HONG KONG OBSERVATORY

Technical Note No. 108

Metadata of Surface Meteorological Observations at the Hong Kong Observatory Headquarters 1884-2015

by

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摘要

香港天文台自 1884 年以來一直在尖沙咀的總部進行氣象觀測，並提供全中國第二長年期的氣象觀測記錄。有見在過去 130 多年間有關天文台總部環境、儀器及觀測方法變化的資料分散記載於不同的年刊、回顧報告和內部通訊中，本報告把 1884 至 2015 年間與天文台總部氣象觀測相關的元數據(包括地圖和照片)整理及總結，以便數據使用者和氣候研究人員參考。

Abstract

The Hong Kong Observatory (HKO) has been conducting meteorological measurements at its Headquarters in Tsimshatsui since 1884. It provides the second longest meteorological observation record in China. As information of changes in site environment, instrument and measurement methods of the HKO Headquarters over the last 130 years or more are scattered in different annual publications, review reports, and internal communications, a review was conducted to collate and summarize relevant metadata (including maps and photos) of the meteorological observations at HKO Headquarters from 1884 to 2015 in this report with a view to providing an easy reference for data users and climate researchers.

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1. Introduction

1.1. Station metadata provide useful background information about the history of a station, instrument types, site environment and observation methods. Good and complete metadata of long term meteorological observations are important for data users to interpret and assess the homogeneity of the observational data and better understand the long term climate variations (Aguilar et al., 2003).

1.2. The Hong Kong Observatory was established in 1883. In 1912, King George V granted the title “Royal Observatory, Hong Kong”, in recognition of the Observatory's services. Eighty-five years later, the Observatory resumed its original name "Hong Kong Observatory" in 1997. Starting in 1884, the Hong Kong Observatory has been regularly conducting and publishing meteorological observations at its headquarters in Tsimshatsui, apart from a break from 1940 to 1946 owing to World War II. It is one of the World Meteorological Organization stations (WMO station code : 45005) in Asia with over a century of continuous observations of essential surface meteorological observations, such as temperatures, rainfall, pressure and relative humidity. It also provides the second longest meteorological observation record in China, after the Shanghai Xujiahui Observatory which was established in 1872. The Hong Kong Observatory Headquarters (45005) has served as the WMO’s reference synoptic reporting station for Hong Kong up to 30 June 1992. The synoptic station was changed to King’s Park (45004) on 1 July 1992 and then changed to the Hong Kong International Airport at Chek Lap Kok (45007) on 1 April 2000 (HKO, 2000). Basic meteorological observations, however, continue to be conducted at the Hong Kong Observatory Headquarters.

1.3. Over the years, metadata of the meteorological observations at the Hong Kong Observatory (HKO) Headquarters have been documented in various reports and annual publications. In 1883, Dr. W. Doberck, the first director of the Observatory (called Government Astronomer at the time), set out the instructions of meteorological observations in Hong Kong and treaty ports in China (Doberck, 1883). Information of the

meteorological observations at the HKO Headquarters were regularly included in the Observatory's annual data publications, namely "Meteorological results part I - surface observations" from 1884 to 1939 and from 1947 to 1986, "Surface observations in Hong Kong" from 1987 to 1992, "Summary of meteorological observations in Hong Kong" from 1993 to 2005 and "Summary of meteorological and tidal observations in Hong Kong" since 2006. The history of the Observatory and relevant meteorological observations at the HKO have also been reviewed in previous technical reports and publications (e.g. Jeffries, 1939; Starbuck, 1951; Peacock, 1952; RO 1963, Dyson, 1983; Ho, 2004).

1.4. Since information of changes in site environment, instrument and measurement methods of the HKO Headquarters over the last 130 years or more are scattered in different annual publications and review reports, it is painstaking work for climate data users to search through hundred of publications to identify relevant metadata for their studies. With a view to providing a comprehensive summary of the metadata of surface observations of the HKO Headquarters from 1884 to 2015, we have collated metadata, maps and photos from various reports, annual publications and internal communications into this note for climate data users' easy reference. Section 2 concisely describes the building and nearby environment changes of the compound of the HKO Headquarters. Section 3 tabulates the major changes in instrument and observation methods of various surface observations at the HKO Headquarters.

2. The Compound of the Hong Kong Observatory Headquarters

2.1. The Observatory occupies about 1.62 hectares (4 acres) of land on the summit of Mount Elgin on the Kowloon Peninsula (Figures 1, 2, 3, 4 and 5). The Main Building with the front entrance facing south was built in 1883 on the eastern hillock at an elevation of about 32 metres (105 feet) above mean sea level. It was a two-storeyed, rectangular building with front and back[1] verandahs which were respectively 8 and 12 feet wide (RO, 1913). The first floor was the Director's Quarters from 1883 to 1934. Starting in 1883, there were four rooms on the ground floor (two on each side of the entrance hall), assigned from east to west as the Clock Room, Director's Office and library, Principal Computing Room, and Instruments Room. There was a Transit Room adjoining the Clock Room on its eastern side. An enclosed portion of the back verandah behind the Clock Room served as the Battery Room. A similar enclosure behind the Instruments Room was the Photographic Dark Room. A one-storey block of Servant's Quarters was built to the north in parallel with the Main Building. Two paths lead up to the Main Building, one from the southwest entrance in Nathan Road and one from the southeast entrance in Observatory Road. In 1912-1913, two rooms were added to the west end of the Main Building, one on each floor (Figure 6, as compared against Figure 4). The additional room on the ground floor became the Director's Office. Rooms in the upper floor were the Director's Private Quarters. Simple layout maps showing the room arrangements of the Main Building before 1912 and in 1913 as depicted in relevant publications (RO, 1913; 1914) are shown in Figures 7(a) and 7(b) respectively. A magnetic hut was constructed to the west of the Observatory for magnetic observations. There was also a special housing for a 6-inch Lee Equatorial telescope near the west end of the Main Building (Figures 8, 9 and 10). The 6-inch Lee Equatorial was returned to the Greenwich Royal Observatory in 1914.

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[1] The back verandahs on the ground and first floor were later (likely after 1950s) enclosed and converted into offices.

2.2. In 1917, a wireless mast (radio mast) was erected to the southwest of the Main Building where the Director's Quarters now stands, next to the dome which housed the Lee Equatorial (Figures 11 and 12). The northeastern wing of the Main Building was enlarged in April 1918 to include space for a small workshop (see Figure 7(b)). With the introduction of the new Local Storm Signal in Hong Kong on 1 July 1917 (Hong Kong Government, 1917), the hoisting of the local storm signals was transferred to the wireless mast (radio mast) at the Observatory in 1920. The old Equatorial Dome was also enlarged to accommodate the local typhoon symbols (RO, 1920; Hong Kong Government, 1920).

2.3. In 1920, the magnetic hut was moved to a point about 40.5 metres (133 feet) north of its original position in order to make room for the building of two staff quarters (the current Quarters No.2 and Quarters No.3) on the western hillock which were completed in September 1921 (Figures 13(a) to 13(c)). An underground chamber was constructed a little to the south of the eastern end of the Main Building in 1924 for the purpose of housing the seismographs and the clocks. In 1926, a wireless station was built about 47 metres (51 yards) south of the western extremity of the Main Building (Figures 14(a) and 14(b)).

2.4. In 1933, the wireless mast which also served as the typhoon mast for hoisting local storm signals was removed from its original position to make way for the Director's Quarters (Quarters No.1) which was completed in February 1934 (Figures 15 and 16). Then, the rooms on first floor of the Main Building were released as additional office and library. The wireless mast was set up a little to the northeast of the Main Building. The thermometer shed which was first set up over the lawn area to the southeast of the Main Building a few years after 1884 (Doberck,1890; Peacock, 1952) was moved to about 15 metres north-northeast of the Transit Room in 1912. The shed was then set up again in the old site to the southeast of the Main Building in 1933 (Figure 11). Photos of the lawn area to the southeast of the Main Building in 1930s with and without the thermometer shed are shown in Figures 17(a) and 17(b). A photograph of the thermometer shed in 1950s is shown in Figure 18.

2.5. Hong Kong came under the attack of the Japanese on the morning of 8 December 1941 and eventually fell to the Japanese on 25 December 1941. The Observatory was forced to suspend its service. During the Japanese occupation of Hong Kong from 1941 to 1945, while the Observatory was used as a meteorological station by the Japanese soldiers, the main activities appeared to have been the operation of two anti-aircraft guns (Starbuck, 1951). The buildings suffered only superficial damages, but almost all the equipment were removed. Apart from the meteorological records in May 1944, no record of Hong Kong weather observations conducted by the Japanese soldiers during the period could be retrieved (HKO, 2013). The sketch maps of the Observatory depicting the key set up and changes from 1883 to 1951 are shown in Figures 11 and 14. An aerial photo of the Observatory in 1951 is shown in Figure 19 (Peacock, 1952; Starbuck, 1951).

2.6. The construction of the additional ground floor and first floor rooms at the western end of the Main Building was completed respectively in 1952 and early 1954 (DRO, 1952, 1954). An aerial network with supporting masts were built in the 1950s for receiving radio broadcasts of weather data and charts. With such information increasingly being transmitted through other more reliable and high speed communication channels, this network ceased operation in mid-1994. Figures 20 and 21 are the photos of the aerial network around 1969-70 and in 2015 respectively.

2.7. Affected by the new buildings erected to the east outside the premises of the Observatory in 1950s, the anemometer head on the roof of the Main Building was further raised by about 6.8 meters in 1959. Moreover, as these newly erected buildings began to interfere with the daily sunshine duration observations during the early morning, another sunshine recorder was set up at King’s Park Meteorological Station (Figure 22) in July 1957 with a view to maintaining a continuous record. After more than three years of parallel operation, the sunshine duration observations at the Observatory Headquarters ceased on 31 December 1960 and was moved to King's Park in 1961 (RO, 1958; 1959; 1960; 1961; 1963; Bell, 1963).

2.8. With the launching of the Geostationary Meteorological Satellite (GMS) by the Japan Meteorological Agency, the Observatory installed a reception system to receive the high-resolution pictures (HR-FAX) from the GMS and a satellite dish antenna was set up on the lawn area to the southwest of the Main Building between August 1979 and April 1982 (about 10 metres from the raingauges, see Figure 23).

2.9. The construction of the new Centenary Building to the east of the Main Building commenced in July 1978 (Figure 24). The wireless mast (also called typhoon mast at the time) and the transit room to the eastern side of the Main Building has been dismantled by then. The structure of the Centenary Building reached the ground level by January 1981 and the height of the rooftop of the Main Building in April 1981 (Figure 25). The construction of the nine-storey Centenary Building was completed in May 1982. Figure 26 shows the locations of instruments at the Observatory in 1982. The satellite antenna dish was relocated to the rooftop of the Centenary Building later in 1982 (RO, 1982).

2.10. The building development in the Tsimshatsui area, in particular to the south of the Observatory, increased progressively since 1950s (Figures 27, 28, 29 and 30). The pace of the development and increase in building height accelerated since 1998 when the building height restriction in Tsimshatsui relaxed after the relocation of the Hong Kong International Airport from Kai Tak to Chek Lap Kok. Studies on the possible influences of local urbanization on the meteorological observations at the Observatory over the last few decades have been conducted (RO, 1958; Ginn et al., 2009; Wu et al., 2011; Chan et al., 2012, Lai, 2014). Figures 31(a) to 31(h) show a series of aerial photos of the compound of the HKO Headquarters in 1949, 1959, 1963, 1972, 1986, 1994, 2007 and 2015 respectively. The panorama photo of the Hong Kong Observatory Headquarters in 2015 is also shown in Figure 32. The sketch map of the compound of the Hong Kong Observatory and the locations of meteorological instruments at the Observatory Headquarters in 2015 are shown in Figures 33(a) and 33(b) respectively.

