Hong Kong's Enhanced Automatic Weather Station Network and its Further Outreach to Society

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Abstract

The Hong Kong Observatory (HKO) has recently enhanced its Automatic Weather Station (AWS) network in response to increasing demands for more comprehensive weather information from the public and overseas visitors. Apart from having a one-stop data quality assurance function to further improve efficiency, the AWS network is also incorporating additional sensors on top of conventional instruments. These sensors include those for heat stress and ultraviolet radiation, as well as network cameras which capture weather photos thus offering the possibility of monitoring the local visibility in real time. The addition of all these sensors is in line with requirements from a health-conscious public.

With heightened awareness towards weather and climate in the community, HKO has also stepped up its efforts to outreach to the public and the education sector. Apart from the co-operation between schools and HKO in establishing AWSs, there are more and more schools and organizations setting up weather stations of their own. Plan is in hand to integrate weather observations from these stations into HKO's weather information service, with quality labels to be tagged to the observations to reflect the degree to which they comply with observation standards. Such an approach is a cost-effective way to expand the weather coverage in Hong Kong. This paper presents HKO's development of a multi-functional AWS network and its strategy in incorporating observations from others into its overall weather information service.

1. Introduction

In recent years, meteorological services are faced with increasing demands for more comprehensive weather information from various sectors of the local community and overseas visitors. In a high-density urban setting like Hong Kong, there are additional challenges and constraints. The need for weather and geophysical information often exceeds that provided by a traditional Automatic Weather Station (AWS) network. Furthermore, to cope with the fast pace of life in Hong Kong and the variety of communication devices that the public is equipped with, there are requirements for high-resolution weather information, both spatially and temporally, captured and delivered in a timely manner through a number of fixed and mobile electronic devices. These demands not only pose a unique challenge but also provide an opportunity for the Observatory to

enhance advance its weather services.

2. Evolving new demands of the AWS network in Hong Kong

The development of a multi-functional AWS network by the Observatory is mainly driven by the requirements from users. These users include: weather forecasters; other government departments in such fields as civil engineering, drainage services, recreation and leisure, and public safety; special clients such as transport and bridge operators, container terminals; organizers of theme parks and sports organizations; and last but not the least, members of the public and tourists. Understanding the needs and demands of these multifarious users is crucial to the successful design and implementation of an AWS network.

2.1 The requirements

Apart from the conventional temperature, relative humidity, pressure and wind readings, new requirements for weather information from the public have emerged, including visibility, weather photos, weather stress indices, ultra-violet index, and environmental radiation levels. Different users have different requirements for the information but the following are some common characteristics they would like to have:

a. reliable and of high quality;
b. timely dissemination – latest data available to users in minutes;
c. available in a variety of communication channels – including radio, TV, PCs, mobile phones and computing devices;
d. user friendly for easy digestion;
e. location specific – high spatial resolution;
f. time specific – high temporal resolution; and
g. environmentally friendly.

3. Meeting user requirements

The following strategy and solutions have been adopted by the HKO:

a. explore the use of new sensors;
b. ensure reliable operation of AWSs with minimum down-time;
c. improve data quality and availability;
d. improve data transmission and reliability;
e. develop user friendly products for easy consumption by users;
f. improve product dissemination in a variety of formats and channels;
g. use renewable energy; and

h. expand the AWS network coverage within the confines of available resources.

3.1 Use and development of new sensors

In recent years, Hong Kong people are increasingly aware of the effects of weather on their well being, such as ultra-violet radiation and heat stress which have an important bearing on outdoor activities. Reduced visibility due to meteorological conditions as well as anthropogenic activities such as construction and industrial development is also a growing concern. To satisfy these needs, various new sensors have been incorporated into the AWS network by the Observatory over the past few years. Examples include:

a. sensors for ultra-violet index (UV Index);
b. real-time weather photos for the public and forecasters;
c. visibility meters;
d. wet bulb globe temperature (WBGT) for heat-stress monitoring; and
e. sensors for ambient radiation level, in connection with the operation of nuclear power plants some 50 km away.

Figure 1 shows WBGT measurement equipment recently developed by the Observatory to provide heat-stress information for the organizer of the 2008 Olympic and Paralympic Equestrian Events in Hong Kong for their planning of racing schedules. The equipment has already been implemented at three locations. The measurements obtained can also be used to provide, in real time, heat-stress information for people engaging in outdoor activities. The equipment, designed according to ISO 7243 specifications, is suitable for prolonged outdoor use. As its electronic components consume very low power, they are powered by batteries and solar panels. The data is transmitted via GPRS to a central computer, and the equipment can be easily installed due to its relatively small size.

