

New Automatic Weather Station System in Hong Kong
Featuring One-stop Quality Assurance, Internet Technology and Renewable Energy

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Abstract

The Hong Kong Observatory (HKO) has developed a new Automatic Weather Station (AWS) System with a capability to carry out one-stop data quality assurance. Data from AWSs are collected by the system's central station and go through quality assurance processes there in real time, resulting in reduced manpower required for subsequent data processing. An added advantage of this feature is that it enables early detection and diagnosis of faults. The fault message is conveyed to the maintenance staff via email to enable early remedial action, enhancing data availability.

Selected AWSs are equipped with a network camera, and pictures taken are uploaded to HKO's website in real time via a mobile telephone network. The pictures would enable the public and tourists to assess the weather conditions at their travel locations in a direct and intuitive manner. As a contribution to conservation, the AWSs are designed to run on solar and wind power. The experience in remote locations in Hong Kong has demonstrated very satisfactory results in terms of data availability and reduced maintenance effort. This paper presents the overall design concepts, quality assurance algorithms, as well as a plan to further expand the capability of the system.

1. Introduction

Since 2000, the Hong Kong Observatory (HKO) started to modernize its Automatic Weather Station (AWS) System with a view to enhancing its public weather service. The modernization process involves the following aspects:

- (i) expanding the capability of the AWS network in making observations;
- (ii) extending the coverage of the AWS network in Hong Kong, China; and
- (iii) enhancing the quality assurance of meteorological data gathered from the AWSs.

For conservation purpose, the AWSs are designed to run on solar and wind power. This paper describes the overall design concept of the new system, its quality assurance algorithms, as well as a plan to further expand its capability.

2. Major components of the new AWS system

The new AWS system consists of the following components:

- (i) AWSs;
- (ii) Network cameras;
- (iii) AWS central data acquisition system; and
- (iv) Integrated data quality assurance system.

Figure 1 shows the technical set-up of the AWS system.

3. AWS network

In expanding the capability of the AWS network, new types of meteorological instruments have been installed at selected AWSs. These include a total sky imager, a device for taking snapshot of the sky to assess the cloudiness during daytime (Figure 2), and a broadband UV sensor for measuring ultraviolet radiation to alert people about the need to adopt protective measures when exposed to the sun (Figure 3). Recently, network cameras have been installed at selected tourist spots to provide high quality weather photographs in real time to the public. Details of the network cameras are described in section 4.

In extending the coverage of the AWS network in Hong Kong, HKO has setup new AWSs and installed additional weather observing instruments at popular tourist spots to provide detailed weather information to the public and tourists (Figure 4).

4. Network cameras

Network cameras have been installed at several places in Hong Kong to provide real-time weather photographs to the public. These network cameras can transmit, without the use of a PC, high quality weather photographs or video clips to the HKO website via broadband network or GPRS in real time. Operational parameters such as picture frequency, mode (photo or video clip) and picture resolution, can be remotely controlled via the Internet (Figure 5).

4.1 New weather service to the public and tourists

The aim of installing network cameras at popular tourist spots is to provide real-time weather photographs via HKO's Internet website (Figure 6), so that tourists and members of the public can plan their travel in a direct and intuitive manner. On the website, they can also view animation of weather photographs for the past three hours as well as some notable weather events of the past.

4.2 Weather monitoring and forecasting

The real-time weather photographs also assist forecasters in monitoring more closely changes in weather conditions such as deterioration in visibility (Figure 7) as well as the development of strong convective weather.

The snapshots shown in Figure 8 are an example of how real-time weather photographs can be used to monitor the development of strong convective weather. The weather on 4 August 2004 was characterized by a broad trough of low pressure lying over South China, which brought showers and thunderstorms to Hong Kong. In the afternoon that day, thunderstorms started to develop over the northeastern part of Hong Kong due to very rapid upward motion of moist air (Figure 8.1(a) and 8.1(b)). Following the northeasterly winds aloft, the cumulonimbus clouds spread to the south-west and obscured the sky (Figure 8.2(a)). As satellite pictures are normally only available once every hour, the use of real-time weather photographs together with radar pictures can help forecasters monitor closely the development of convective weather and if necessary issue weather warnings in good time.

4.3 Promoting public education on weather

Because of its continuous operation, the network cameras have captured valuable snapshots of weather events. Figure 9 shows a picture sequence of cumulonimbus clouds captured in the afternoon of 14 July 2004. The weather that day was generally fine at first with light to moderate southerly winds blowing over the coast of south China. On the radar (not shown), strong convection was observed to develop over inland areas in the afternoon, about 50 to 100 km north of Hong Kong. The photograph sequence shows strong vertical motion of very moist air developing to a great height. An anvil, with its characteristic fibrous texture, gradually formed and spread out from left to right, a result of westerly winds aloft.

