

# Meteorological services to aviation

by Chi Ming Shun<sup>1</sup>, Ian Lisk<sup>2</sup>, Carr McLeod<sup>3</sup> and Kevin L. Johnston<sup>4</sup>

## Introduction

Wilbur also requested and scrutinized US Weather Bureau data, and selected *Kitty Hawk* after writing to the government meteorologist stationed there.

Thus began a relationship between aviators and meteorologists in the lead-up to the first controlled powered flight by Wilbur and Orville Wright in 1903.

The next 50 years saw incredible advances in the technology of aviation and in the development of meteorology as a science. By the late 1930s, air travel between countries was becoming feasible. It rapidly became clear that support and standardization were needed to ensure the safe operation of international flights. The year 1944 saw the drafting of the Convention on International Civil Aviation (see box opposite, which was eventually ratified by a sufficient number of nations to come into effect in 1947.

Better known as the Chicago Convention, it created the International

Civil Aviation Organization (ICAO) as an agency of the United Nations and provided the mechanism for international agreement on all issues related to civil aviation. The Convention has 18 annexes establishing standards for areas such as air traffic control, navigation systems and communications systems. Important to meteorologists is Annex 3—Meteorological Service for International Air Navigation.

WMO became a specialized agency of the United Nations in 1951. ICAO and WMO soon established working arrangements that set out who does what when it comes to meteorological services to aviation. The relationship is conceptually simple: ICAO establishes the requirements for meteorological services to international aviation and WMO establishes how to meet these requirements and sets standards for service delivery.

The international aviation user organizations (the International Air Transport Association, the International Federation of Air Line Pilots' Associations, the European Regions Airline Association, etc.) communicate their needs to ICAO

and WMO works with National Meteorological Services (NMSs) to deliver these services. Since the responsibilities are shared, Annex 3 is duplicated mutatis mutandis as a WMO publication (WMO-No. 49, Volume II), approved by the WMO Executive Council. Amendments to ICAO Annex 3/WMO-No. 49 are introduced every three years and have to be approved by the Councils of ICAO and WMO. Fundamental changes, however, require deliberation by the conjoint sessions of the ICAO Meteorological Division and the WMO Commission for Aeronautical Meteorology (CAeM), with these conjoint sessions typically held once every decade.

For all NMSs, aviation is more than just another client requiring weather services. Part of the arrangements between aviation and meteorology is the well-established and internationally coordinated practice of cost recovery for services rendered. This can be a controversial issue, although the importance of serving aviation and recovering costs for those services should not be underestimated. In some cases, aviation provides up to 80 per cent of the budget of small NMSs, so the aviation client deserves to be well served.

As noted, the arrangements are simple in concept. What follows will help to show some of the complexities in the details of service to aviation and some emerging issues brought

1 Hong Kong Observatory, Hong Kong, China; vice-president, WMO Commission for Aeronautical Meteorology (CAeM)

2 Met Office, UK; Chair of the CAeM Expert Team on Education and Training

3 President, CAeM

4 US Federal Aviation Administration; Chair of the CAeM Expert Team on New Terminal Weather Forecast

# Preamble to the Convention on International Civil Aviation (the Chicago Convention) of 1947

**WHEREAS** the future development of international civil aviation can greatly help to create and preserve friendship and understanding among the nations and peoples of the world, yet its abuse can become a threat to the general security; and

**WHEREAS** it is desirable to avoid friction and to promote that cooperation between nations and peoples upon which the peace of the world depends;

**THEREFORE**, the undersigned governments having agreed on certain principles and arrangements in order that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically;

Have accordingly concluded this Convention to that end.

for managing the quality of any service delivered. Continuous improvement and development of the service to suit the evolving needs of the users are also key to the success of the NMS in an increasingly competitive global environment.

In many countries, liaison groups and industry forums have been established by weather services to foster the relationship with airlines, pilots, general aviation stakeholders, dispatchers and ramp operators. Apart from covering the standard services specified by ICAO Annex 3/ WMO-No. 49, close liaison with users can identify the user's need for customized and value-added services, driving further development of the local aviation weather information delivery (see box overleaf), as well as international developments of new aviation weather services.

about by changes in the aviation industry and advances in the science of meteorology.