To provide a direct view of the weather in real time to the public, tourists and transport operators, the Observatory has also enhanced its weather camera network, from 3 cameras in 2005 to 6 in 2006, to cover more popular tourist spots in Hong Kong, including the Victoria Harbour and the newly opened Wetland Park and Disneyland (Figure 2a). Well known places are also indicated to enable users to have an immediate assessment of the local visibility (Figure 2b).

Figure 3 shows the latest technical set-up of the Observatory's AWS network.

3.2 Reliable operation with minimum down-time

To ensure reliable operation with minimum down-time, the Observatory have installed redundant sensors, improved the power supplies, enhanced lightning protection, and implemented on-site data logging to ensure that all data including those for climatological purposes can be

recovered in the event of telecommunication failures.

To further improve the reliability of AWSs, the Observatory have achieved positive results in using sensors and equipment that operate on DC as far as possible and installing battery banks to isolate power surges which may occur in the city mains during thunderstorms. Adding surge filters also helps to protect the sensors, electronics and communication equipment from lightning damage. All the above measures, especially the installation of redundant sensors, entail additional cost and a balance has to be struck between cost effectiveness and reliability of operation.

3.3 Improved data quality and availability with real-time data quality assurance system

AWS data is received by a central data acquisition system which passes it on to downstream systems for processing and archival. The Observatory has developed a system to provide one-stop data quality assurance (QA) by carrying out quality control, in real time, of the data received by the central data acquisition system. The data flow and processing are summarised in Figure 4a. As the system is highly automatic, it serves to enhance efficiency and reduce the manpower required for quality control. The operation of the AWS network is monitored via a webpage which displays the status of each AWS in real time (Figure 4b). Through various real-time and non-real-time automatic data quality control processes, the system assigns a QA flag to each data received from an AWS, filters out erroneous data from the data stream, and alerts the maintenance staff to immediate remedial action via automatic emails (Figure 5). The advantage of this automatic alerting feature is that it enables early detection and diagnosis of faults, including those due to telecommunication failures, thus enhancing data quality and availability. Apart from monitoring the operation of the AWS network, the QA flags also facilitates reference by the users in future case studies and climatological research. Details of the QA algorithms are given in WMO (1996), and in Shaver *et al*. (2000), Tam *et al*. (2004) and (2005).

3.4 Improved data transmission and reliability – redundant communication paths and a higher bandwidth

Besides traditional land communication lines and radio links, public mobile data communication is now available at a reasonable cost and with a good spatial coverage, thus providing greater flexibility in the deployment of AWSs. For key stations, a redundant communication path can be accomplished through the combined use of land lines, radio links and public mobile data communication. This not only improves data transmission and reliability, but the higher bandwidth now available from public mobile data services such as GPRS and 3G also allows the transmission of more AWS data at a higher temporal resolution and makes possible the dissemination of graphics products of large file size, such as weather photos.

3.5 User-friendly products to meet user demands

To cater for the specific needs of various users of weather information, the Observatory has developed user-friendly products packaged in an easily digestible way. One such example is the provision of real-time weather photos on the Observatory website which enables the public and overseas visitors to assess the weather conditions at various popular tourist spots, so that they can plan their activities ahead. Animation of weather photos acquired over the past few hours is also available, as are some notable weather events of the past, which serves the purpose of public education. Rainfall information is now provided in an analyzed form through the use of coloured isohyets so that the public can easily appreciate the situation, especially during rainstorms. Figure 6a shows some user-friendly products on the Observatory website to cater for various needs. Figure 6b shows a recently developed display to alert people to the occurrence of strong, gale force winds or above anywhere in Hong Kong.

3.6 Improved product dissemination in a diversity of formats

With the increasing popularity of the Internet and the enhanced multi-media capability of mobile phones and portable devices, the Observatory has taken the opportunity to revolutionize its product dissemination means to take advantage of the latest technology. Comprehensive weather information is now delivered in text, images, video clips and voice files on the HKO website, as well as on mobile phones and PDAs through specially designed webpages, thus catering for all members of the public including the under-privileged (Figure 7).