5. AWS central data acquisition system

At present, the AWS central data acquisition system is still running on a DOS platform. It is responsible for acquiring meteorological data from over 70 AWSs once every minute via the public telephone network. HKO is now working on migrating the system to a high-speed and stable platform running on the UNIX operating system so that multi-tasking operation and faster data transfer can be supported.

6. Integrated data quality assurance system

The AWS data received by the central data acquisition system are passed to the integrated data quality assurance system for quality control. The latter system has been developed by HKO to provide one-stop data quality assurance. The data flow and processing are shown in Figure 10. The system is highly automatic. It serves to enhance data quality and at the same time reduce manual labour. Through various real-time and non-real-time automatic data quality control processes, the system carries out quality assurance for each data received from the AWS by assigning a quality assurance flag to the data, filtering out erroneous data from the AWS, and alerting maintenance staff to action via automatic email. Operation of the AWSs can also be monitored via a webpage which displays the status of the AWS network in real-time (Figure 11). The advantage of this automatic alerting feature is that it enables early detection and diagnosis of faults, enhancing data availability. Apart from monitoring the operation of the AWS, the quality assurance flags also serve as an indication of quality, facilitating reference by users in future case studies and climatological research.

6.1 Quality Assurance Algorithms

The following automatic QA algorithms have been implemented in the system:

- (i) Range test: The range test (WMO (1996) and Shafer (2000)) is an algorithm that determines if an observation lies within a pre-determined range. The allowable ranges are based on sensor specifications, sensor location, monthly and annual climate extremes in Hong Kong. Every meteorological element at each site has a unique set of limits. If a datum is observed to lie outside the allowable range, it is assigned with a specific flag.
- (ii) Trend test: The trend test (Shafer (2000)), also known as the step test, uses sequential observations to determine, for each of the elements measured, which abrupt change in the data represents unrealistic “jump” during the observation time interval. Observations that exceed the maximum allowed value will receive a specific flag (different from the one for (i) above).
- (iii) Inter-sensor consistency test: This test (WMO (1996) and Shafer (2000)) makes use of the internal consistency of an element against other element(s) measured at the same site with the use of established physical and meteorological principles (e.g. dew point and wet-bulb temperature cannot exceed the ambient temperature).

Other automatic QA tests (Shafer (2000)) are being developed and tested to further enhance the effectiveness of the system. These include spatial test for rainfall (with reference to radar echoes) and persistence test for wind speed and direction.

For each data, a set of QA flags corresponding to the automatic QA tests will be generated by

the system. Following the guidelines of WMO (1996), a composite QA flag, also known as final quality control flag, is assigned by the system to each weather data element based on the QA flags of the various QA tests. The composite QA flag will be assigned a value of “1” if the data passes all QA tests; it will be assigned a value of “3” if the data fails in any of the QA tests; it will be assigned a value of “2” if the data is treated as suspicious by any of the QA tests. The meaning of the QA flags is explained in Table 1 and 2. A typical error log generated by the system is shown in Figure 12.

Assigning different values to the QA flag allows the data user to decide on the level of QA they prefer for their applications and exercise caution when interpreting the data. The “suspicious” QA flag may sometimes help to identify a real but unusual meteorological event, e.g. an extreme value breaking previous records. The system also allows manual editing of the QA flag by a meteorologist. The raw AWS data together with the final QA flag thus serve as a complete record of the data as well as a key for reference by users.

7. Use of Renewable Energy

HKO has been using renewable energy for about 20 years. Since the 1980s, solar panels have been used to power some AWSs in Hong Kong, particularly for AWSs in remote areas and on outlying islands with no city power supply. However, insufficient sunshine due to prolonged periods of overcast or rainy weather has occasionally resulted in inadequate power to keep a station running. Since early 2000, HKO started deploying a hybrid of solar panel and wind-powered generator at some remote stations. Experience indicates that the windy conditions that normally come with overcast weather complement the sunshine shortage quite well in terms of providing a continuous supply of renewable energy. Moreover, as AWSs with renewable energy do not run on city power, they do not suffer from power interruptions. As of today, there are altogether 22 AWSs utilising solely solar and wind energy in Hong Kong (Figure 13). Results so far have demonstrated very satisfactory performance in terms of higher data availability and reduced maintenance effort. The plan is to deploy more AWSs on renewable energy in future.

