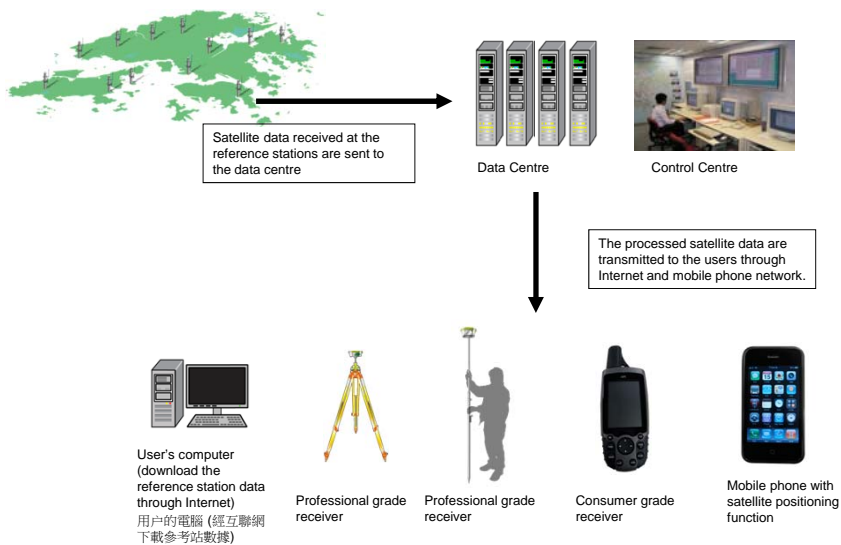
## 12 continuously operating reference stations

- 9 reference stations on open ground
- 3 reference stations on the roof of buildings



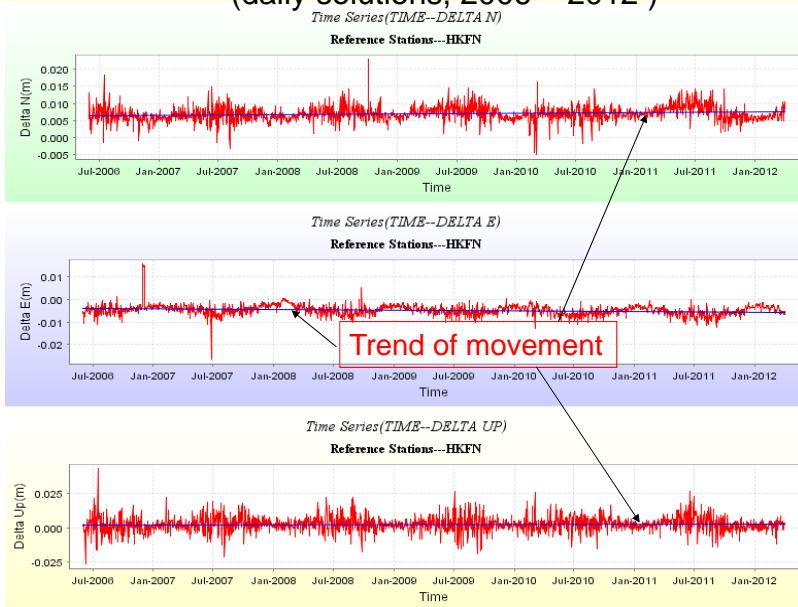
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## The Hong Kong Satellite Positioning Reference Station Data Services



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The Stability of the Hong Kong Reference Station Network are monitored by the Lands Department, Hong Kong SAR (daily solutions, 2006 – 2012 )