3.7 Use of renewable energy and improved power supply

AWSs sited in remote areas with no city power supply should be designed to operate with instruments which work on DC and operate on low power. Normally, solar panels are used to power these AWSs. However, insufficient sunshine due to prolonged periods of overcast or rainy weather will occasionally result in inadequate power at the stations and thus more frequent service visits by the maintenance personnel. To enhance efficiency, a hybrid of solar panel and wind-powered generator has been deployed in some AWSs in Hong Kong. Experience indicates that the windy conditions which often accompany overcast weather complement the shortage of sunshine quite well. This way, the hybrid ensures a continuous supply of renewable energy. Moreover, as AWSs operating on renewable energy do not require city power, they are immune to power interruptions from the city mains and to damage by power surges caused by lightning. This has resulted in enhanced data availability (Figure 8) and reduced maintenance effort, as the down time due to failure of power supply has since decreased considerably. The use of renewable energy also contributes to environment conservation, as evidenced by good press coverage on the launch of the first AWS in the Victoria Harbour operating entirely on renewable energy (Figure 9).

4. Expanding the local weather coverage through cooperation with schools and other organizations

With heightened awareness of the community towards the weather and climate, the Observatory has stepped up efforts to reach out to the public and the education sector. Through the use of robust and inexpensive weather sensor packages, more and more schools and organizations in Hong Kong are setting up their own weather stations. It is to the advantage of the weather service to cooperate with them in order to extend the local weather coverage and to promote science education. While the instruments used and the exposure of the locations may not be fully compliant with the relevant WMO guidelines, they nevertheless still provide useful information to the community given the proper advice, training and assistance in the optimal siting, operation and maintenance of the instruments. Plan is in hand to integrate the weather measurements from school stations into HKO's weather information service, with quality labels to be tagged to the measurements to reflect the degree to which they comply with the relevant standards. The weather elements currently measured include: air temperature, relative humidity, rainfall and solar radiation. Other elements being contemplated include: ultraviolet radiation and negative ion. Figure 10 presents an overview of the cooperation so far, as well as a prototype webpage aimed at incorporating real-time weather measurements made at the schools and conveyed through the Internet, including a score of schools making up the Joint School Meteorological Network. Looking ahead, HKO is actively liaising with district authorities in the establishment of weather stations with a view to covering every district in Hong Kong.

The HKO has also recently cooperated with the tertiary sector in conducting a raingauge design competition among primary and secondary schools in Hong Kong. Talks, workshops and visits were arranged to familiarize the students with the basic principles and the considerations required to ensure accuracy and reliability when designing their rain gauges. The event proved to be very successful in arousing students' interest, as witnessed by their innovative designs (Figure 11) which take account of the dynamic and variable nature of rainfall. Similar activities will be arranged in the future, to give the students the opportunity to put theory into practice and to further weather education and enhance public preparedness towards natural disasters.

5. Discussion

Over the past few years, the AWS network in Hong Kong has gone through extensive development and improvement. New weather services giving the public more weather information, in quantity, in type and in detail, have been received very positively. The adoption of new technology in equipment and communication, as well as the automation of processes such as quality assurance, have resulted in less the efforts required for equipment maintenance and thus more manpower for equipment implementation and service development. These in turn have

empowered HKO to be more responsive to user needs. More importantly, they have enabled HKO to provide new services at no extra resources.

Looking ahead, a plan is in hand to add more sensors at various locations in Hong Kong, including WBGT equipment for heat-stress monitoring, UV monitors for protection against sunlight's harmful effects, and network cameras to allow real-time assessment of the weather conditions. These new sensors offer the opportunity for new weather services and products. For instance, images from network cameras can be usefully deployed in monitoring the atmospheric visibility and sea states, which have implications on the city's aesthetic quality and marine safety respectively. Plan is also in hand to expand cooperation with schools and organizations in the establishment of a 'community meteorological network' so as to enhance the weather coverage in Hong Kong and to further public education and disaster preparedness.

References

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3. Tam, K.H., B.Y. Lee and K.W. Chan, 2005: New automatic weather station system in Hong Kong featuring one-stop quality assurance, internet technology and renewable energy, WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation (TECO-2005), Bucharest, Romania, 4 -7 May 2005.

4. 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: Wet Bulb Globe Temperature (WBGT) equipment developed by the Hong Kong Observatory for heat-stress measurement

Figure 2a: The "weather photo" webpage on the Observatory website.