8. Discussion

The introduction of new weather services giving the public more weather information, in quantity, in type and in detail, has been received very positively. Feedback of the public has enabled HKO to make further improvements to the services.

The plan for the intermediate future is to add network cameras to more strategically located AWSs in Hong Kong. Plan is also in hand to integrate additional sensors into the AWSs, e.g. sensors for measuring radioactivity and solar radiation.

References

- Shafer, M.A., C.A. Fiebrich, D.S. Arndt, S.E. Fredrickson, and T.W. Hughes, 2000: Quality assurance procedures in the Oklahoma Mesonet, *J. Atmos. Oceanic Technol.*, 17, 474-494.
- World Meteorological Organization, 1996: *Guide to Meteorological Instruments and Methods of Observation*, WMO-No.8, Geneva, pp II.1-10 to pp II 1-12.

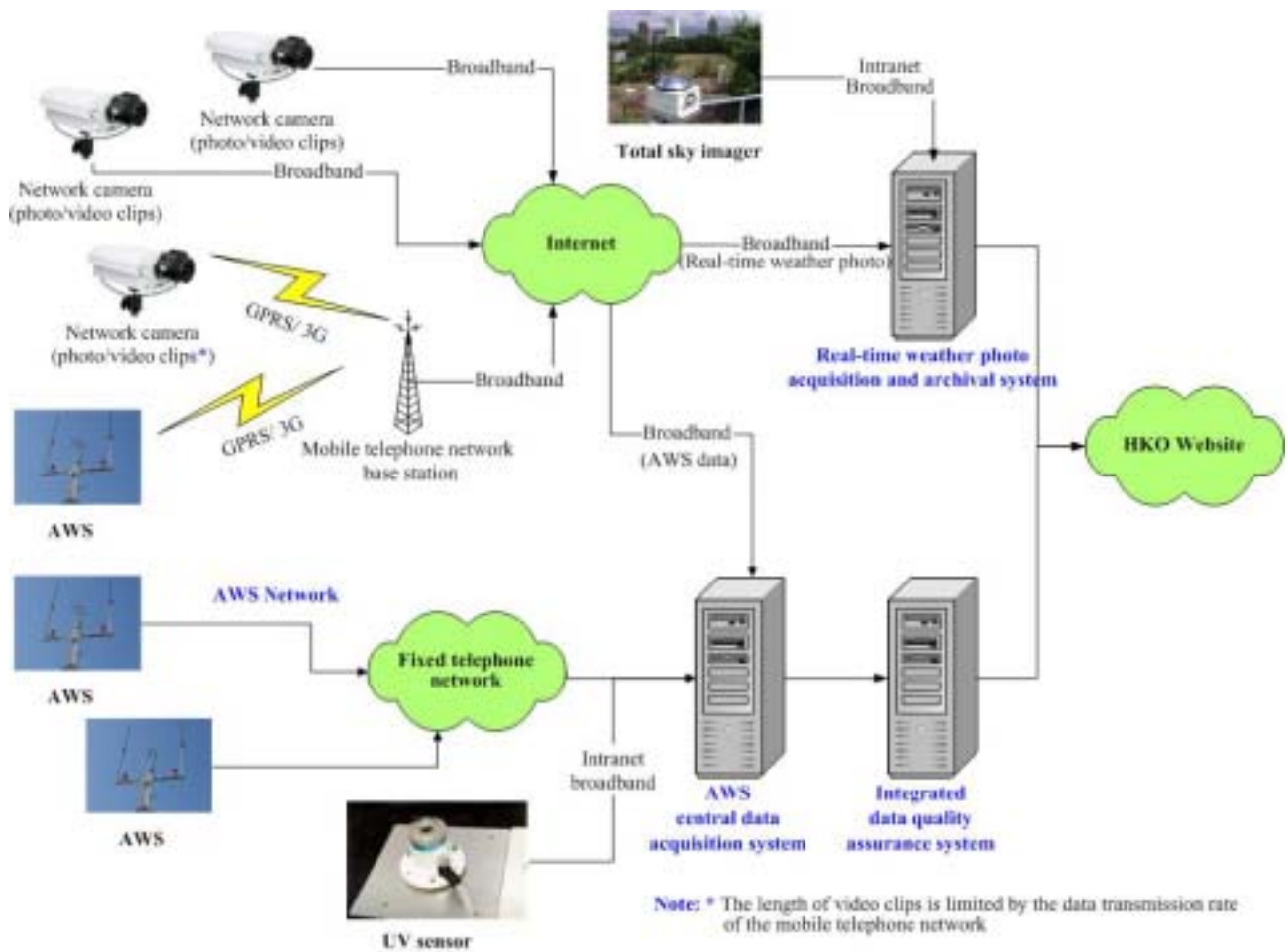


Figure 1: The technical set-up of the new Automatic Weather Station (AWS) System in Hong Kong



Figure 2(a): The total sky imager takes snapshot of the reflected sky from a convex mirror every 10 minutes. The snapshot is useful for observing clouds and assessing cloudiness during daytime.