2.11. The latitudes and longitudes (reference to meteorological shed) as well as ground elevation of the Hong Kong Observatory are listed below :

Hong Kong Observatory Headquarters
Lat. : 22° 18' 07"
Long. : 114° 10' 27"
Elevation above Mean Sea Level (MSL) : 32 m

3. Summaries of major changes in meteorological measurements

3.1. Temperatures

Year	Instruments and Methods of Observation
1 April 1884 (Peacock, 1952; Doberck 1884, 1885)	● Rotating thermometers - dry and wet-bulb thermometers mounted on a whirling machine. Held about 1.2 m (four feet) above ground, rotating in the wind (if any) and in shade. Four observations daily at 10, 13, 16 and 22 H. (since 10 June 1885) ● Kew Thermograph in the Instrument Room with fixed dry and wet bulb thermometers in a zinc screen mounted outside the northern window of the Instrument Room (Figure 11). The bulbs of the thermometers were about 33 m (108 feet) above MSL, about 1.2 m (four feet) above ground. ● Hourly values read off from the temperature trace of the Kew Thermograph with the baseline determining from the rotating thermometers values. ● Maximum and minimum thermometers mounted in a Stevenson screen which was likely about 23 m (75 feet) southwest of the western extremity of the main building (near the rain gauges at the time). Fixed thermometers were also installed alongside to reduce the readings to the rotating thermometers. ● The thermometers used were frequently compared with the Kew Standard No. 647
Around June 1889 or earlier (Peacock, 1952; Doberck, 1890)	● Stevenson screen discontinued. ● An "Indian pattern" double roof palm-leaf shelter (thermometer shed) was constructed at 23 m (75 feet) southeast of the Main Building. The shelter covered 7.6 m by 6.1 m (25 feet by 20 feet), was 0.9 m (3 feet) high at the eaves, 2.7 m (9 feet) at the ridgepole, and had a about 15 cm (6 inches) air space between the two roofs.
27 May 1912	● Registration of the Kew Thermograph was

(RO, 1913, 1914)	discontinued.
Summer 1913 (RO,1914)	● A new shed was erected about 15 m (50 feet) to the north-northeast of the Transit Room ● The thermometer shed to the southeast of the Main Building, which contained the dry bulb and maximum and minimum thermometers, was destroyed by a typhoon on 17 August 1913. The thermometers were transferred to the new shed. ● All published hourly temperatures were referred to the rotating thermometer readings during the change to avoid interruption and discontinuity of measurement. ● Comparisons between the dry bulb rotating thermometer and the dry bulb thermometer in the shed were made hourly from 09H to 17H and every three hours from 19H to 07H, furnish corrections to the readings of the maximum and minimum thermometers in the shed.
April 1914 (Peacock, 1952)	● Griffin Standard Thermometer received and compared with the Kew Standard No. 647 for the next three years. The change of the index of Kew Standard was no more than a tenth of degree Fahrenheit. Kew Standard continued as the Observatory standard.
March 1917 (Peacock, 1952; RO, 1918)	● Richard bimetallic thermograph was installed in the palm-leaf shelter. ● Daily maximum and minimum were determined from the trace of Richard thermograph with the rotating thermometers readings establishing the baseline.
1918 (RO, 1918)	● Dry and wet bulb temperatures were derived from the hourly measures of the Richard thermograph with the rotating thermometers readings establishing the baseline.
1933 (Peacock, 1952; RO, 1933)	● A new thermometer shed was constructed on the old site in the southeast of the Main Building. It was a 6.1 m by 4.5 m (20 feet by 15 feet) shelter with double palm-leaf roof extending to within 0.9 m (3 feet) of the ground on all sides except the north, which is left completely open.

June 1934 (RO, 1934)	● Richard thermograph was substituted by the Platinum resistance thermometers and a thread recorder by the Cambridge Instrument Co. ● Maximum and minimum temperatures were determined from this thermogram.
1941-1946 (Peacock, 1952)	● The platinum resistance thermometers were damaged beyond repair during Japanese occupation.
14 April 1947 (Peacock, 1952; RO, 1947)	● All thermometers were about 1.4 m (4.5 ft) above ground level in the shed. ● Negretti and Zambra mercury-in-steel distant recording thermograph was installed for continuous dry and wet bulb temperature measurement. ● Shelter temperatures have been read hourly but rotating thermometer observations have not been resumed. ● The maximum and minimum thermometers were similarly exposed and were read at midnight, readings were checked against the thermogram
3 December 1959 (RO, 1959)	● The double palm-leaf roof of the open shed was replaced by a roof made of two separated layers of matting.
1960 (RO, 1960)	● The thermometers were about 1.2 m (4 ft) above ground level in the shed.
1 April 1961 (RO, 1961)	● New thermometers, reading directly in degrees Celsius were used.
1978 (RO, 1978)	● The shed was rebuilt between 17 April and 13 July 1978. Temperatures were taken in a Stevenson screen located 5 m north of the shed (Figure 11).
12 August 1981	● Negretti and Zambra mercury-in-steel distant recording thermograph was damaged by construction work.
7 May 1982 (RO, 1982)	● Dry and wet bulb temperatures were read visually from thermometers in the open shed up to and including 14 H on 7 May 1982. ● Starting from 15 H on 7 May 1982, dry and wet bulb temperatures were read from a digital display of a microprocessor-based system connected to platinum resistance thermometers placed in the open shed.

	● Maximum and minimum temperatures were also read from the digital display unit. Conventional maximum and minimum thermometers in the shed served as back up. ● A Casella bimetallic thermograph, Model B.S. 3231, Serial No. 8652 was also installed in the shed for quality control of the temperature data.
April 1983 (RO, 1983)	● The open shed under renovation in April 1983. The thermometers were temporarily housed in a Stevenson screen about 5 m north of the open shed between 01 H 21 April to 02 H 29 April 1983.
March 2010	● The "Heat Stress Monitoring System" developed by the Observatory to measure the Natural Wet Bulb Temperature, Globe Temperature and Dry Bulb temperature was installed in the east side of the lawn area (Figure 33(b))

Remark:

- A comparison between temperatures measured in the shed and in the screen was made and documented in Technical Note No. 49 (Chen, 1979).
- The construction of the digital thermometer and its comparison with mercury-in-glass thermometers in the shed was documented in Technical Note (Local) No.25 (Chen et al., 1979).

3.2. Grass temperatures

Year	Instruments and Methods of Observation
1950 (RO, 1950)	● Observations of grass minimum temperatures were made daily at 07H.
1956 (RO, 1956)	● Observations of grass minimum temperatures were made daily at 08H.
May 1995 (RO, 1995)	● Grass minimum temperature was automatically recorded by platinum resistance thermometer and read from a computer display. The original mercury-in-glass thermometers were used as back up.

3.3. Soil (Earth) temperatures

Year	Instruments and Methods of Observation
6 January	● Thermometers were suspended within tubes at

1950 (RO, 1950)	depths of one and four feet (0.3 and 1.2 m). Soil temperatures were read twice daily at 0700H and 1900H.
1967 (RO, 1967)	● Observations of the soil temperature were made twice daily at 0700H and 1900H at depths of 0.3 m (1 ft), 1.2 m (4 ft), 10 cm, 20 cm, 50 cm, 100 cm and 150 cm.
1971 (RO, 1971)	● New thermometers at depths of 0.3 m (1 ft) and 1.2 m (4 ft) were placed near to the those at depths of 0.5 m, 1.0 m and 1.5 m, since it was found that the readings from the old ones sited just above the seismometer cellar were persistently too high.
1 November 1976 (RO, 1076)	● All reading of soil temperatures at depth of 0.3 m (1 ft) and 1.2m (4 ft) at the Observatory and King's Park were discontinued.
12 October 1977 (RO, 1977)	● Soil temperature at depth of 300 cm installed.
1 October 1978 (RO, 1978)	● Soil temperature at depth of 5 cm installed.
May 1995 (RO, 1995)	● Soil temperatures were automatically recorded by platinum resistance thermometer and read from a computer display. The original mercury-in-glass thermometers were used as back up.

3.4. Pressure

Year	Instruments and Methods of Observation
1 April 1884 (Peacock, 1952; Doberck, 1884, 1885)	● Negretti and Zambra Standard Barometer No. 1368 (0.5 inch bore) was used for standard pressure measurement. The height of the barometer cisterns was about 33.2 m (109 feet) above MSL. ● Standard pressure observations conducted four times a day (at 10, 13, 16 and 22 hours). ● Continuous records of pressure were made by Kew Barograph by Munro (inside the Instrument Room), wherein mercury level was illuminated and photographed through a slit. Hourly pressure readings were taken from the

	charts with the baseline determining from the standard observations.
8 June 1897 (Peacock, 1952)	● Casella Standard No. 1323 (0.5 inch bore) was brought into use as the station barometer
1911 (Peacock, 1952; RO, 1914)	● Casella Standard No. 2451 was used as the standard reference. ● No. of observations increased to 6 times a day (at 02, 06, 10, 14, 18 and 22 hours).
1 January 1916 (Starbuck, 1951; RO, 1916)	● Eye observation of pressure were made hourly
1922 (Peacock, 1952)	● Marvin compensated syphon barograph was used to replace the Kew Barograph.
October 1941 - June 1946 (Peacock, 1952)	● Marvin Barograph was damaged during the Japanese occupation.
1947 (Peacock, 1952)	● 24 hour eye observations of pressure by Negretti and Zambra (Kew Type) No. 1409 from 1 January to 31 August 1947 and by No. 3336 from 1 September onward. ● Regularly compared with the Casella Standard No.3623
1 December 1950 (RO, 1950)	● The Negretti and Zambra (Kew Type) No. 3336 was replaced by the F Darton (Kew Type) No. 3478/46.
21 July 1962 (RO, 1962)	● Kew Pattern barometer No. S3423/47/56 by F Darton was used.
1 July 1977 (RO, 1979)	● Kew Pattern barometer No. S3495/46/54/56 by F Darton was used.
7 May 1982 (RO, 1982)	● The station barometer was moved to the Central Forecasting Office on the top floor of the Centenary Building at elevation of 62m above MSL (since 14 hours on 7 May 1982)
1 April 2000 (HKO, 2000)	● Setra Model 361 digital pressure gauge was used. A mercury-in-glass barometer was used as back-up.
2003	● Hourly atmospheric pressure was measured

(HKO, 2003)	using a Setra Model 270 pressure gauge. A mercury-in-glass barometer was used as back-up.
16 December 2005 (HKO, 2005)	● The barometer at the Observatory was moved to 40 m above MSL.
2010 (HKO, 2010)	● Atmospheric pressure was measured using Setra Model 470 digital pressure gauge. Another Setra Model 470 was used as back-up.

3.5. Dew point and relative humidity

Year	Instruments and Methods of Observation
1884 (Doberck, 1884; Blanford, 1877)	● Dew point and relative humidity were calculated from dry and wet bulb readings using Blandford's Hygrometric Tables.
1913 (RO, 1913)	● Hygrometric tables (Indian Meteorological Department) were used to compute the dew point and relative humidity.
1928 (RO, 1928; Peacock, 1952)	● Pertner's "Strong Wind" formula were used
1947 (RO, 1947)	● The UK Meteorological Office Hygrometric Tables were used
1950 (RO, 1950; Bilham, 1927)	● The Bilham Humidity Slide Rule was used
1961 (RO, 1961)	● The UK Meteorological Office Mk 5 and M6 Slide Rules were used.
1988 (RO, 1988; Sargent, 1980)	● A computer programme was developed to compute vapour pressure, relative humidity and dew point temperature from the readings of dry and wet bulb temperatures using the Hooper's method described by G.P. Sargent.

3.6. Rainfall

Year	Instruments and Methods of Observation
1 March 1884 (RO, 1914)	● Hourly rainfall measurement conducted using Beckley's mercury floating pluviograph located

	on the ground about 23 m (75 feet) southwest of the Main Building. The rim of the pluviograph was 11.25 inches in diameter and about 21 inches above ground. ● A standard 8 inches raingauge which was about 1.5 m (5 feet) to the Beckley Pluviograph with its rim of 18 inches above ground. ● Readings of the pluviograph were checked by daily rainfall readings at 10:00 am of the standard raingauge.
1906 (RO, 1906)	● The Halliwell pluviograph was installed.
21 September 1912 (RO, 1913)	● The Halliwell pluviograph was discontinued.
14 January 1913 (Peacock, 1952; RO, 1914)	● The Nakamura pluviograph was installed to replace the Halliwell pluviograph
15 January 1933 (Peacock, 1952; RO, 1933)	● The raingauges were moved to a point about 15 m (50 feet) south by west of the Observatory entrance on account of its original site by the Director's new quarters.
1935-1936 (RO, 1935, 1936)	● Rainfall measurement by Nakamura pluviograph and Casella pluviograph in 1935 ● Rainfall measurement by Casella pluviograph in 1936
October 1941 - June 1946	● No measurement during the Japanese occupation.
1946 (Peacock, 1952)	● Rainfall measurements resumed in July 1946 using the 8” standard raingauge.
April 1947 (Peacock, 1952; RO, 1947)	● A Dines Tilting Syphon Rain Recorder was set up in the same position of the pre-war recorder. ● Rainfall was measured twice daily with the 8” standard raingauge. Hourly values were taken from the records of the Dines titling syphon gauge adjacent to the ordinary raingauge.
1949 (RO, 1949; Peacock,	● Rainfall was measured hourly with an 8" standard raingauge whose rim was 18" above ground level. Hourly values were checked

1952)	using the records of a Dines titling syphon gauge adjacent to the ordinary gauge. ● A pitted Recorder of the same type was installed in a conical concrete pit so that the rim of the gauge was at level of the surrounding ground.
1967 (RO, 1968)	● A Jardi raingauge was installed at the Observatory
Around 1970s	● Precipitation detector was installed in the western side of the lawn area
1 January 1989	● Closing down of the standard gauge. ● Installation of a 203mm gauge on front lawn about 8.5m from 1883 Main building, 7.5 m North of the ex-official gauge. ● Rim of the new raingauge above ground level: 300mm
2001	● Precipitation detector was relocated from the lawn to the roof of the Centenary Building
2007 (HKO, 2007)	● Observations of 203mm gauge were checked against the records of a Casella 100573E tipping-bucket raingauge nearby.
2011	● SL3-1 0.1 mm tipping-bucket raingauge was installed in the western side of the lawn area (Figure 33(b))
January 2015	● 0.1-mm resolution weighing raingauge was installed in the west side of the lawn area (Figure 33(b))

3.7. Wind speed and directions

Year	Instruments and Methods of Observation
1 March 1884 (Peacock, 1952)	● Beckley Cup Anemometer of Robinson type was set up in the center of the roof of the Main Building (Figure 11). The four cups, 23 cm in diameter, were mounted on arms of 60 cm long and the plane of rotation was about 4 m (13 feet) above the roof, 13.6 m (45 feet) above the ground and 47 m (155 feet) above MSL.
January 1910 (Peacock, 1952; RO, 1914)	● Dines-Baxendall Pressure tube Anemometer was installed on the roof about 3 m (10 feet) north-northeast of the Beckley Cup Anemometer with the vane 0.15 m (6 inches) higher than that of Beckley.