## Client focus

### Civil Aviation Authorities

The national Civil Aviation Authority (CAA) or, in some cases, the air navigation service provider, is a primary user of weather services, ensuring efficient flight operations and aviation safety. Many NMSs are also designated as the meteorological authority and are thus responsible for regulating the provision of weather services for international air navigation. There is an increasing trend in some regions for the CAA or a similar authority to also take up the regulatory role for the weather service provision, as well as setting the level of service and the cost to be recovered by the NMS for delivery. In some other countries, the NMS, being the designated meteorological authority, enjoys a parallel and direct relationship with the other sectors of the aviation community, with service provision and cost recovery closely coordinated

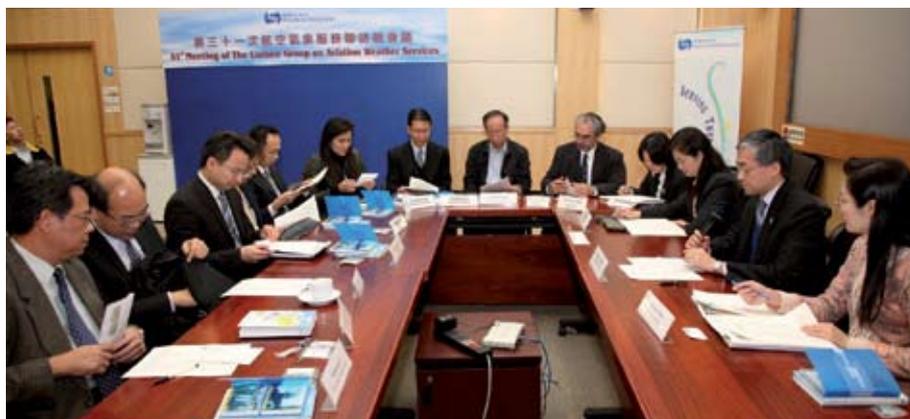
directly with the airlines and airport authorities. Irrespective of the model adopted, it is imperative for the NMS to establish close coordination arrangements with the CAA.

### Airlines and pilots

Being the end-users of the weather services for flight planning and operations, it goes without saying that the airlines and pilots should be the focus of user liaison for any NMS. Customer satisfaction surveys and users' feedback are essential drivers

## Evolving users

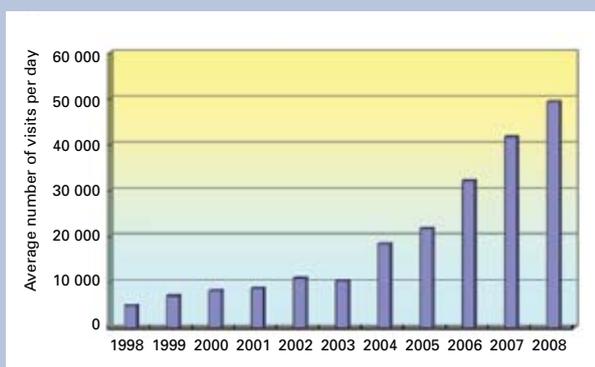
With the significant increase in air traffic over various regions in the past decade, demands for increasing consultations and new types of weather products (see "Developing services" above) by the airport management and air traffic management (ATM) stakeholders are increasing. This has become a critical issue for the major regional hubs in Europe, North America and Asia. Provision of added-value services to assist in decision-making and advance planning to mitigate the disruption of



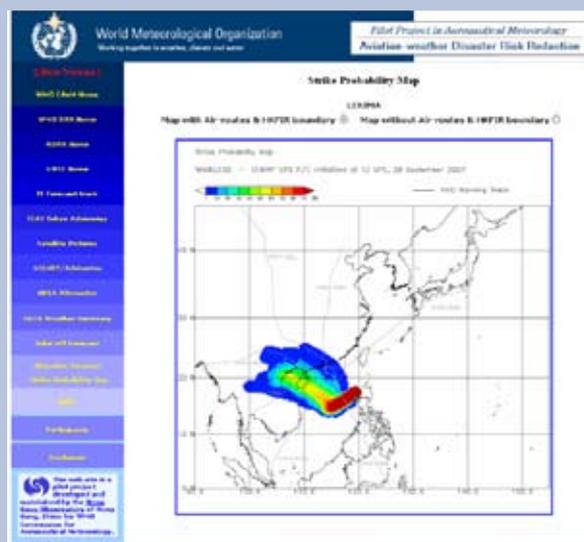
*Liaison groups and industry forums promote relationships with aviation users and gather important customer feedback.*

# Aviation Meteorological Information Dissemination System

The Aviation Meteorological Information Dissemination System (AMIDS), a Web-based information delivery system operated by the Hong Kong Observatory, China, for airlines, pilots, despatchers, ramp operators and general aviation, saw an almost 10-fold increase in usage in the past decade (see chart), during which air traffic volume increased by about 80 per cent. Apart from the introduction of ICAO-specified products, such as the digital forecasts of World Area Forecast System, the significant increase in aviation weather information usage was related to the demand by users for local weather information, such as weather radar, local winds and, more recently, lightning information and thunderstorm nowcasting products. AMIDS has also been developed into a platform for prototyping international demonstration projects and collecting user's feedback from the aviation community.



Aviation weather information usage in Hong Kong shows significant growth at a rate higher than air traffic growth.