Figure 2(b): Halo captured by the total sky imager on 7 May 2002.



Figure 3(a): Broadband UV sensor

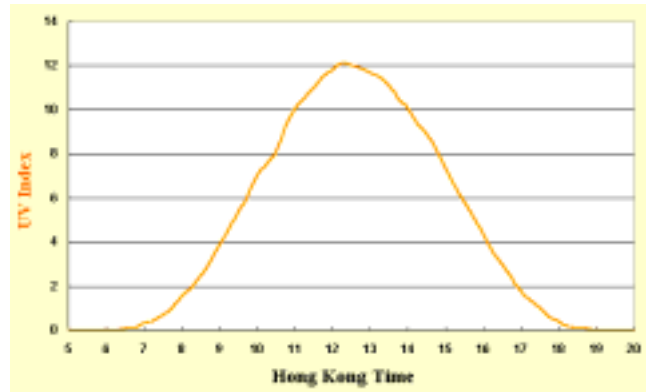
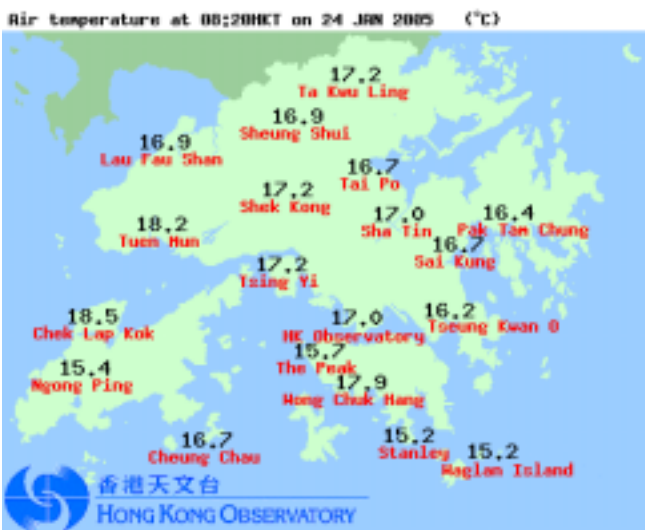


Figure 3(b): Time series of UV index on a hot summer day.



(a)



(b)

Figure 4: HKO's regional weather webpage showing distribution of (a) temperature, and (b) wind in Hong Kong