1938 (Peacock, 1952; RO, 1938)	● The Beckley Anemometer and Dines Anemometer were dismantled on 1 October and 4 October 1938 respectively. ● The Dines Anemometer was moved to the central position on 21 November 1938 and the head was raised from about 4 m to about 9.8 m (32 feet) above the roof. ● A new tank was installed to record gusts up to 180 knots.
October 1941 - June 1946	● No measurement during the Japanese occupation.
1947 (RO, 1947)	● Hourly wind values were taken from the records of the Dines-Munro pressure tube anemograph with an M.O. twin-pen direction recorder ● The head was 9.8 m (32 feet) above the highest point of the roof of the Main Building, and 22.3 m (73 feet) above ground level (Figure 14(b)).
1959 (RO, 1959; RO, 1963; Bell, 1963)	● From 1 January to 2 July at 09H, the readings were obtained with the head 32 feet above the highest point of the roof of the Main Building. ● From 2 July at 10H to 25 July at 12H, the winds were estimated during the raising of the head of the Dines Anemometer from 9.8 m above the roof of the Main Building (22.3 m above ground) to about 16.6 m (54.3 feet) above roof level (about 29 m (95.3 feet) above ground level). The readings commenced again at 13H on 25 July. (Figure 34)
1982 (RO, 1982)	● The record of winds at the Headquarters suspended from January to May 1982 and wind data of Hong Kong International Airport (Kai Tak) was used for publication. ● A MK4 cup-generator anemometer and vane were installed on the western end of the Observatory compound. The cup centre was 71.7 m above MSL. (Figure 35) ● From 01H on 1 June 1982 onwards, wind data recorded with the MK4 anemometer and vane were used for publication. ● A standby MK4 anemometer and vane was installed on the roof-top of the Centenary Building. The cup centre was 73.8 m above

	MSL (8.6 m above the roof). It is only used as back up because of the possible sheltering effect of the satellite reception antenna radome installed to the southwest of it.
31 July 1992 (RO, 1992)	● The anemometer on the western end of the Observatory compound was dismantled and replaced by the anemometer on the roof-top of the Centenary Building.

Remark: The standardization of the cup anemograph readings from Beckley Anemometer to Dines Anemometer was given in Bell (1963) and Poon (1982)

3.8. Duration of bright sunshine

Year	Instruments and Methods of Observation
1 March 1884 (RO, 1884; Peacock, 1952)	● Campbell-Stokes Sunshine Recorder No. 51 by Lecky was installed on the roof of the Main Building (about 10.4 metres (34 feet) above ground on the central coping stone of the south parapet).
1917 (Peacock, 1952; RO, 1924)	● Estimated correction applied to some of the observations (16 January to 29 March and 16 September to 28 November) due to the construction of the wireless mast to the southwest of the recorder (Figure 11).
1921 (Peacock, 1952)	● Another Campbell-Stokes by Hicks was set up at the Western extremity of the roof parapet
1930 (RO, 1930)	● The Campbell-Stokes by Hicks was adopted as the standard.
January 1933 (Peacock, 1952; RO, 1933)	● Wireless mast (typhoon mast) was relocated to the northeast of the Main Building. ● Campbell-Stokes by Hicks was moved to the central coping stone and adopted as the standard.
October 1941 - June 1946 (Peacock, 1952)	● Sunshine recorder was the one of the few instruments left intact during the Japanese occupation.
1957 (RO, 1958)	● Due to the interference of the newly erected buildings to the east of the Observatory, another Campbell-Stokers Sunshine recorder was installed at King's Park in July 1957.
1960	● Recording of the sunshine duration at the

(RO, 1960, 1961)	Observatory ceased on 31 December 1960.

3.9. Solar radiation (HKOHq and King's Park)

Year	Instruments and Methods of Observation
1958 (RO, 1958)	● A bimetallic actinograph (British Meteorological Office Pattern Mark III) was installed at the Observatory in May 1958 with records commencing in 1 June 1958.
1959 (KP) (RO, 1959)	● Solar radiation measurement was moved to King's Park.

3.10. Visibility

Year	Instruments and Methods of Observation
1947 (RO, 1947)	● Eye estimates of visibility were made hourly, using international code figures (Xo-99)
1955 (RO, 1955)	● Eye estimates of horizontal visibility were made hourly, using the WMO international code figures (00-89)

3.11. Amount of cloud

Year	Instruments and Methods of Observation
1884 (Peacock, 1952)	● The percentage of clouded sky was calculated from eye estimates in tenths (1-10) made every six hours.
1885 (Doberck, 1885; Pedgley, 2003)	● Observations of amount (1-10), name (Howard's classification) and direction whence coming of clouds were made every three hours.
1908	● Observations made at hourly intervals.
1913 (RO, 1913)	● Cloud classification of London Meteorological Office was adopted.
1947 (RO, 1947)	● Visual observations of cloud type and amount and estimates of the height of low cloud were made hourly.
1 January 1949	● Eye estimates of clouded sky in eights (oktas).
1962 (RO, 1962)	● An entry of "OBSC" was introduced which means that the sky was obscured and the total cloud amount was not observed. Entries of "OBSC" were treated as missing data in

	calculating the mean total cloud amount.
1 April 2000 (HKO, 2000)	● Only cloud amounts were observed.

Acknowledgement

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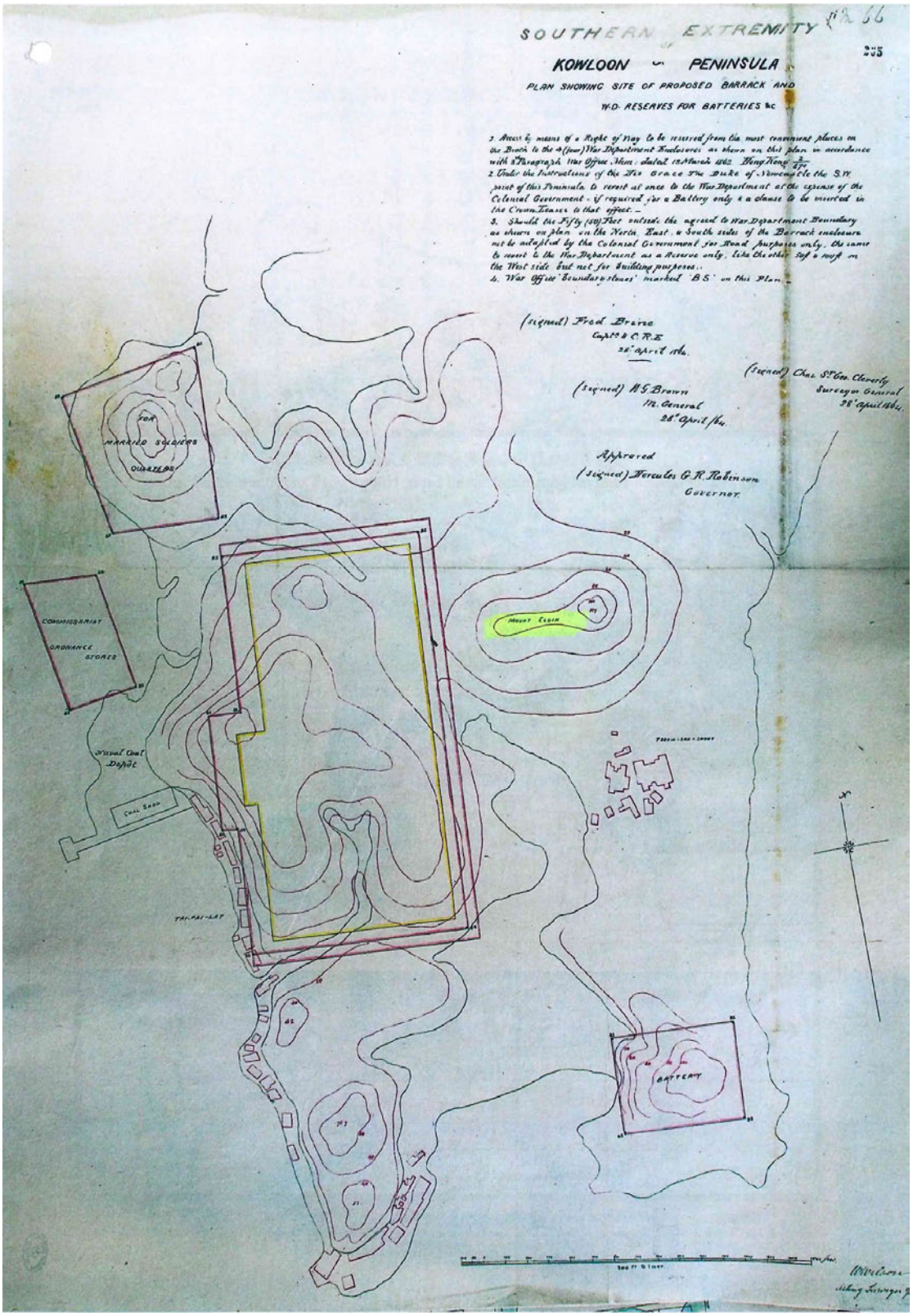


Figure 1. A map of Kowloon Peninsula showing the location of Mount Elgin (highlighted in yellow) in 1864 (Courtesy of The National Archives of the UK)

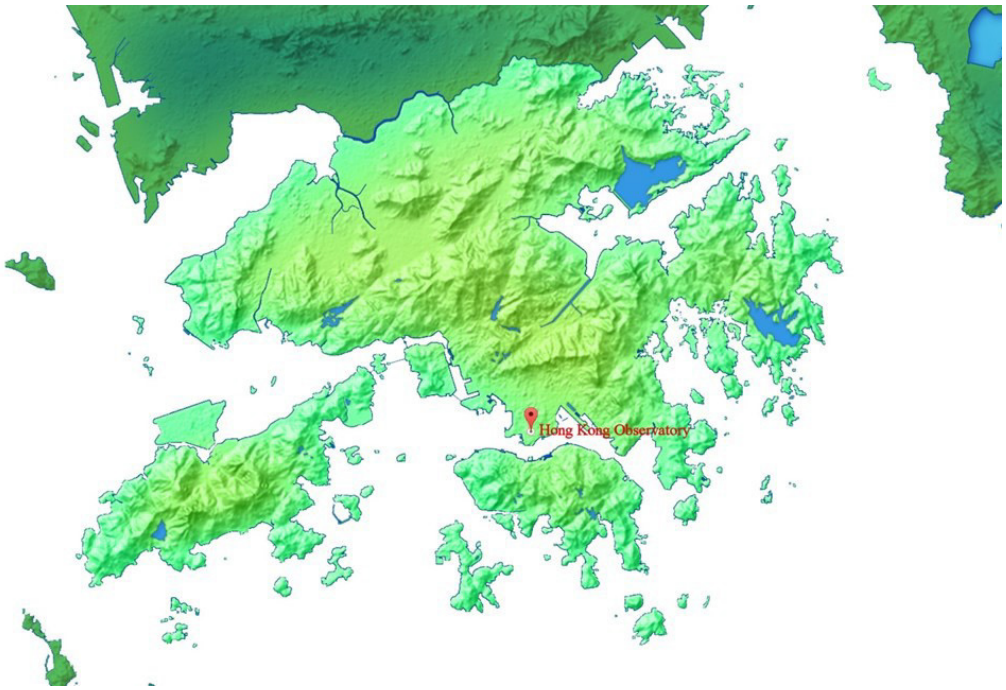


Figure 2. Location of the Hong Kong Observatory in Kowloon Peninsula (2014)

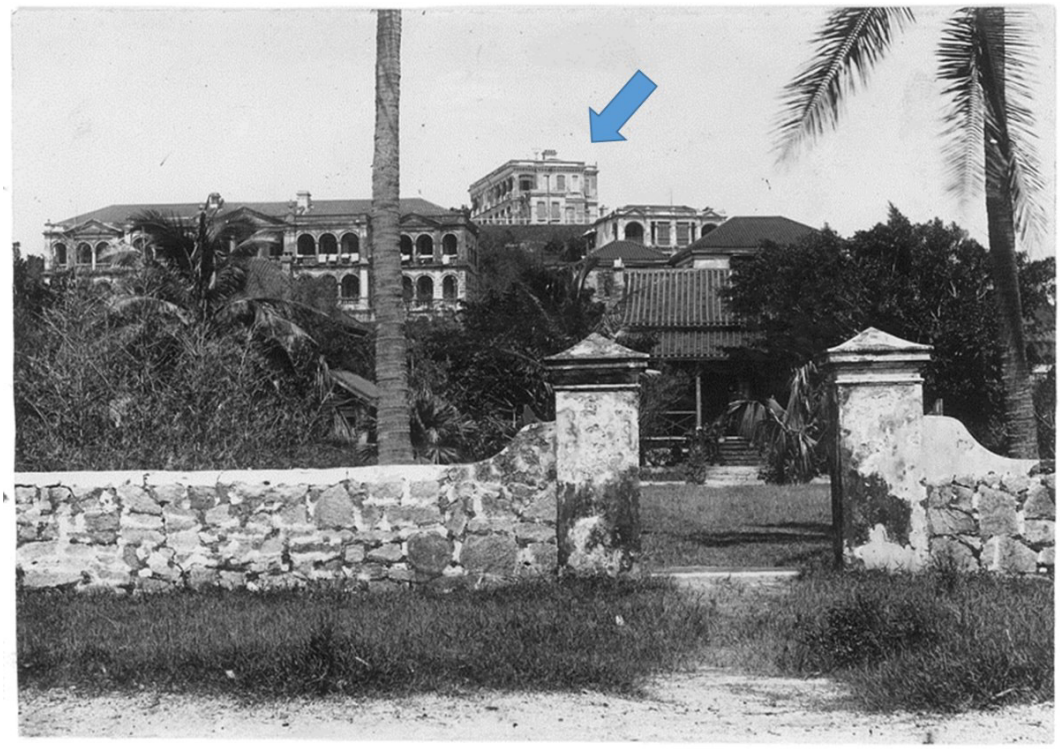


Figure 3. The side view of the Observatory's Main Building (blue arrow) from the east in 1905 (Photo courtesy of Mr Shun Chi-ming, Director of the Hong Kong Observatory, 2011-present)