Aviation-weather Disaster Risk Reduction pilot project Web page showing a probabilistic forecast of a tropical cyclone

operations by high-impact weather such as tropical cyclones, winter snowstorms and icing is increasingly welcomed by airlines, ATM and airport management.

## Current services

### Observations

Airfield weather observations (meteorological aerodrome reports) routinely provide aviation-critical weather information using the concise and easy-to-interpret METAR code format. Reports of significant changes in the weather that take place in between routine observations are also reported as Special Weather Reports in the SPECI code format. A two-hour forecast known as a "TREND" can also

be appended to METAR messages for selected aerodromes to indicate any significant changes expected in the two hours immediately following the time of the report.

METARs are produced by staff trained in accordance with WMO Aeronautical Meteorological Observer (AMO) guidelines. Most AMOs are meteorological support staff, although there has been an increasing tendency for this role to be fulfilled by Air Traffic Control (ATC) operations staff and, more recently, by technologically advanced automatic weather observing equipment.

METARs are supplemented by PIREP reports. These are pilot reports of the actual weather conditions encountered

by an aircraft-in-flight. A PIREP is usually generated when a potentially hazardous weather phenomenon is encountered, for example, severe aircraft icing, turbulence or wind shear.

METARs and PIREPs are used by meteorologists, pilots, Air Traffic Control staff and flight dispatchers for the purposes of monitoring, flight planning and safety.

### Forecasts

The aviation sector is a major meteorological customer and, historically, most of the developments made in forecasting have been for the improvement of meteorological



Volcanic Ash Advisory Centres, which form part of the International Airways Volcanic Watch, and six Tropical Cyclone Advisory Centres. These centres support the timely provision of SIGMETs of volcanic ash and tropical cyclones by the Meteorological Watch Offices.

Appropriate training and ongoing maintenance of skills and knowledge of personnel providing aviation weather services are facilitated by WMO through the CAEM Expert Team on Education and Training (<http://www.caem.wmo.int/moodle/>).

## Flight planning

ICAO, in coordination with WMO, has established the World Area Forecast System (WAFS) with two designated centres for providing specialist global aviation weather services. World Area Forecast Centre (WAFC) London and WAFC Washington are responsible for producing global aviation wind, temperature and significant weather forecasts in support of flight planning, mainly for flights above 24 000 feet. Equipped with satellite reception systems and/or access to Internet service, aerodrome meteorological offices are able to receive the WAFS digital forecast products for compilation of flight documents and provision of weather information to suit the requirements of airlines and flight crews in flight planning and operations.

Traditionally, aircrew received face-to-face briefings during which the forecaster would highlight any flight-safety issues expected during the proposed flight. In the light of economic constraints and logistical reasons, however, the norm has increasingly become for aircrew to self-brief using either Internet-based briefing services or using documentation retrieved from Web-based servers or sent via facsimile.

*Winter snowstorms bring disruptions to major airports every year.*

services to aviation. Advances in technology and aircraft design, together with the relentless drive for ever more efficient and safe operations, have resulted in a requirement for increasingly accurate, varied and customer-focused meteorological products and services, particularly for the first 36 hours of the forecast period.

Aeronautical Meteorological Forecasters are qualified and trained in accordance with WMO guidelines and the challenge that they face daily in weather monitoring and forecasting

is evident in the range and scope of the forecasts they produce. For example, an Aerodrome Meteorological Office forecaster will focus on aerodrome warnings and forecasts that are vital for flight safety, such as the Terminal Aerodrome Forecast (TAF). A Meteorological Watch Forecaster, meanwhile, has responsibilities for national and/or regional forecasts and for generating SIGMETs/AIRMETs for warning of hazardous en-route aviation weather.

ICAO, in coordination with WMO, has established nine designated



*A typical aerodrome meteorological observation system*



*Volcanic ash is a major hazard to aviation.*

## Telecommunications

Operational aeronautical meteorological data (OPMET), including METARs, TAFs and SIGMETs/AIRMETs, are disseminated in real-time over ICAO-approved regional and global telecommunication networks, such as the Aeronautical Fixed Telecommunications Network. The associated international coding protocols and formats are agreed between ICAO and WMO working groups.

WAFS products are disseminated by satellite as part of the dedicated ICAO Aeronautical Fixed Service, utilizing the United Kingdom's Satellite Distribution System (SADIS) and the US International Satellite Communications System. Increased use is also being made of the ICAO-approved SADIS, Internet-based ftp service.