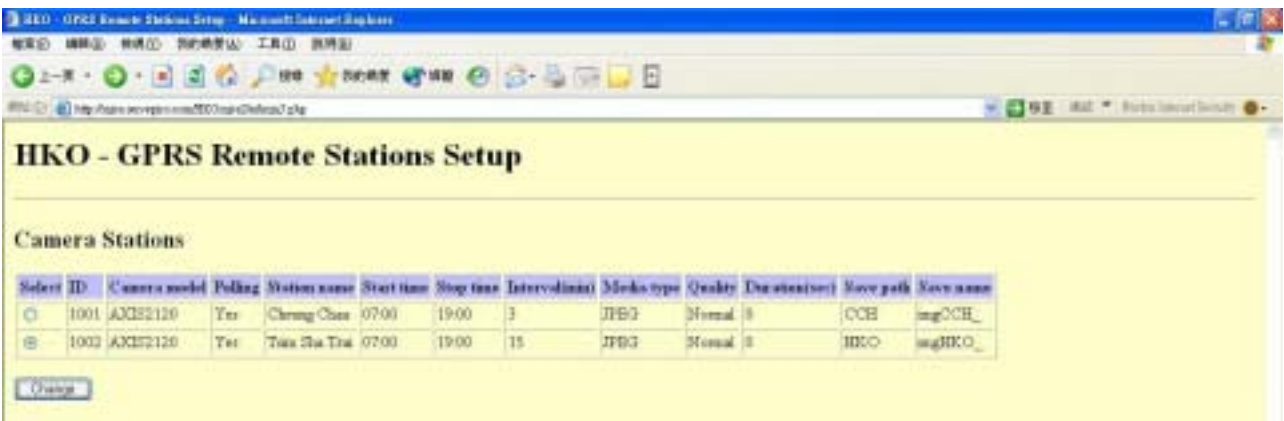


Figure 5: Network camera operation is remotely controlled via the Internet

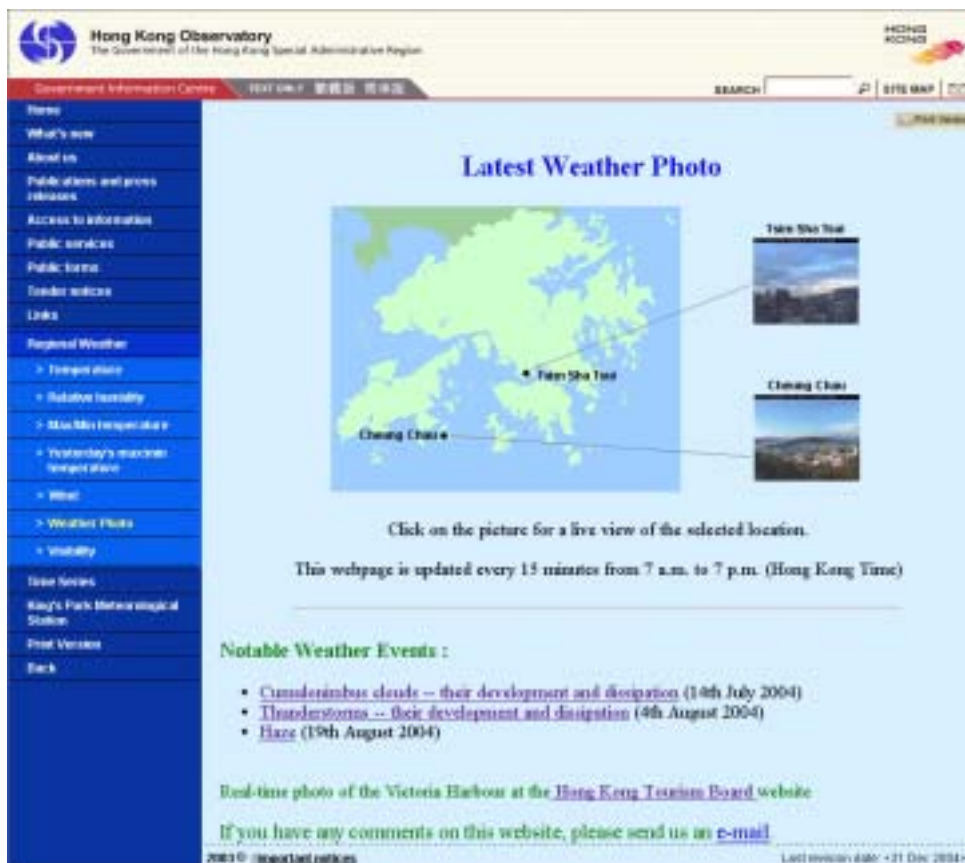


Figure 6(a): The “weather photo” webpage on the Hong Kong Observatory website



Figure 6(b): A downward link to the webpage in Figure 6(a), showing the latest weather photo at Cheung Chau, an outlying island in the south-western part of Hong Kong.



Figure 7: Haze captured by the network camera at Cheung Chau (left) and at the HKO Headquarters (right) on the morning of 19 August 2004. The visibility at Cheung Chau at the time was only about 1 km.



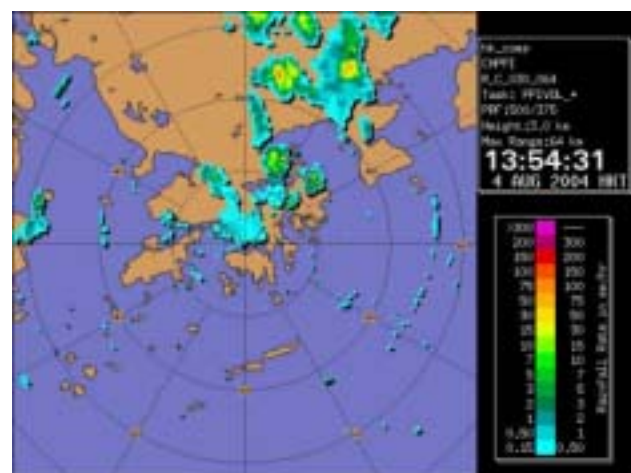
8.1(a)



8.1(b)



8.2(a)



8.2(b)

Figure 8: Simultaneous use of real-time weather photographs and radar pictures helps forecasters to closely monitor the development of strong convective weather and the movement of the convective clouds.