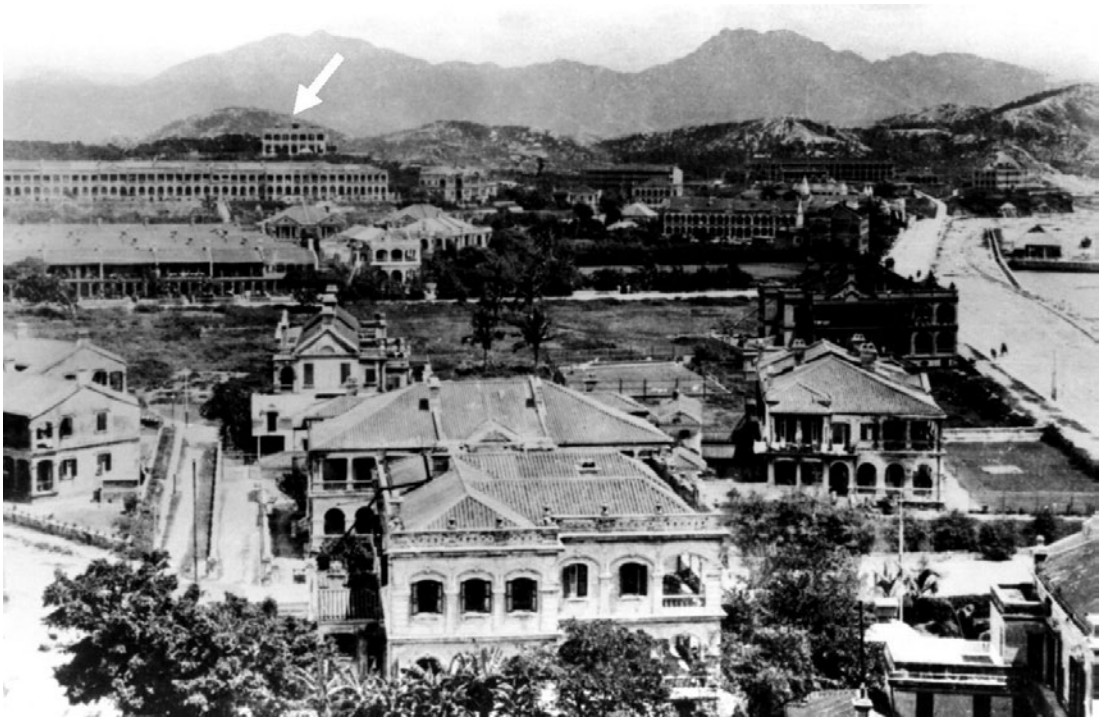


Figure 4. Viewing north across Tsimshatsui in 1908. The arrow shows the location of the Observatory on Mount Elgin

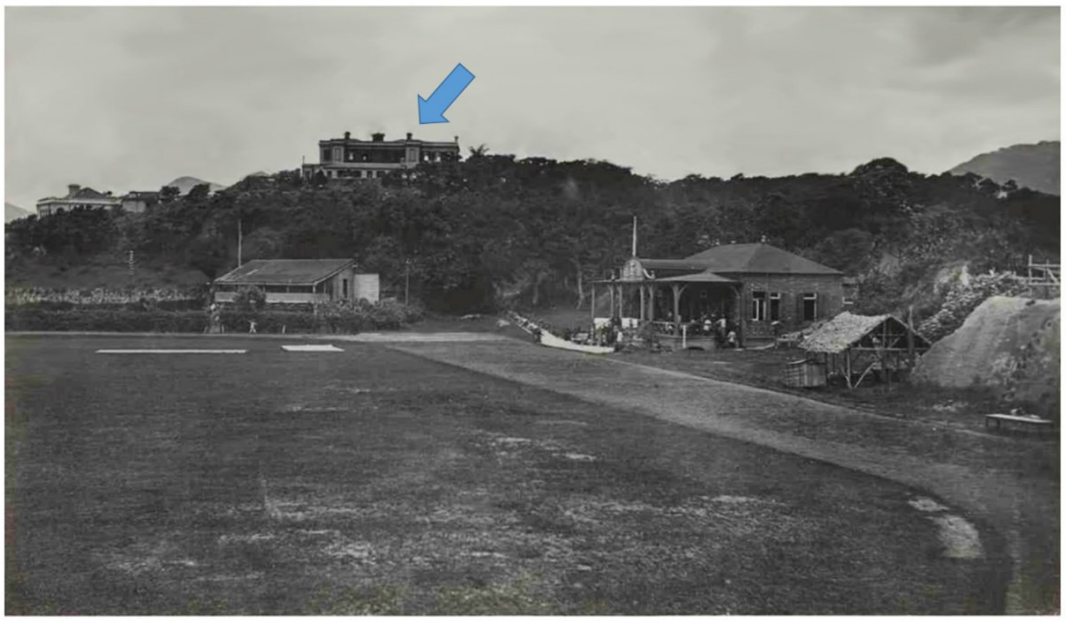


Figure 5. The rear view of the Main Building (blue arrow) of the Observatory taken from Kowloon Cricket club in around 1912-1917 (Photo source : http://gwulo.com/atom/18165)

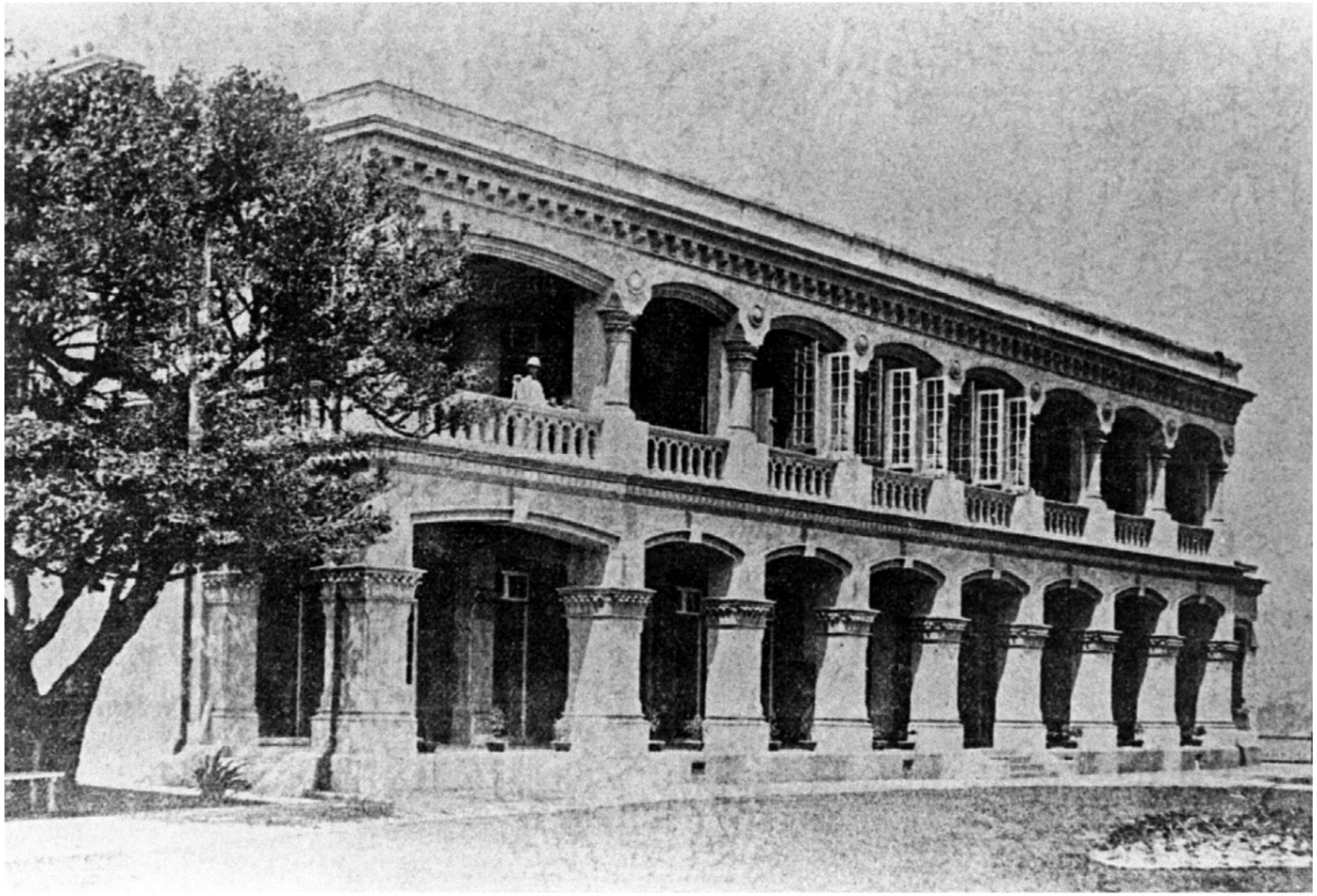
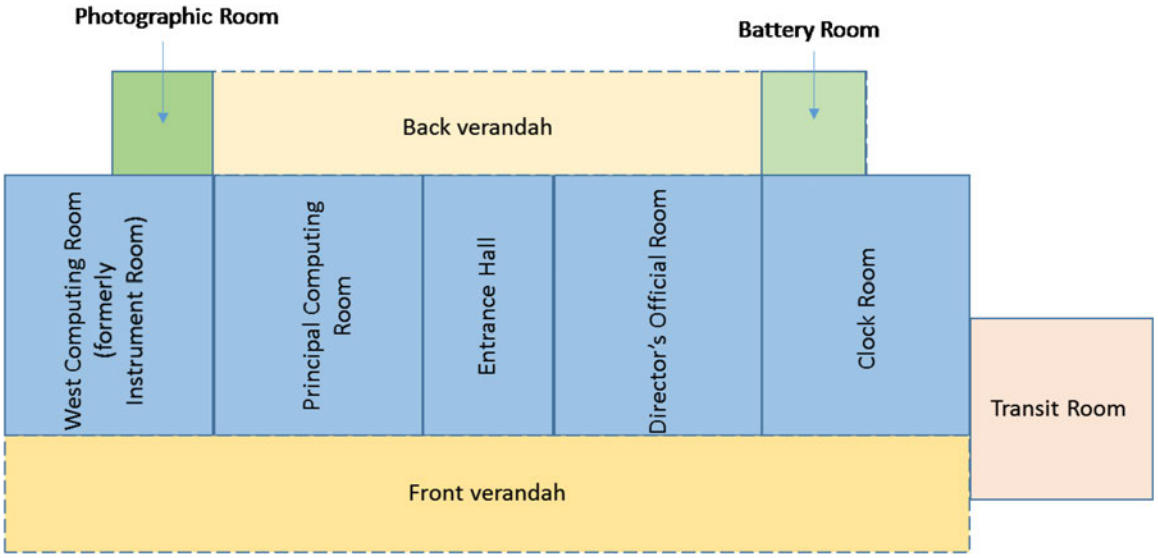
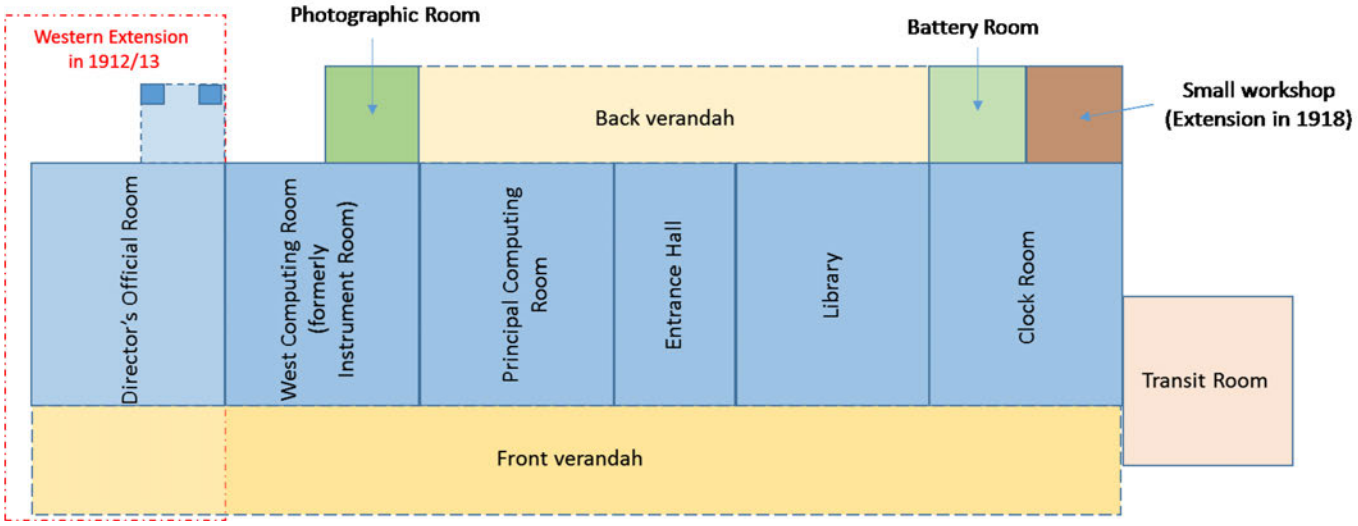