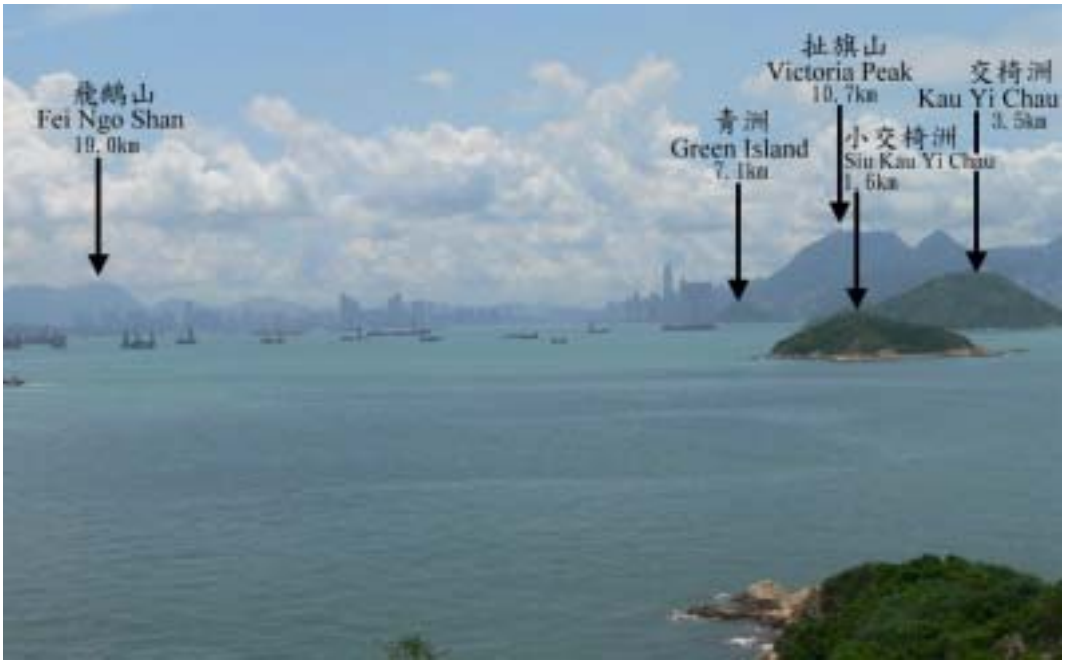


Figure 2b: Landmarks on the weather photos to help people monitor visibility in real time.