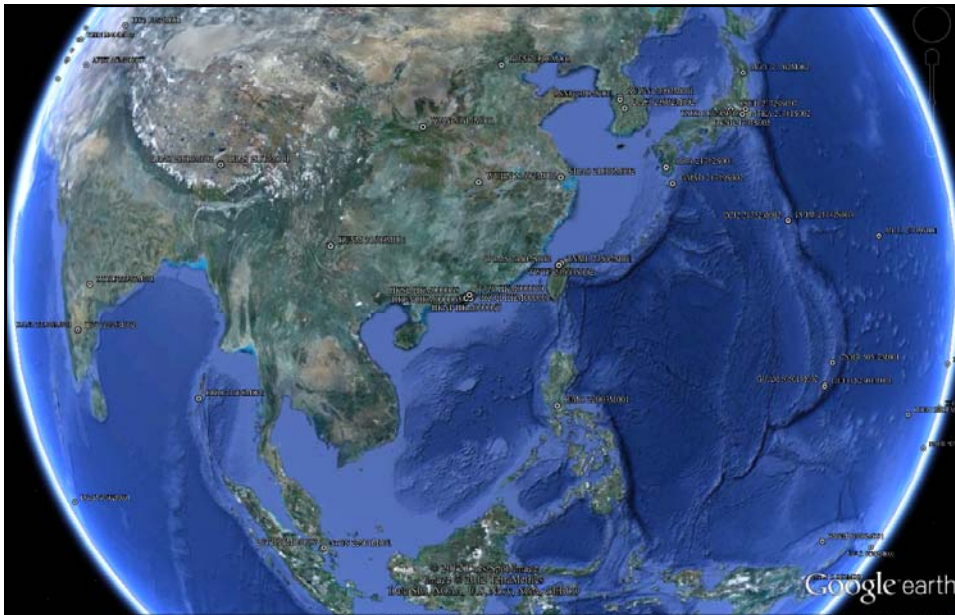
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The Asia-Pacific Reference Frame (APREF)

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- The Asia-Pacific Reference Frame (APREF)
- Maintained by the Permanent Committee for GIS Infrastructure for Asia and Pacific under the United Nations Regional Cartographic Conference.
- Maintain an accurate and densely realised geodetic framework based on continuous observation and analysis of GNSS Data.

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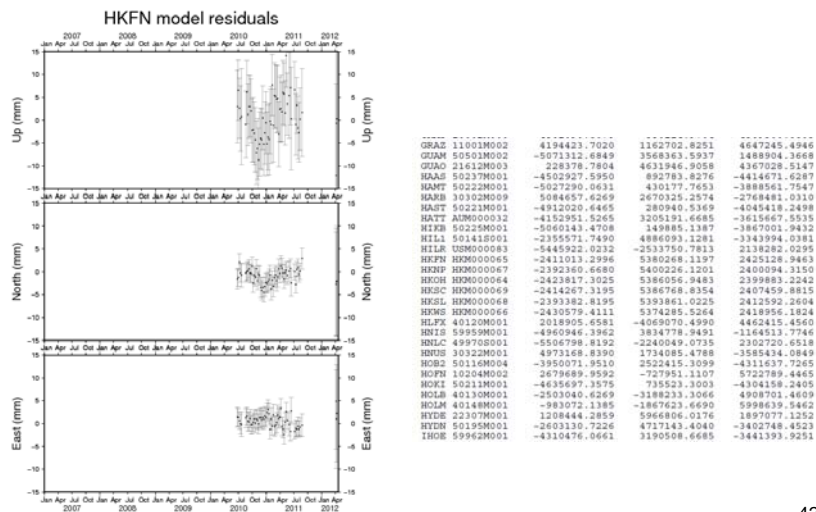


Daily data are collected from the CORS stations in the Australia, Antarctica and the South Pacific Region. 40

- Hong Kong provides daily GNSS data of 6 Continuously Operating Reference Station to APREF Analysis Center (Geoscience Australia)
- Geoscience Australia perform analysis of the data collected from the Australia, Antarctica and the South Pacific Region GPS Network.
- Weekly solution is created from a combination of the 7 daily solutions which are aligned with ITRF2008 reference frame using a minimum constrain method to a set of core stations.

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- Position of the Hong Kong Reference Station Network in relation to the APREF were monitored (2010 - 2011 Results)



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