Figure 6. The Main Building, with extension on the left, in 1913



(a)



(b)

Figure 7. Simple layout of the room arrangements of the ground floor of the Main Building (a) before 1912 and (b) in 1913 (with 1918 extension included). Rooms in the upper floor were the Director's Private Quarters. Note : the layouts are not to exact scale

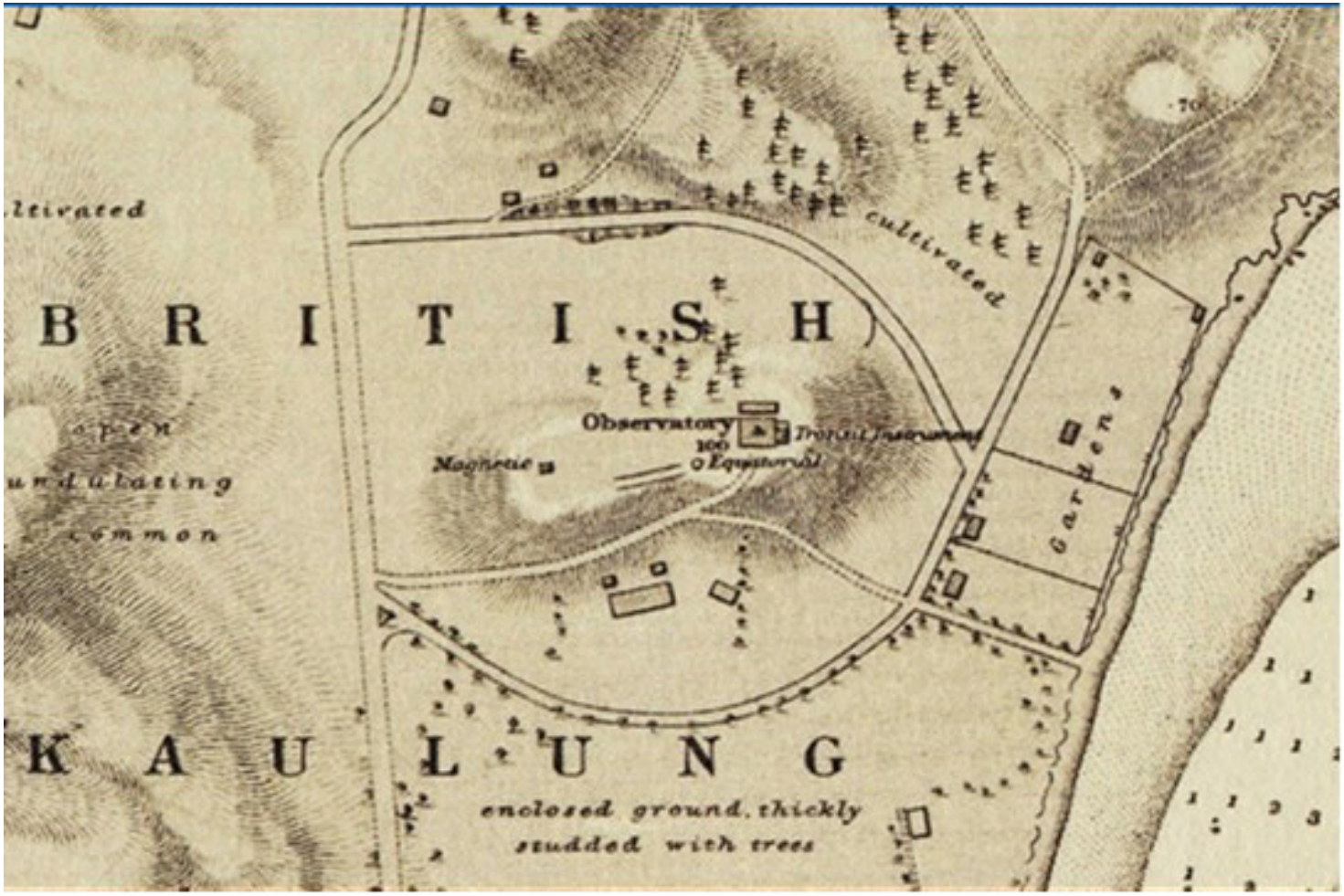


Figure 8. Map showing the location of the Observatory and the locations of the magnetic hut, equatorial telescope, and transit telescope in 1886-1887 (Courtesy of Mr Shun Chi-ming, Director of the Hong Kong Observatory, 2011-present)

Figure 9. Photo of 1886 showing the Main Building (yellow arrow) and the magnetic hut (blue arrow) of the Observatory on Mount Elgin in Kowloon (Photo courtesy of Mr Shun Chi-ming, Director of the Hong Kong Observatory, 2011-present)

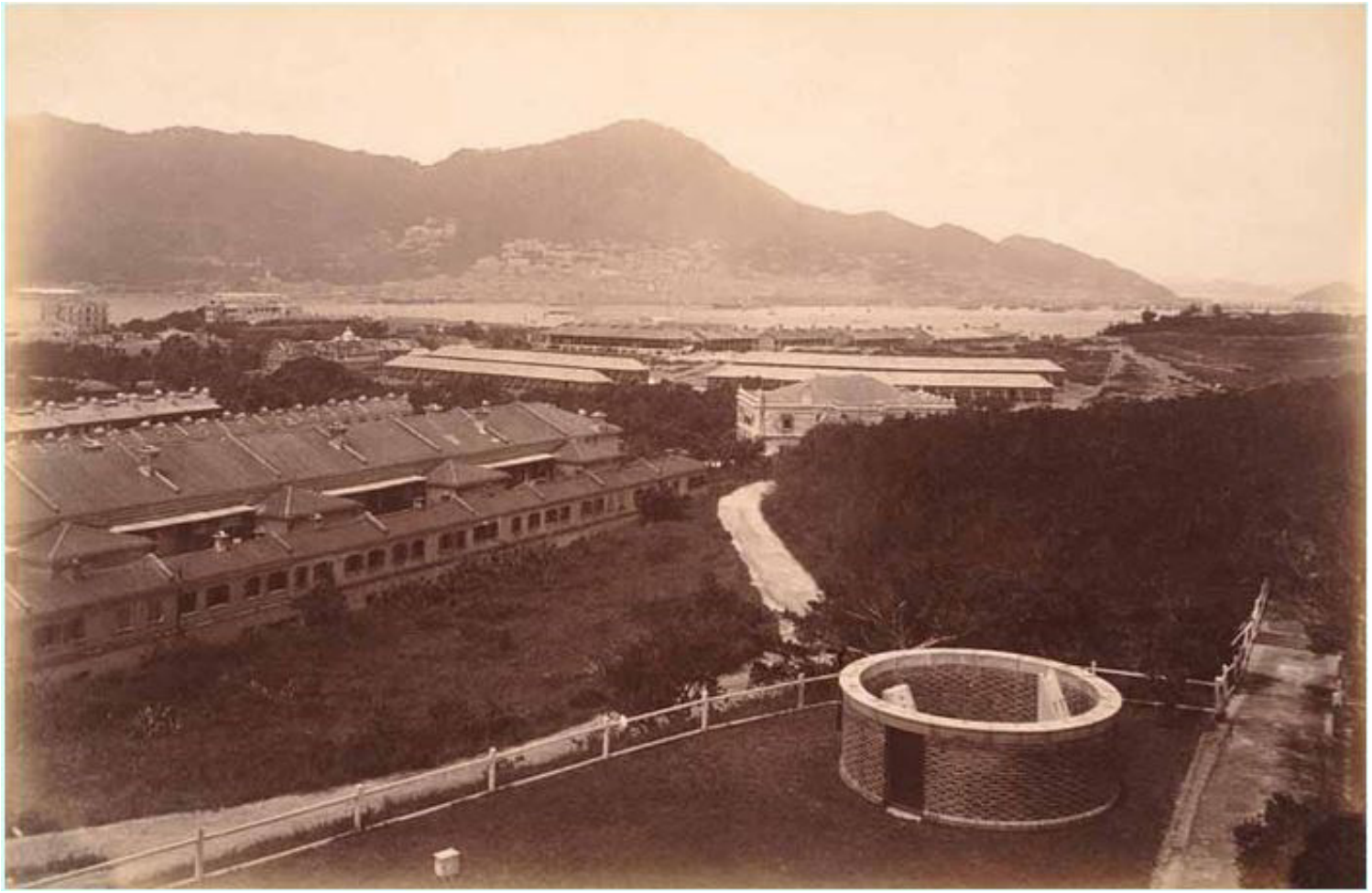


Figure 10. A photograph taken at the Observatory facing southwest in around 1897. On the left are buildings of Knutsford Terrace. The round structure shown on the lower right was used to house the 6-inch Lee Equatorial telescope. The structure was demolished in 1933 and the site was used to build the Director's Quarters (Photo courtesy of the Hong Kong Museum of History)

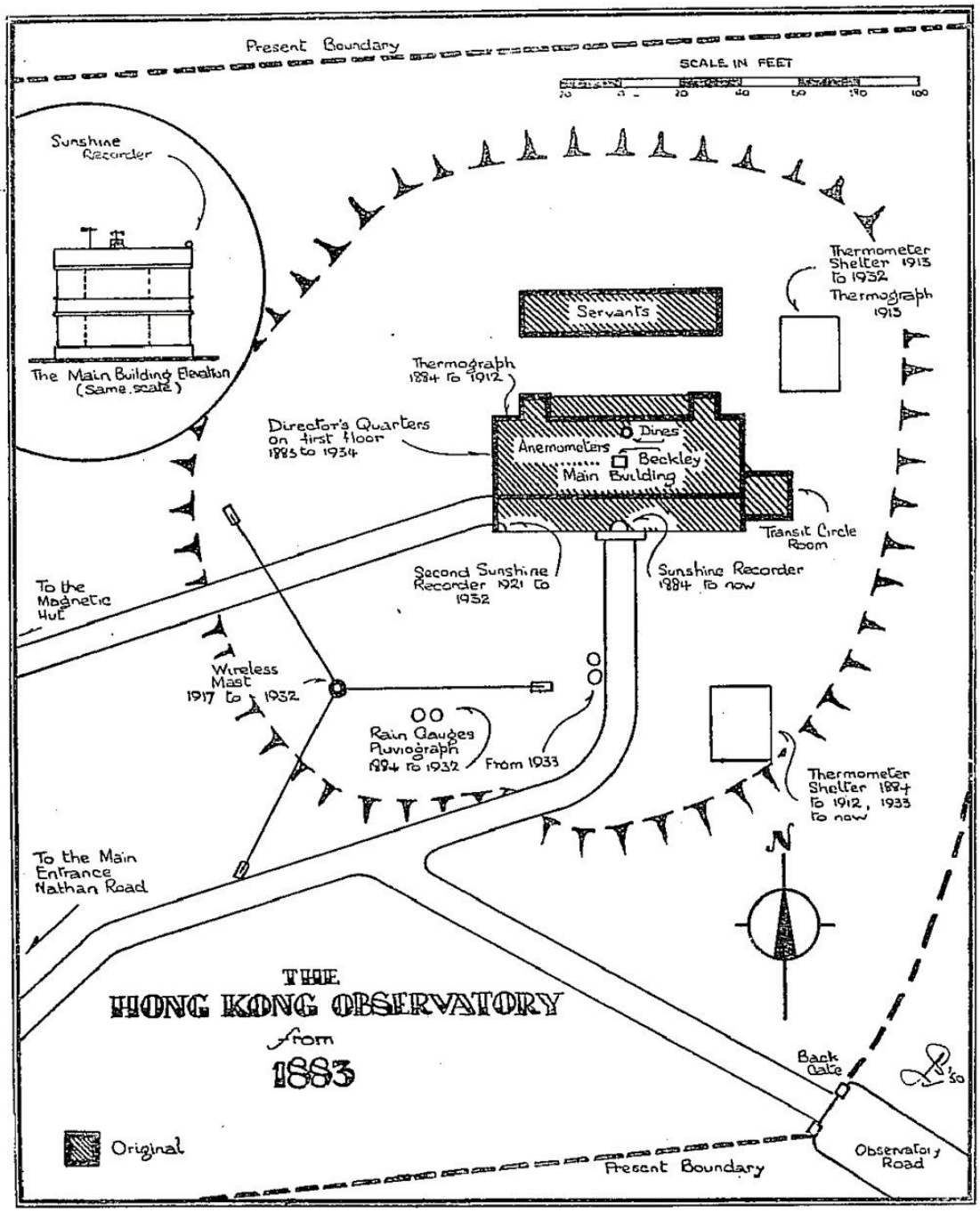


Figure 11. Sketch map of the Hong Kong Observatory, from 1883 (extracted from Starbuck, 1951)