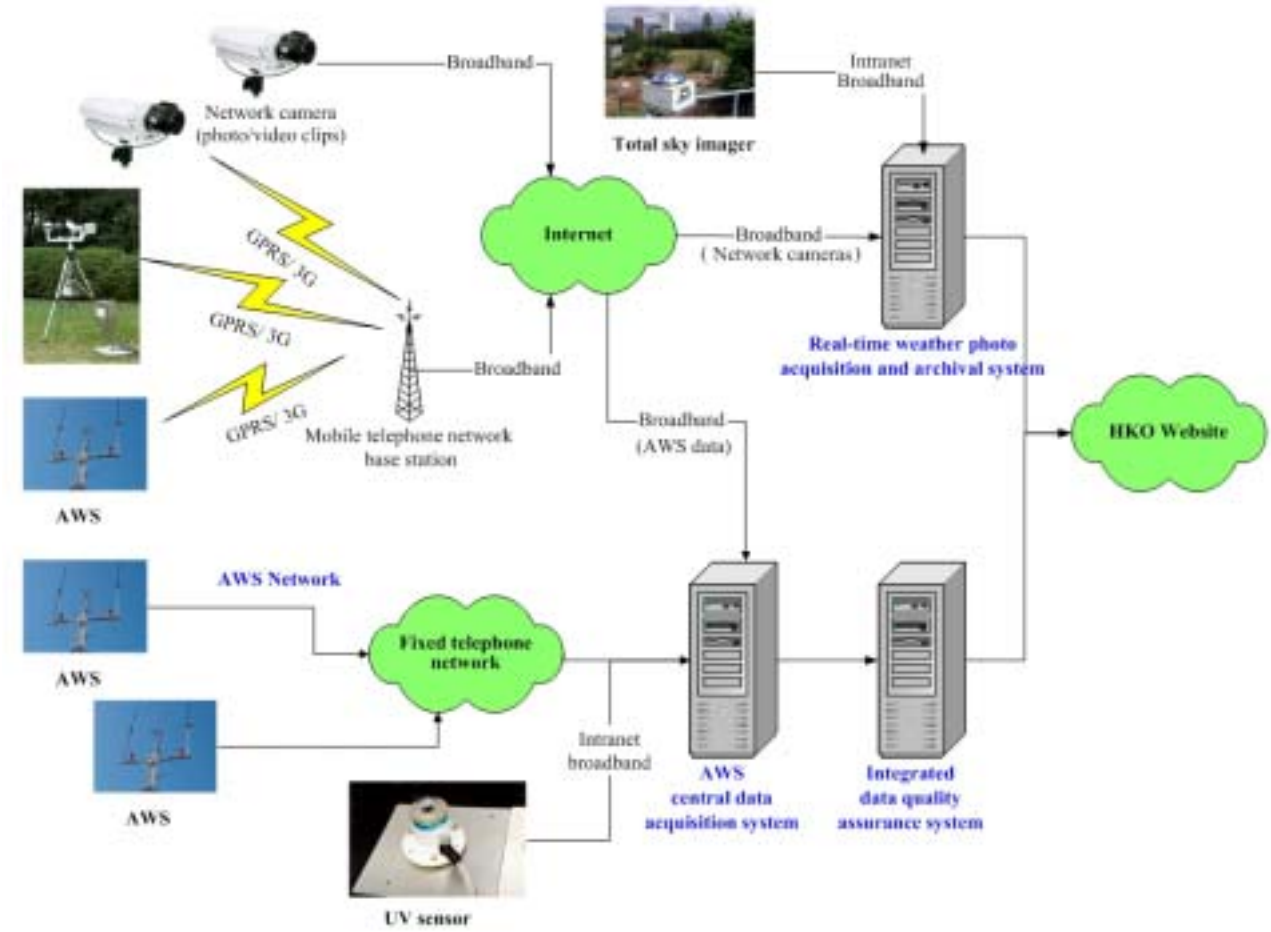


Figure 3: The technical set-up of the Automatic Weather Station Network in Hong Kong