9.1



9.2



9.3



9.4

Figure 9: Development of cumulonimbus clouds over inland areas on the afternoon of 14 July 2004. The picture sequence helps the public understand such natural phenomenon in a direct manner.

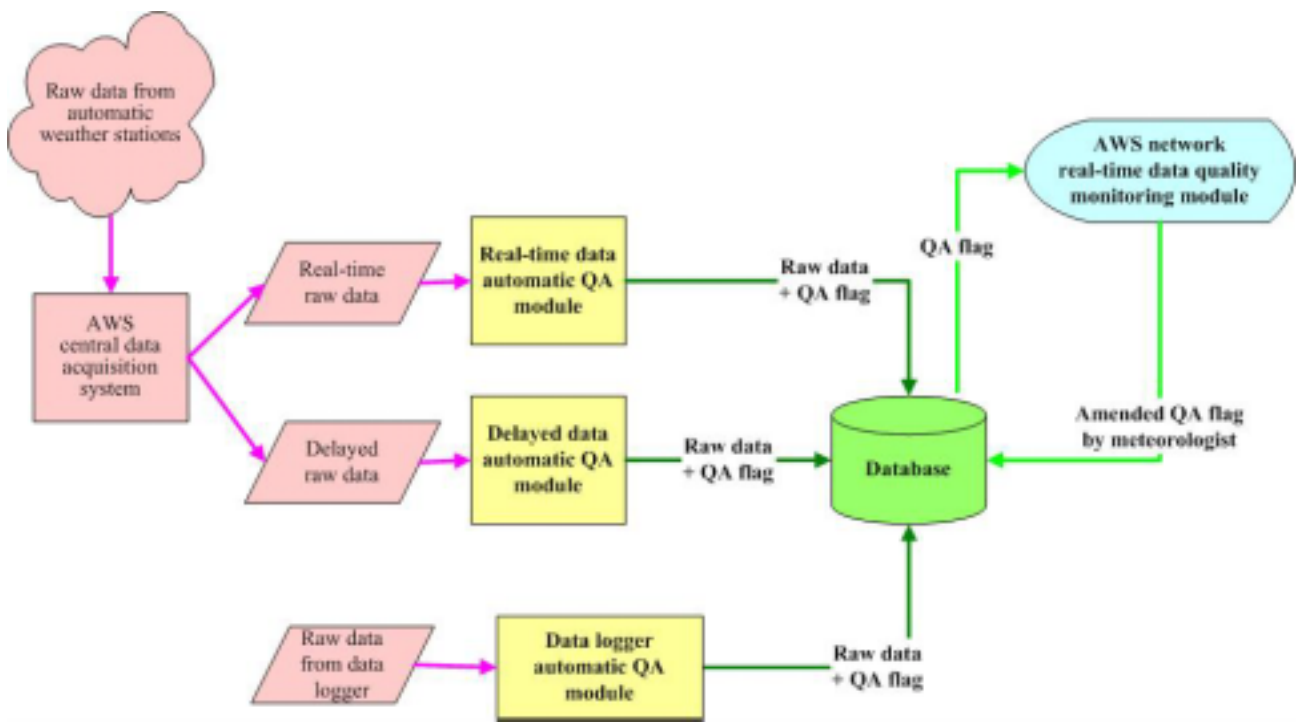


Figure 10: Data flow and processing by the integrated data quality assurance system

香港天文台
HONG KONG OBSERVATORY

Integrated Meteorological Data Quality Assurance System

Maintenance / Log System / Network Data Availability Manual QC

Regional Weather On The Internet

Data Last Updated : 2005-1-12 18:07

Station Name	Wind-Dir	Wind-Spd	Wind-Gust	T-Dry	T-Wet	RH	Pressure	Rainfall
CbeK Lap Kok (CLL)	/	/	/	✓ (100.0%)	✓ (100.0%)	✓ (100.0%)	⊖ (0.0%)	✓ (0.0%)
Cheung Chau (CCH)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (74.7%)
Ching Pak House (CPH)	✓ (100.0%)	✓ (100.0%)	✓ (100.0%)	✓ (100.0%)	✓ (100.0%)	✓ (100.0%)	/	✓ (100.0%)
HK Observatory (HKO)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (78.0%)
King's Park (KP)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (74.7%)
Lau Fau Shan (LFS)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (70.0%)
Ngong Ping (NGP)	✓ (07.0%)	✓ (07.0%)	✓ (07.0%)	✓ (07.0%)	/	/	/	/
Sai Kung (SKG)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	/	/
Sha Tin (SHA)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (74.7%)
Shek Kong (SEK)	✓ (100.0%)	✓ (100.0%)	✓ (100.0%)	✓ (100.0%)	/	✓ (100.0%)	✓ (100.0%)	✓ (00.0%)
Ta Kwu Ling (TKL)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (74.7%)
Tai Po (TPO)	/	/	/	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	/
Toeng Kwan O (TKO)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	/	✓ (74.7%)
Tuen Mun (TUN)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	✓ (00.0%)	/	✓ (00.0%)	/	/
Victoria Peak (VPI)	/	/	/	✓ (100.0%)	/	/	/	✓ (100.0%)
Waglan Island (WGL)	✓ (100.0%)	✓ (100.0%)	✓ (100.0%)	✓ (100.0%)	✓ (100.0%)	✓ (100.0%)	✓ (100.0%)	✓ (00.0%)