Figure 12. Photo of 1920s showing the Main Building and the signal mast of the Observatory (Photo courtesy of Mr Shun Chi-ming, Director of the Hong Kong Observatory, 2011-present)

Figure 13(a). Photos of Quarters No.2 and No.3 in 1930s (Photo courtesy of Mr G.S.P. Heywood, Director of the Royal Observatory, 1946-1956)

Figure 13(b). Photo of Quarters No.2 and No.3 in 1958 (Photo courtesy of Mr Gordon Bell, Director of the Royal Observatory, 1965-1981)

Figure 13(c). Panoramic view of the Quarters No. 2 (right) and Quarters No.3 (left) in 2014

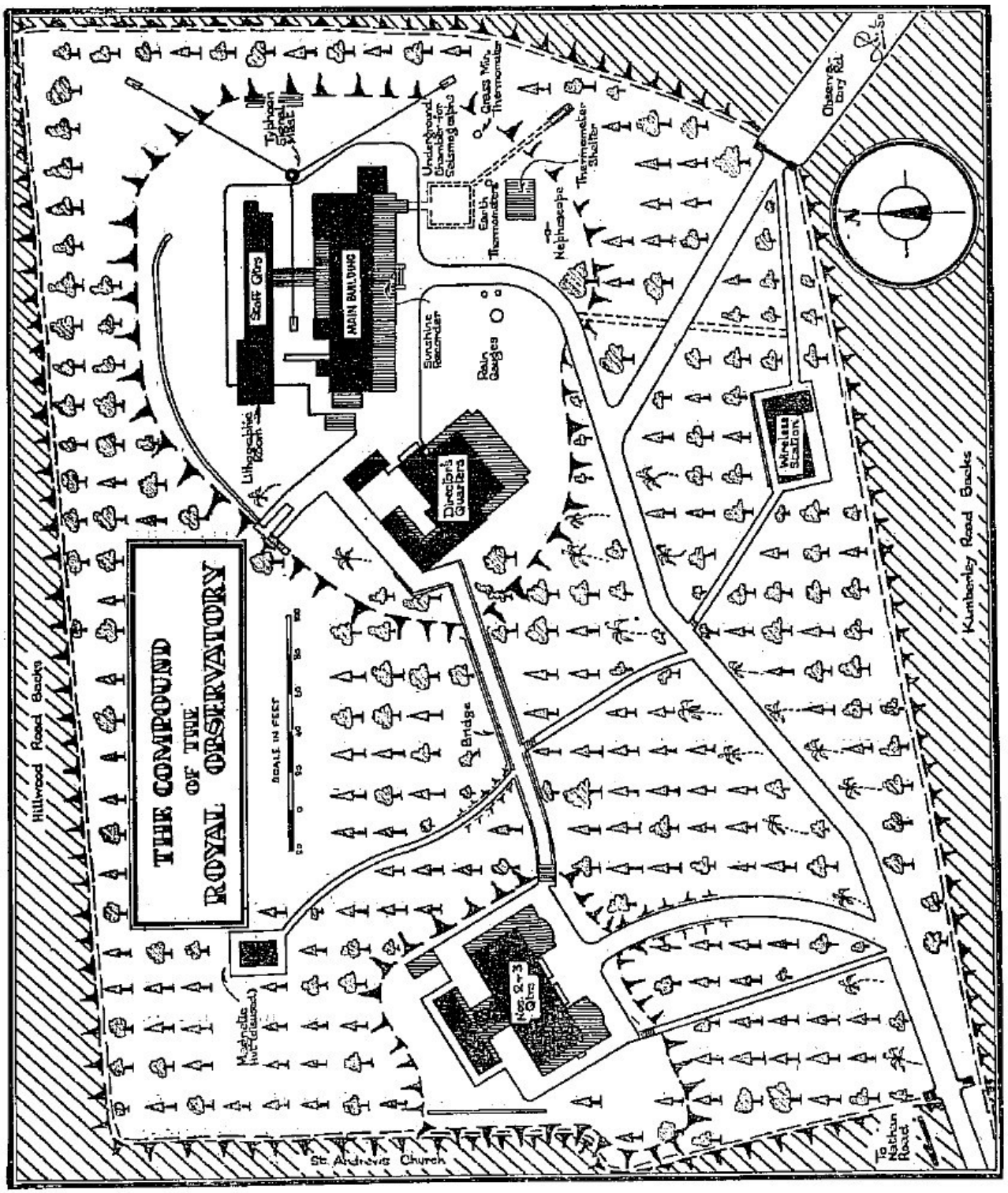


Figure 14(a). Sketch map of the compound of the Hong Kong Observatory (Royal Observatory) in 1950s (extracted from Starbuck, 1951)

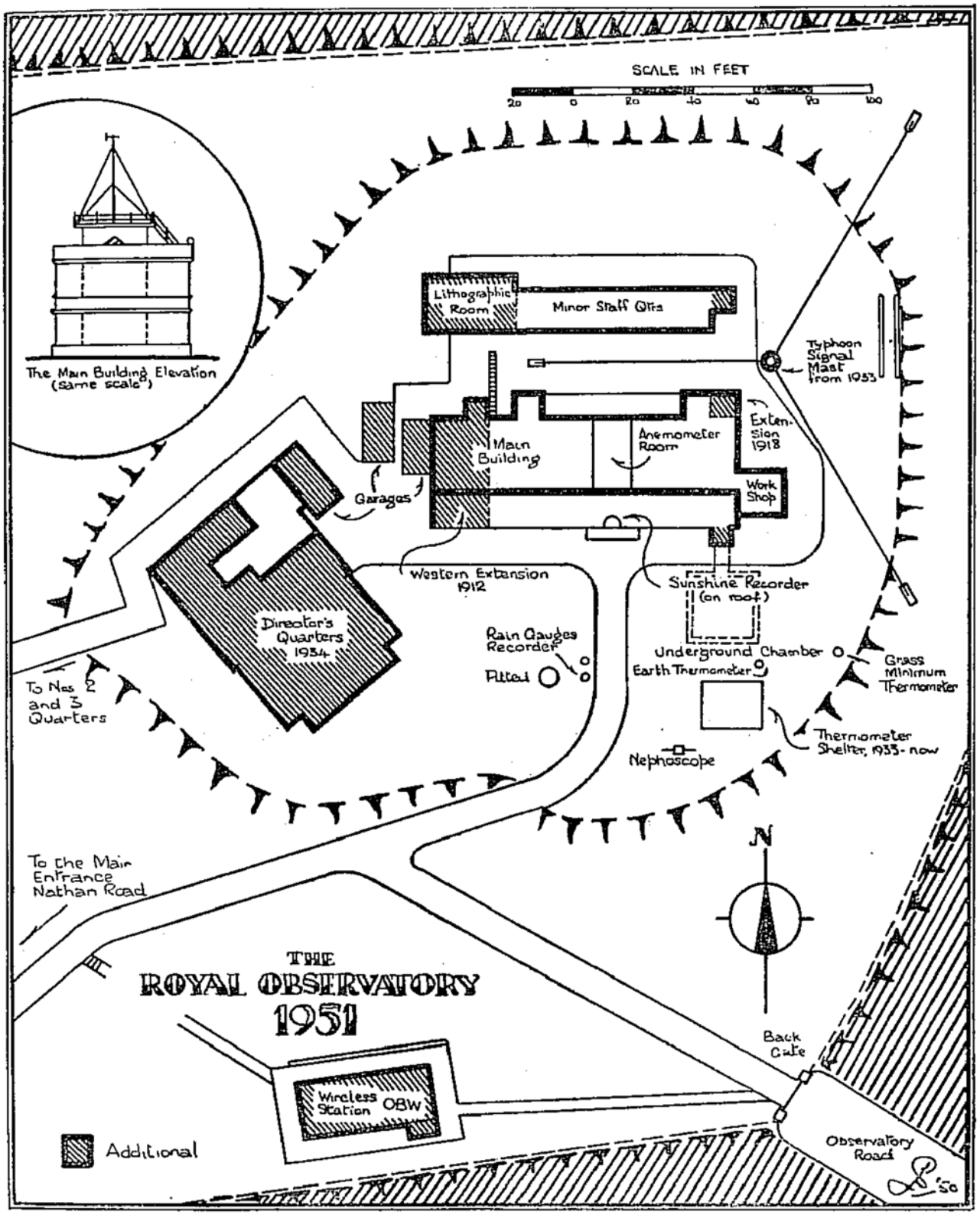


Figure 14(b). Sketch map of the Hong Kong Observatory (Royal Observatory) in 1950s (extracted from Starbuck, 1951)

Figure 15. Photo of Quarters No. 1 (to the right) in 1930s (Photo courtesy of Mr G.S.P. Heywood, Director of the Royal Observatory, 1946-1956)

Figure 16. The Director's Quarters (Quarters No. 1) in 2014

(a)

(b)

Figure 17. Photos of the lawn area to the southeast of the Main Building in 1930s : (a) without the thermometer shed, and (b) with the thermometer shed (blue arrow) (Photo courtesy of Mr G.S.P. Heywood, Director of the Royal Observatory, 1946-1956)

Figure 18. Photo of the thermometer shed in 1950s (Photo courtesy of Mr G.S.P. Heywood, Director of the Royal Observatory, 1946-1956)

Figure 19. An aerial view of the Observatory in 1951 showing the Main Building (middle), Quarters No.1 (to the left), the typhoon signal mast and annex building (to the right)

Figure 20. Photo of aerial network around 1969-1970 (Photo courtesy of Mr Shun Chi-ming, Director of the Hong Kong Observatory, 2011-present)