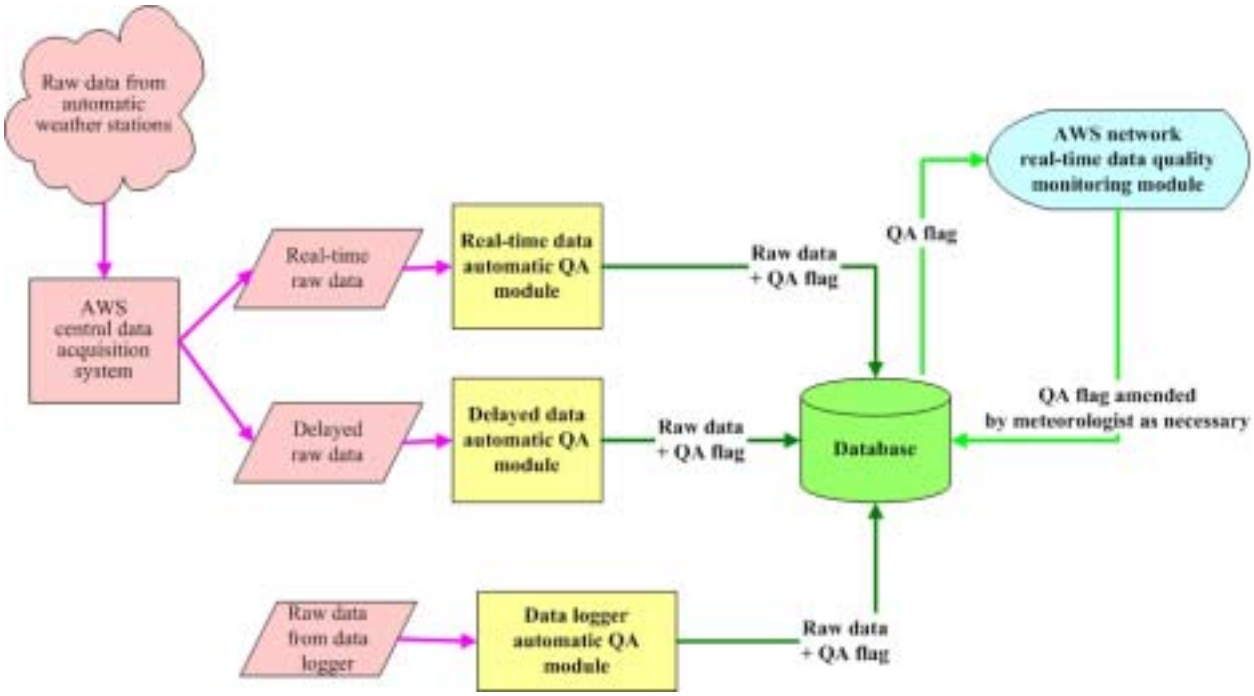
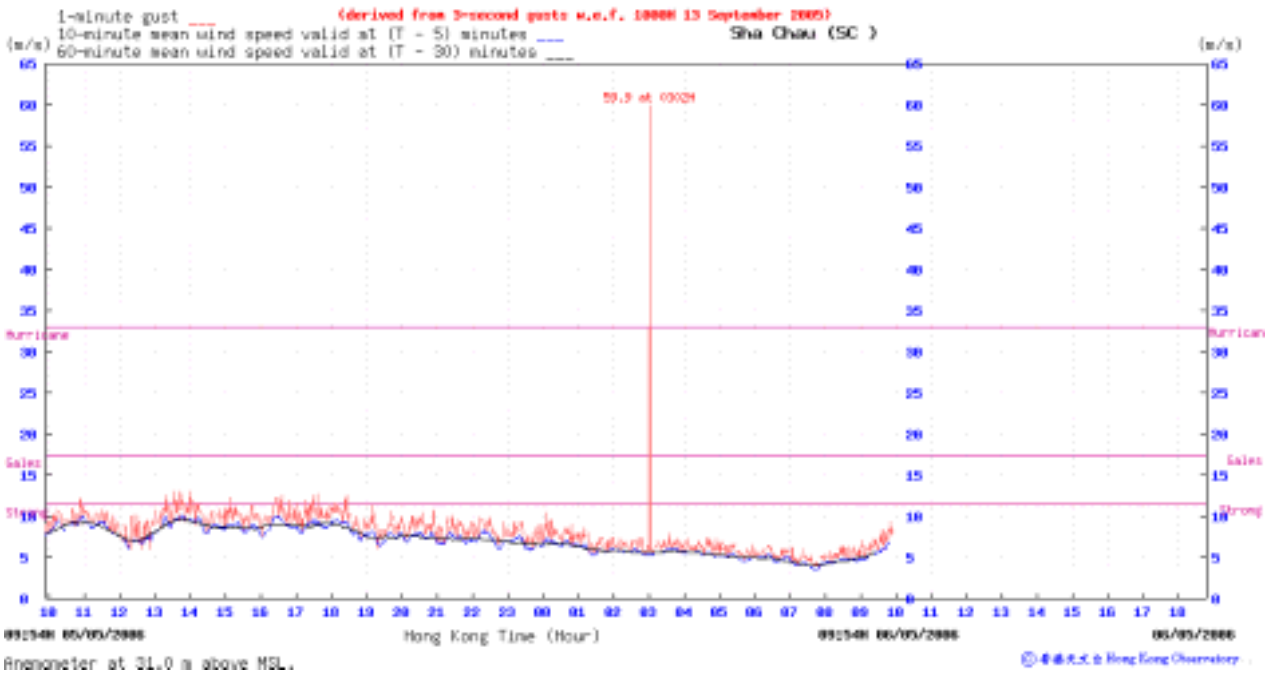