Figure 11: A typical display of real-time data quality monitoring of the AWS network

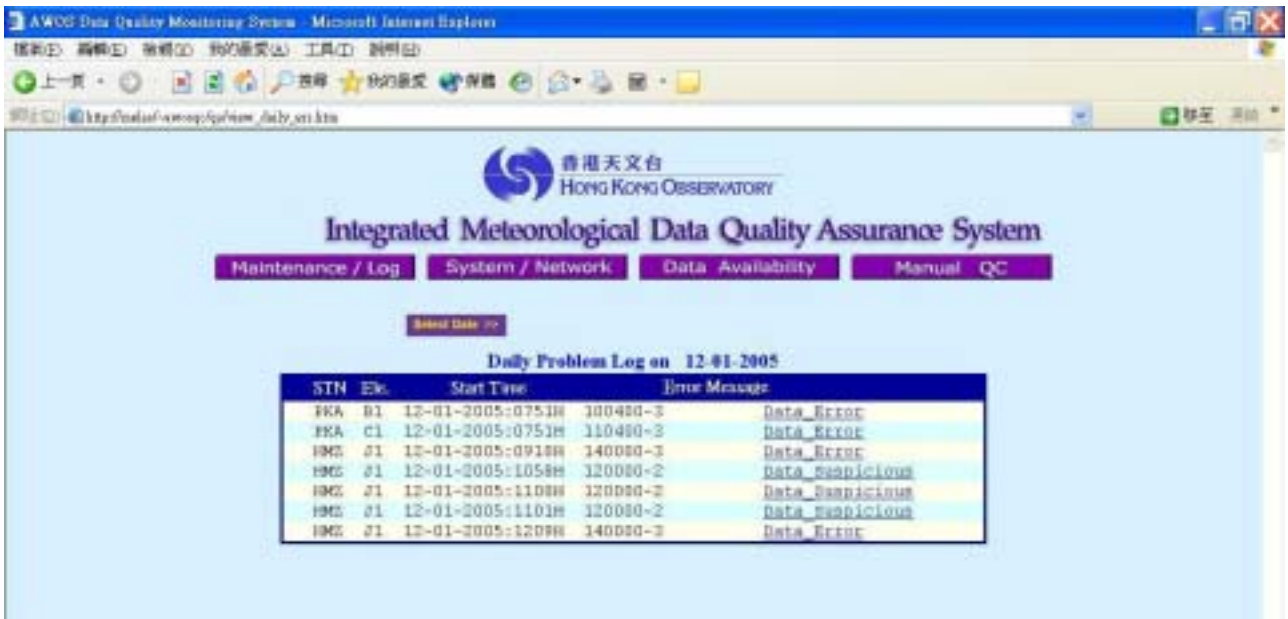


Figure 12: A typical error log generated by the integrated data quality assurance system. The fourth column shows the QA flags for the individual tests and the last digit is the composite QA flag for the data concerned. This webpage is updated once every 10 minutes.