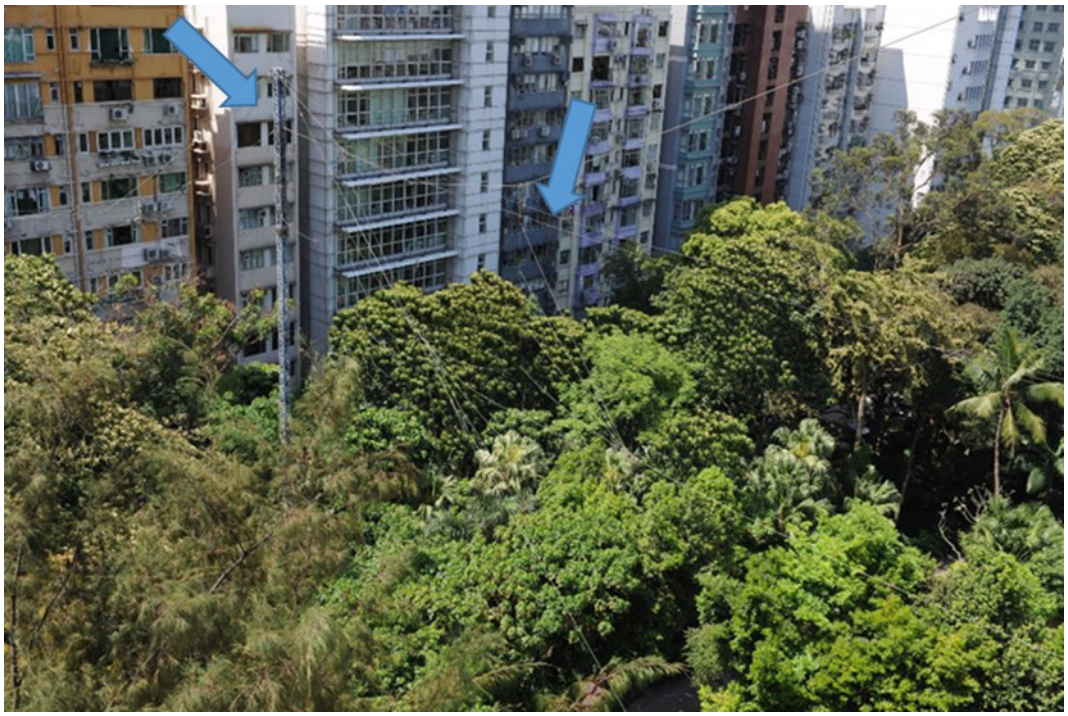


Figure 21. Photo of the aerial network in 2015

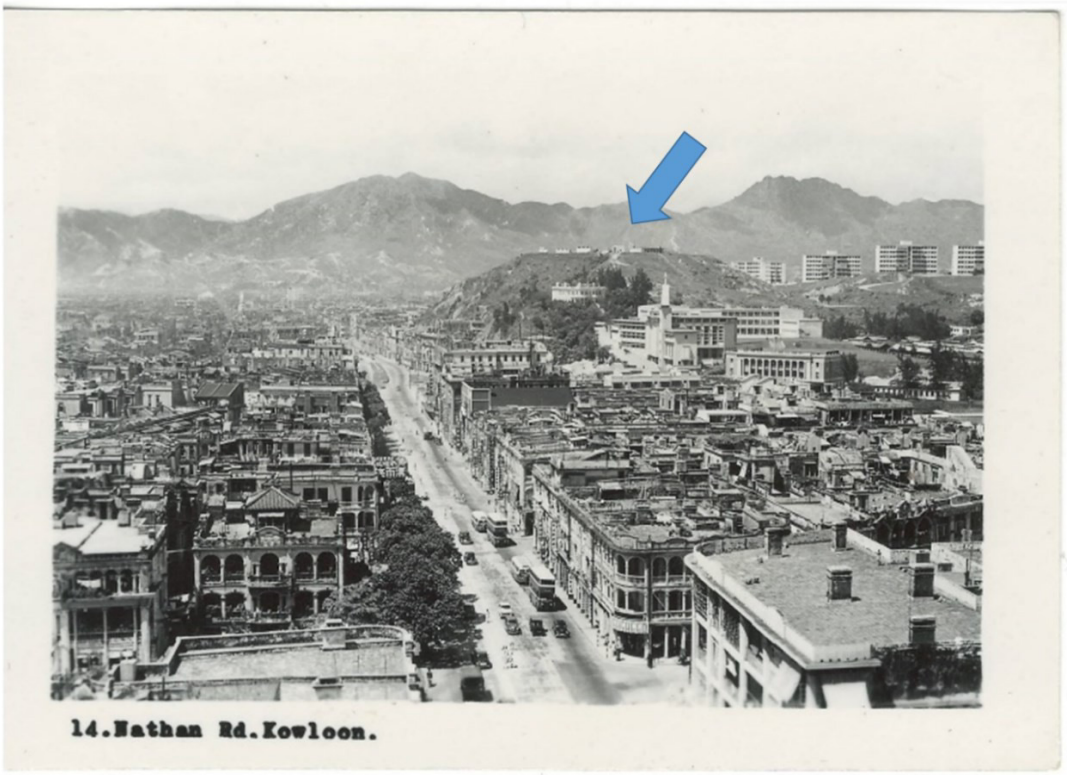


Figure 22. Photo of the King's Park Meteorological Station (blue arrow) in the Kowloon in 1950s (Photo courtesy of Mr Shun Chi-ming, Director of the Hong Kong Observatory, 2011-present)

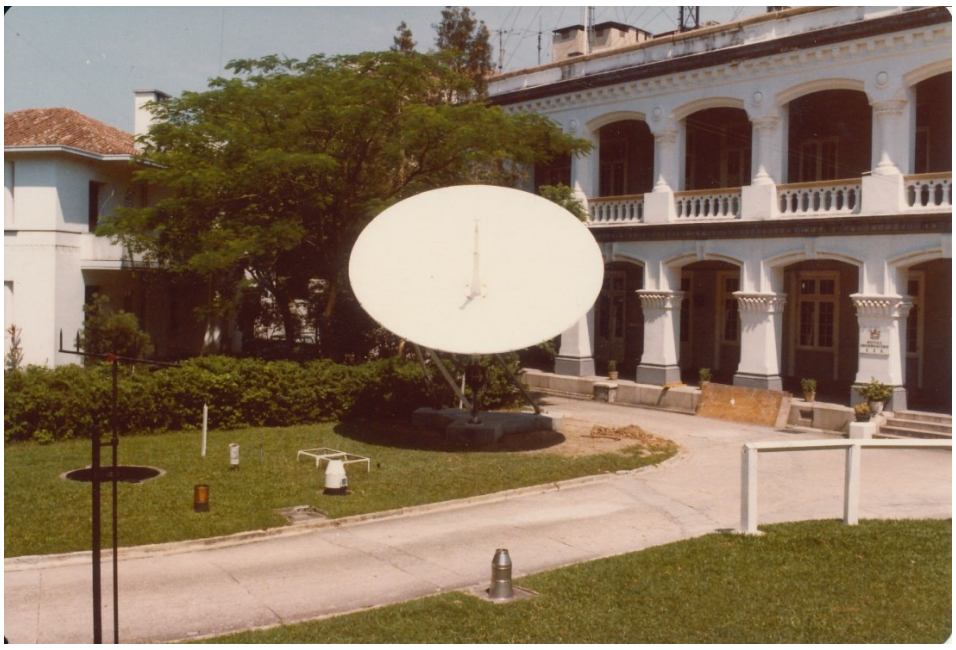


Figure 23. Satellite dish antenna was set up on the lawn area to the southwest of the Main Building between August 1979 and April 1982

Figure 24. An aerial view of the Observatory in September 1979, with the construction of the Centenary Building to the right of the Main Building (courtesy of Survey and Mapping Office, Lands Department)

Figure 25. Photo of the Centenary Building under construction in 1980 (Photo courtesy of Dr C M Tam)

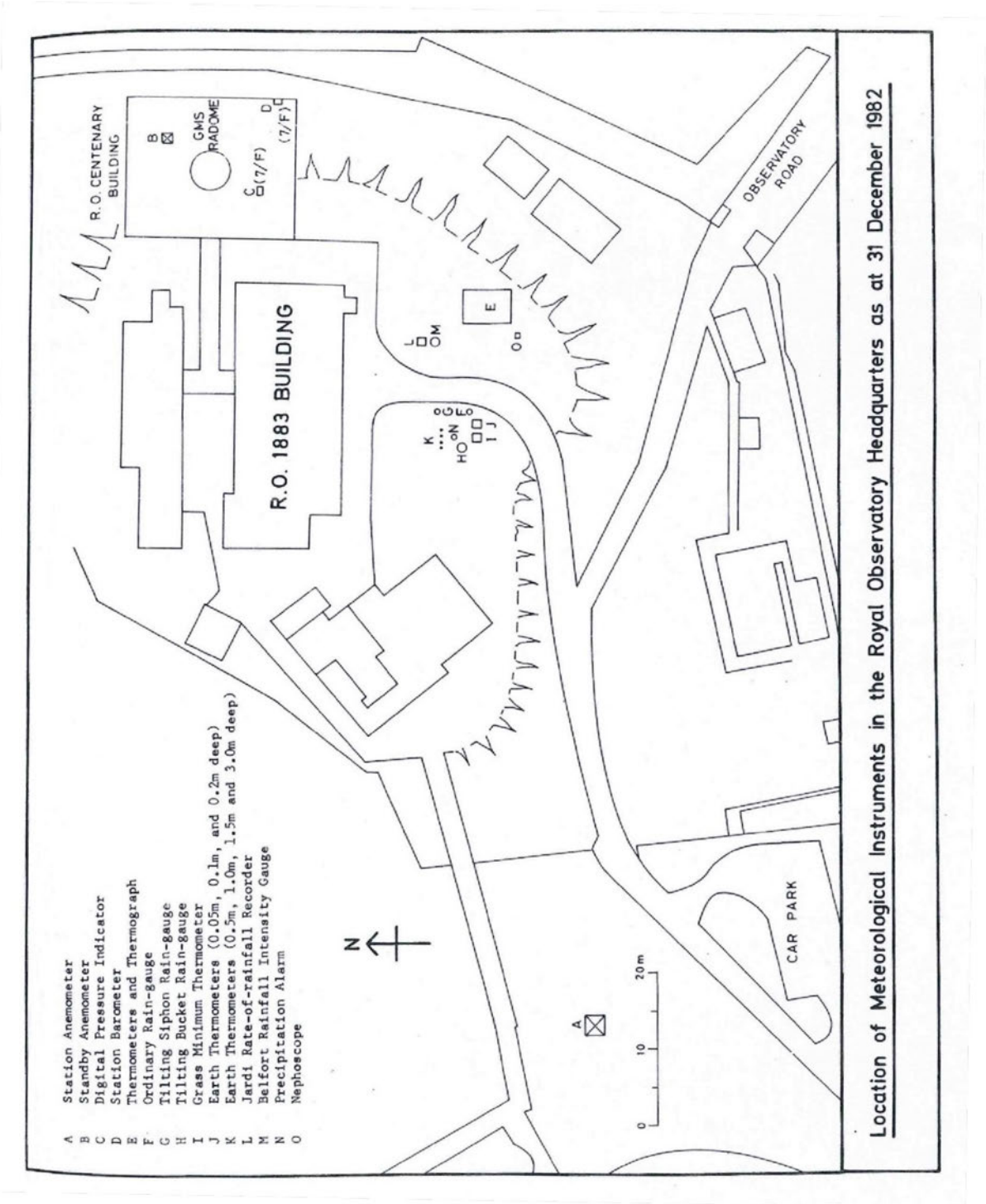


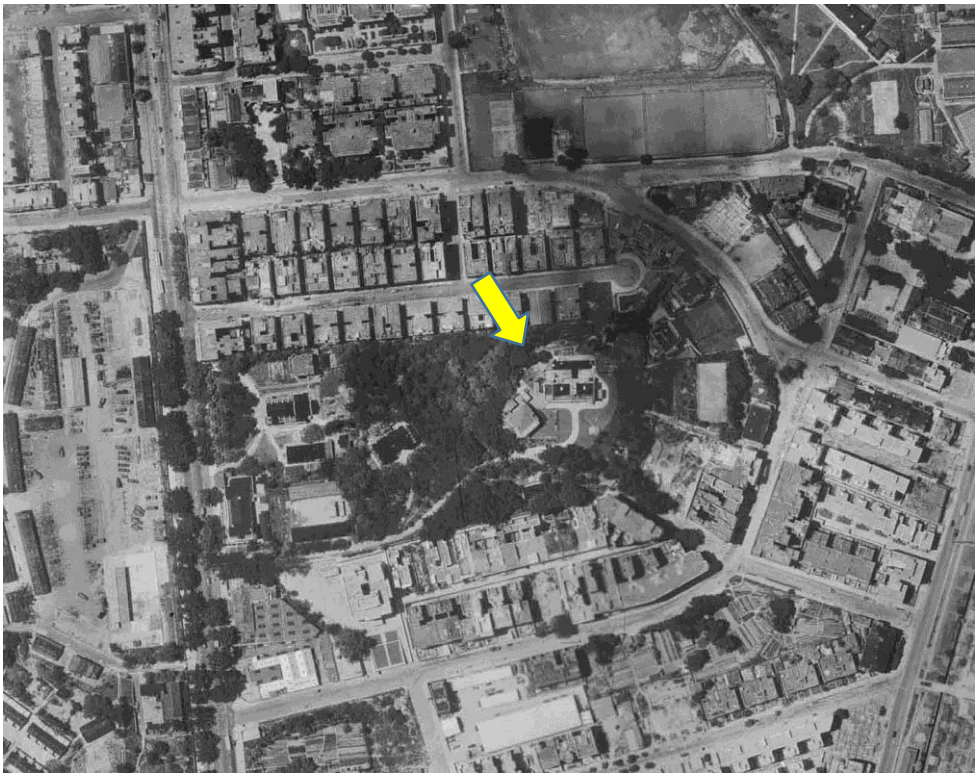
Figure 26. Locations of instruments at the Observatory as at 31 December 1982 (extracted from RO, 1982)

Figure 27. The open shed of the Observatory in 1950s (towards south)

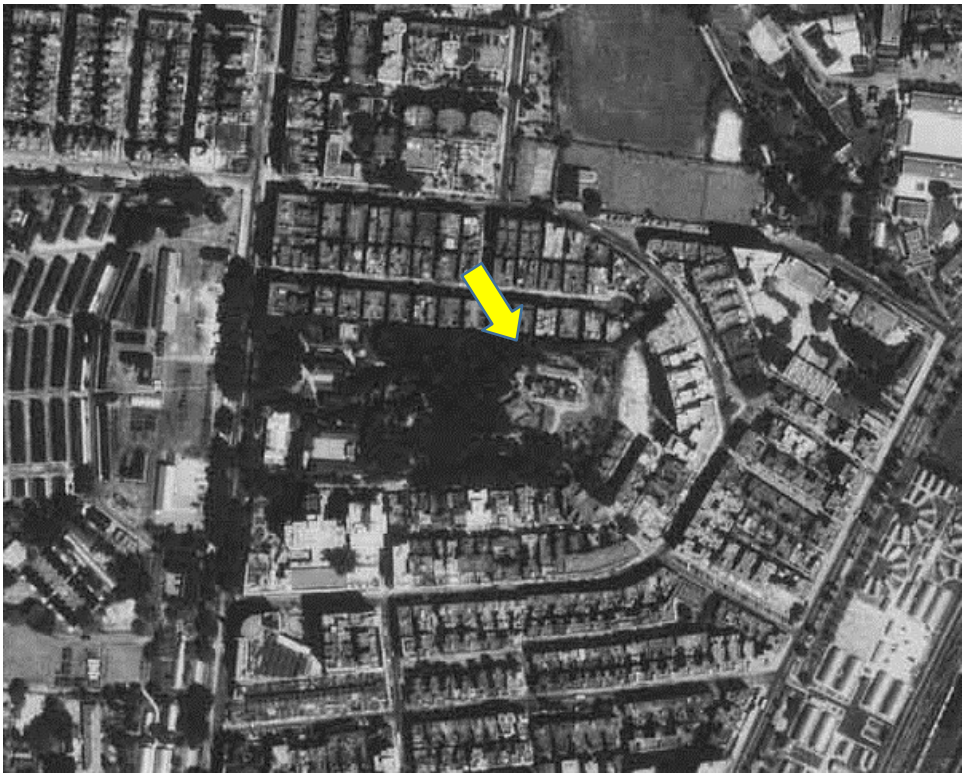
Figure 28. Aerial photo of the Observatory in 1964 (Photo courtesy of Mr Gordon Bell, Director of the Royal Observatory, 1965-1981)