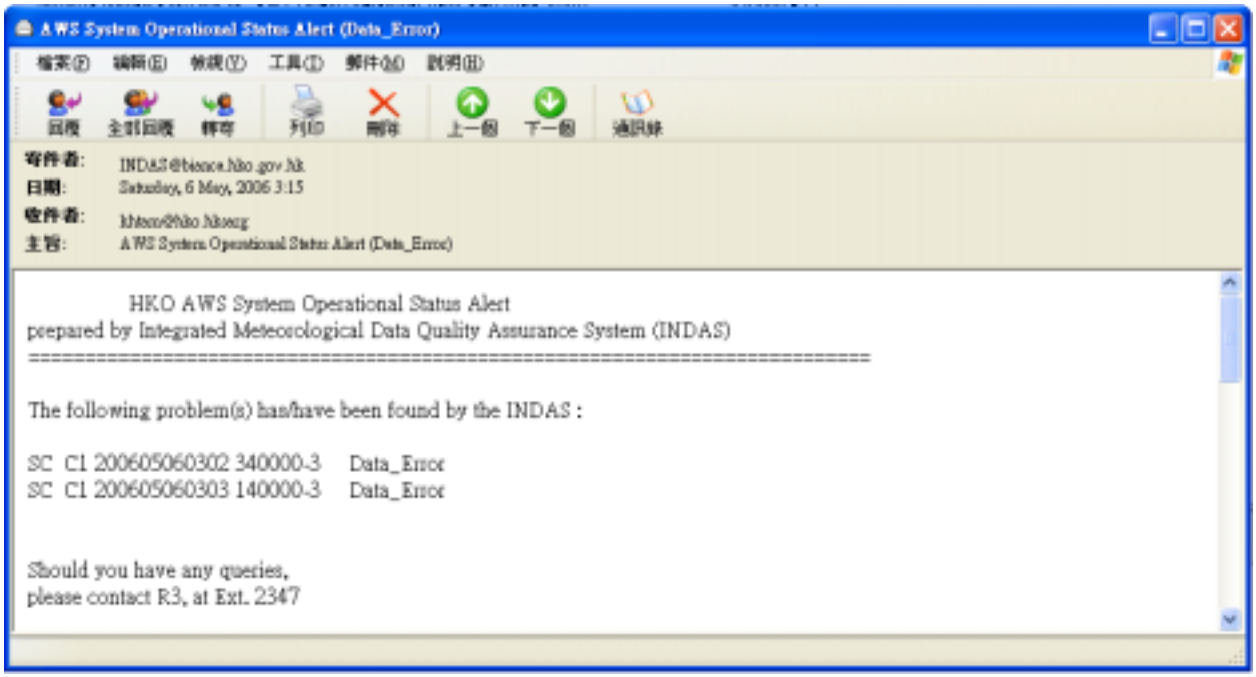