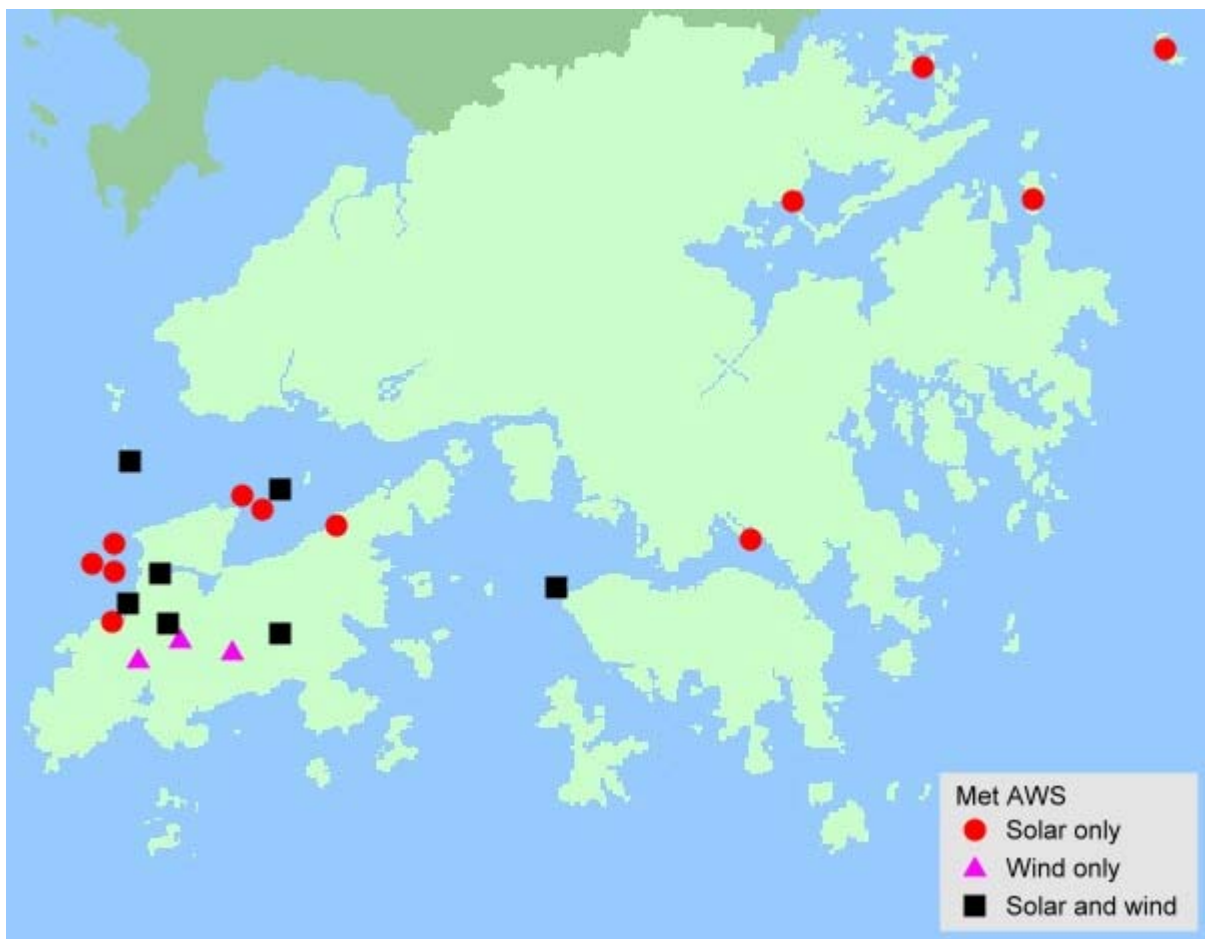


Figure 13: A map showing automatic weather stations utilising renewable energy in Hong Kong.

Character	Descriptions
E_nE_n	Weather element identifier (2 characters)
Q₁	QA flag value for range test (1 character)
Q₂	QA flag value for trend test (1 character)
Q₃	QA flag value reserved for persistence test (1 character)
Q₄	QA flag value for inter-senor consistency test (1 character)
Q₅	QA flag value reserved for spatial test (1 character)
Q₆	Reserved QA flag (1 character)
Q₇	Composite QA flag value based on the result of the various QA tests (1 character)
Q₈	Final QA flag assessed manually by meteorologist, if required (1 character)
vv	Auto-QC algorithm version number (2 characters).

Table 1: Format of QA flag - E_nE_nQ₁Q₂Q₃Q₄Q₅Q₆Q₇Q₈vv (12 characters)

QA Flag	Values and Meaning
Q₁, Q₂, Q₃, Q₄, Q₅, Q₆	0 – test not implemented 3 – warning (highly suspicious) 1 – passed auto-QC 4 – erroneous 2 – suspicious
Q₇	0 – auto-QC not implemented 3 – erroneous 1 – passed auto-QC 8 – instrument under maintenance 2 – suspicious 9 – data unavailable
Q₈	0 – QA flag not assessed by meteorologist (default); 1 – data confirmed correct by meteorologist; 3 – data confirmed erroneous by meteorologist.
vv	Version number, ranging from 01 to 99, refers to the particular set of QA algorithms implemented

Table 2: Meaning of QA Flags