Figure 29. Panoramic view of the lawn area of the Observatory (towards south). According to the building history to the south, this photo was likely taken in early 1970s

Figure 30. Panoramic view of the lawn area of the Observatory in 2007 (towards south)

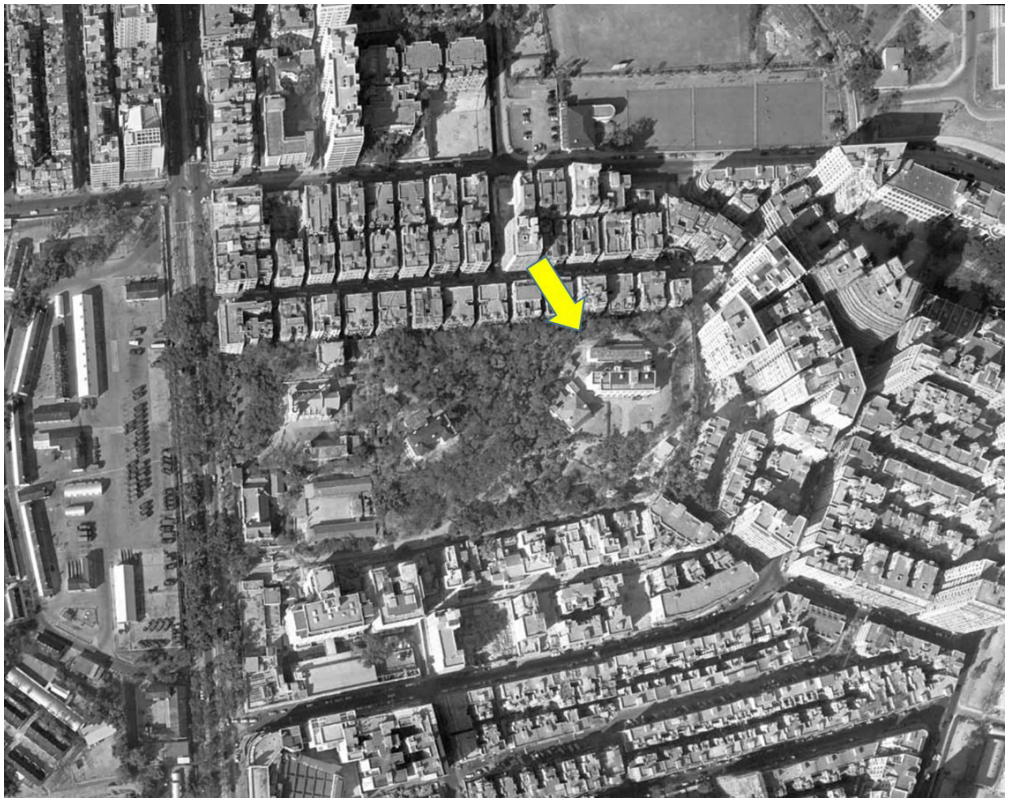


(a) 19 May 1949

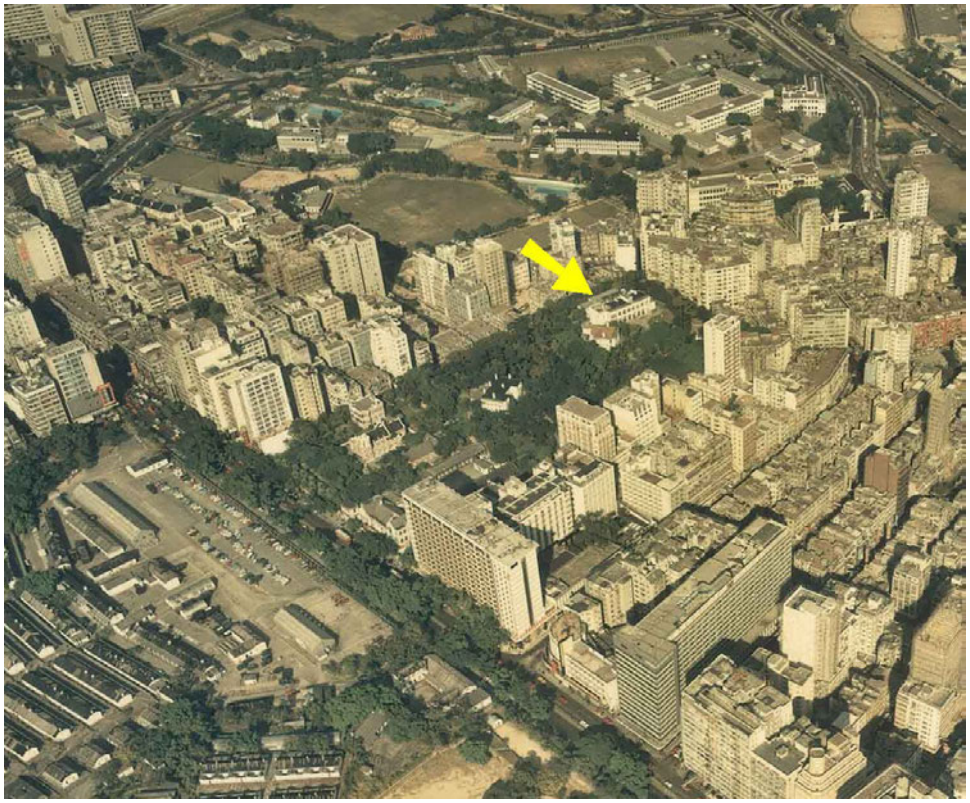


(b) 5 October 1959

(Aerial Photographs from Lands Department)



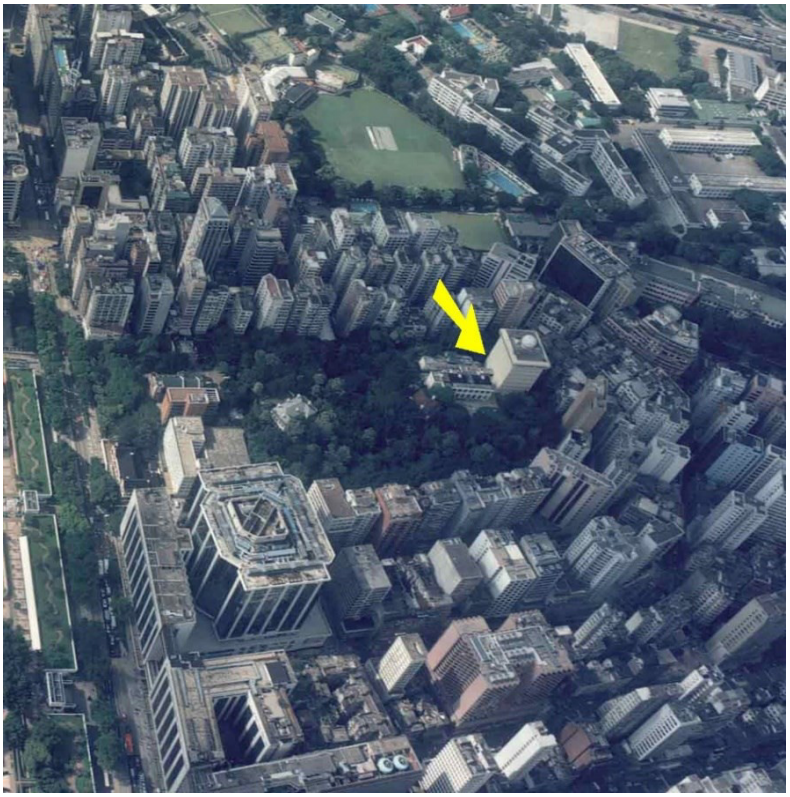
(c) 27 January 1963



(d) 15 December 1972

(Aerial Photographs from Lands Department)

(e) 20 October 1986



(f) 27 June 1994

(Aerial Photographs from Lands Department)

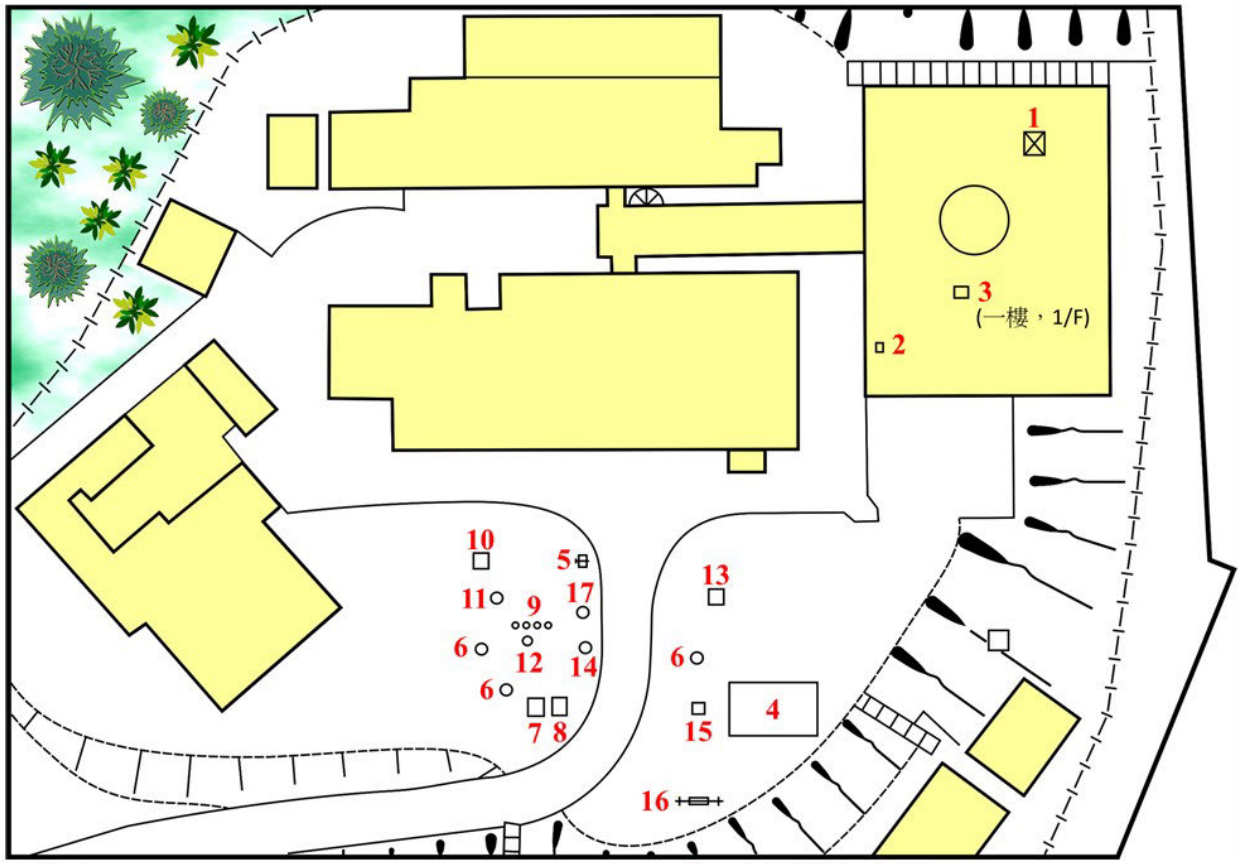
(g) 30 May 2007
(Aerial Photograph from Lands Department)

(h) 28 March 2015
(Aerial Photograph from Lands Department)

Figure 31. Aerial photo of the compound of the HKO Headquarters in (a) 1949, (b)1959, (c) 1963, (d) 1972, (e) 1986, (f) 1994, (g) 2007 and (h) 2015 (Photo courtesy of Survey and Mapping Office, Lands Department)

Figure 32. Panorama photo of the Hong Kong Observatory Headquarters in April 2015

Figure 33(a). Sketch map of the compound of the Hong Kong Observatory in 2015



1. 風速表 Anemometer
2. 降雨探測器 Precipitation Detector
3. 氣壓表 (一樓) Barometer (1/F)
4. 溫度表 (開放棚架) Thermometers (Open Shed)
5. 普通雨量器 Ordinary Raingauge
6. 0.5毫米翻斗式雨量器 0.5mm Tipping-bucket Raingauge
7. 最低草溫溫度表 Grass Minimum Thermometers
8. 土壤溫度表 Soil Thermometers
9. 土壤溫度表 Soil Thermometers
10. 查迪型降雨率測量器 Jardi Rate-of-rainfall Recorder
11. 降雨探測器 Precipitation Detector
12. 0.1毫米翻斗式雨量器 0.1mm Tipping-bucket Raingauge
13. 溫度計百葉箱 Thermometer Screen Box
14. 虹吸式雨量器 Tilting Siphon Raingauge
15. 暑熱壓力測量系統 Heat Stress Monitoring System
16. 測雲器 Nephoscope
17. 秤重雨量計 Weighing Raingauge

Figure 33(b). Locations of Meteorological Instruments at the Observatory Headquarters in 2015

Figure 34. The anemometer mast on the roof of the Main Building in August 1977

Figure 35. The anemometer mast set up on the western end of the compound of the Observatory (left) between 1982 and 1992 with the Main Building and Centenary Building (to the right)