Figure 4a: Data flow and processing by the integrated AWS data quality assurance system.

Figure 4b: A typical display of real-time data quality monitoring of the AWS network.



(a)



(b)

Figure 5: A spike occurring in the wind record (a) was captured by the real-time data quality assurance program and an email (b) was automatically generated to alert maintenance staff for follow-up actions.

Figure 6a: Samples of user-friendly and well-packaged products shown on the Hong Kong Observatory website.

Figure 6b: A new product presented in an easily comprehensible manner to let people appreciate the wind distribution in Hong Kong, especially during the passage of tropical cyclones.

Figure 7: Disseminating weather products via a variety of channels and formats.

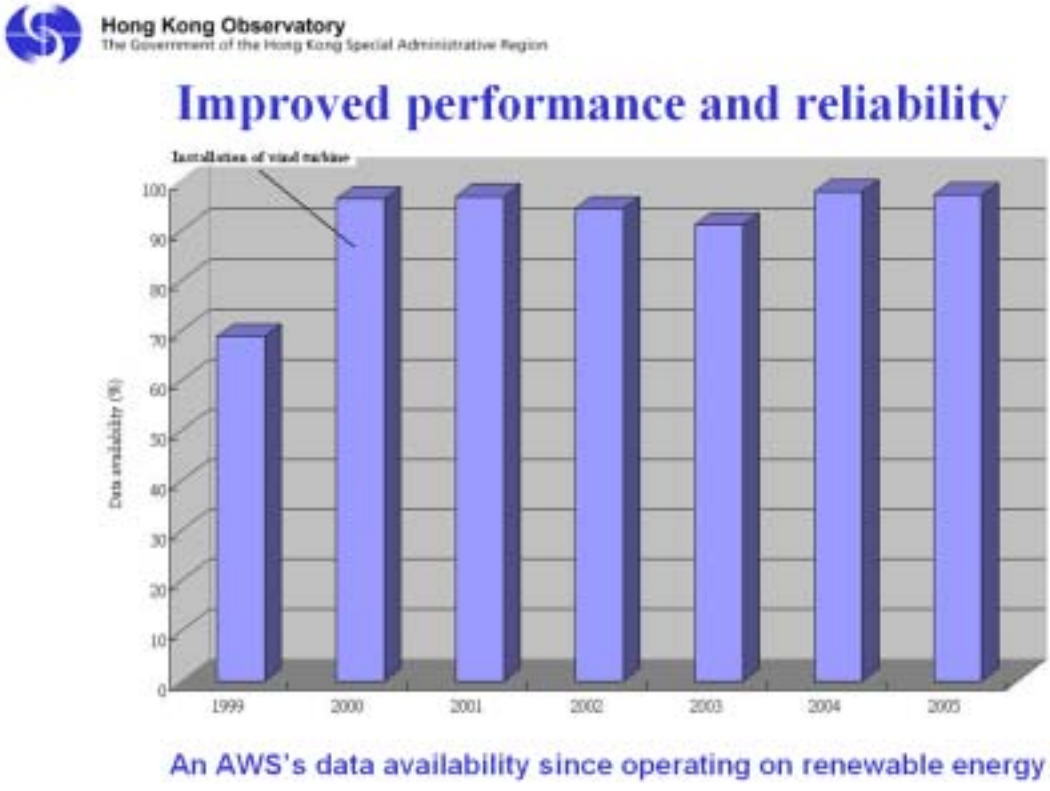


Figure 8: Improved performance and reliability of an AWS using renewable energy.

Figure 9: A press event organized by the Hong Kong Observatory in 2005. The use of renewable energy on the AWS on Green Island contributes to conserving the environment and projects a positive image for the Weather Service.

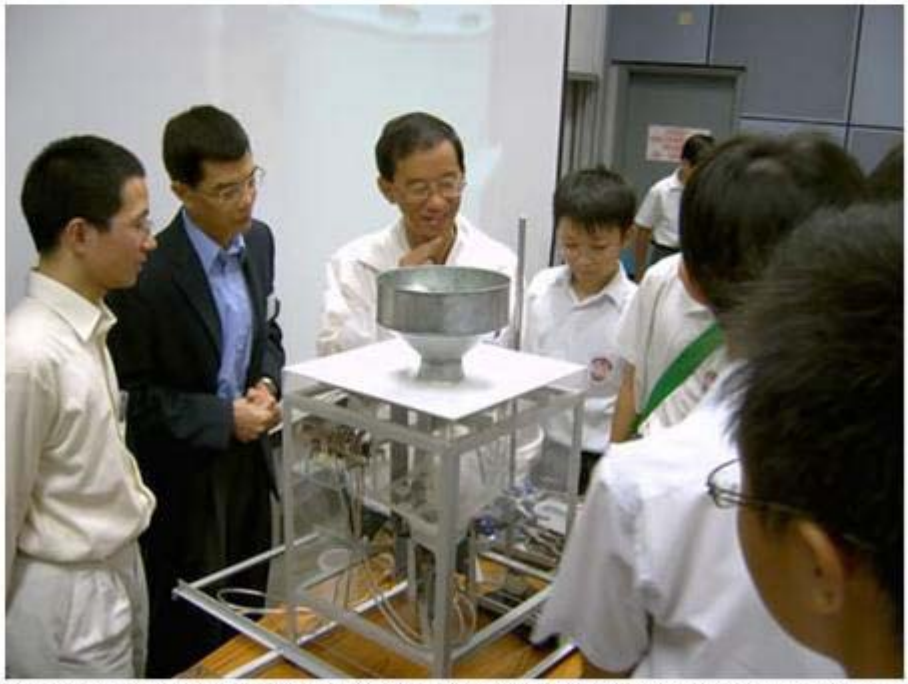
Figure 10: Cooperation with schools to expand the AWS network coverage:
(a) a school AWS;
(b) a typical school;
(c) a prototype school AWS webpage; and
(d) carrying out experiments with teachers.

HKO Side Lights

Students awarded for their innovative rain gauges

The first Rain Gauge Design Competition in Hong Kong, jointly organized by the Hong Kong Observatory and the Faculty of Engineering, the University of Hong Kong, was satisfactorily completed. The awards ceremony was held on 9 September at the University of Hong Kong.

Mr. C.Y. Lam, Director of the Hong Kong Observatory, greatly appreciated the effort and ideas of the students, in particular the rain gauge of the Senior Champion Team - Tin Shui Wai Government Secondary School. Their design ingeniously took account of the dynamic and variable nature of rainfall. The Champion of the Junior category was a team of primary five students from C.& M.A. Chui Chak Lam Memorial School. They were commended for their rigorous observations and one and a half month's worth of test data.



Mr. C.Y. Lam (third left), Director of the Hong Kong Observatory, and the judges - Dr. Y.S. Hung (second left), Department of Electrical & Electronic Engineering and Dr. C.L. Yip (leftmost), Department of Computer Science of the University of Hong Kong, appreciating the rain gauge of the Senior Champion Team.

Figure 11: A student raingauge design competition to outreach to schools and promote science education.