## Advances in techniques and quality of services

In the past couple of decades, advances in remote-sensing and new observation techniques, including meteorological satellites, weather radars, lightning detection networks, aircraft observations (AMDAR) and numerical weather prediction (NWP) have offered great opportunities for enhancing weather services, especially for aviation. Using the example of automatic low-level wind shear alerting, the emergence of the Doppler Light Detection and Ranging (LIDAR) technology has made it feasible for weather services to detect hazardous wind shear induced by complex terrain under non-rainy conditions and issue alerts to aircraft automatically. This has gone a long way in enhancing aviation safety since the introduction of

anemometer-based wind shear detection systems in the 1970s and radar-based systems in the 1990s.

Another recent thrust of weather service development for aviation has also taken advantage of the availability of weather radar and lightning-detection networks and advanced nowcasting techniques for short-term prediction of thunderstorm movement, thus mitigating the impact of weather in disrupting air traffic management and airline operations at busy aviation hubs and airspace. Further discussion on this new terminal forecast development will follow in the next section.

The advances of NWP techniques and computational power have also brought significant benefits to the industry with the accuracy of predicted flight times achieving the order of minutes nowadays, thanks to the continuous reduction of the



*High-level SIGWX forecast from WAFS London*

upper-air wind forecast errors. With the increased availability of high-resolution NWP forecast products on global, regional and local scales, better support of air traffic management and flight operations, such as the introduction of airport approach sequencing and fuel-saving flight trajectories, can be expected.

## Developing services

To meet the needs of air traffic management to improve safety and efficiency of air traffic, a WMO Expert Team is working with ICAO to develop a new terminal forecast (NTF) product. It is envisaged that this product will provide forecasts of weather elements critical to aviation in the terminal area\* with much finer resolution in space (to include vertical domain) and time compared to traditional aviation products such as the terminal area forecast and various WAFS products.

The new terminal forecast will be produced in a digital, gridded format, initially being available as a Web-based graphic in the 2013 time frame. At this time, the product will include forecasts of convection, winds, low ceiling and visibility and winter weather. Further out in time (by about 2018), other elements important to aviation and the environment will be included, such as icing, turbulence, wake vortices, noise abatement and air quality. In addition, probabilistic attributes of the various weather elements will be included. The new terminal forecast will be a critical component to ongoing worldwide activities to develop future air traffic management systems such as NextGen and SESAR activities in the

\* The terminal area is defined as that portion of the airspace within the proximity of a controlled aerodrome within which arriving and departing aircraft are managed to provide separation, assurance, appropriate arrival spacing, appropriate departure spacing and final approach sequencing.



*Face-to-face briefings (above) are increasingly being replaced by self-briefings, using automated systems (below).*

USA and Europe, respectively. These future ATM systems will integrate weather information with aircraft and other operational information to provide pilots, dispatchers and controllers with a common operating picture that will increase efficiency and, at the same time, reduce the impact of aviation on the environment. Pilots' ability to receive the weather information, in both textual and graphical format, directly in the

cockpit by uplink will be particularly crucial in achieving this.

Several Members are involved in the development of the new terminal forecast and plans are being developed to prototype the first phase of the product in 2009-2010. A Website (<http://www.ntf.weather.gov.hk/>) has been developed to facilitate this development and evaluation of the prototypes by aviation users.

## Quality

A primary focus of the aviation industry is safe and economic operations and, in terms of the delivery of aviation weather services, this is underpinned by the quality of the products (and forecasts, in particular) provided.

An internationally recognized strategy to improve service delivery has been the implementation of a quality-management system (QMS). The adoption of a QMS approach to the delivery of aviation weather services has been on ICAO's agenda for several years and, more recently, that of WMO through its Intercommission Task Team on the Quality Management Framework.

ICAO and WMO standards and recommended practices for the delivery of aviation weather services will, with effect from 2010, call on States/Members to implement a properly organized quality system which should be in conformity with the International Organization for Standardization (ISO) 9000 series of quality assurance standards.

Although ISO certification requirement will likely remain a recommendation in 2010, there is already an intrinsic desire embedded in the majority of NMSs to continually improve the quality of the products and services it provides to the aviation industry. The aviation industry is highly regulated and adoption of a QMS framework and, in particular, the achievement of certification under the ISO 9001:2000 Quality Management Standard, therefore sits well within the aviation environment. WMO has been proactive in assisting Members' implement QMS through the sponsoring of several QMS seminars, publication of a selection of QMS guides (available at <http://www.wmo.int/pages/prog/www/QMF-Web/Documentation.html>), establishment of a QMS demonstration project in



*Schematic diagram of LIDAR wind shear alerting system*

the United Republic of Tanzania and also development of methodologies for forecast verification.

The adoption of QMS principles as a framework for the delivery of aviation weather services offers significant value-added benefits to NMSs and, in turn, to the aviation industry, not least because two of the key underlying principles are continual improvement and customer relations. For example, the systematic verification and evaluation of aviation forecasts provides a mechanism for the ongoing improvement of aviation service provision in terms of quality, timeliness and customer focus.

It is also of note that NMSs that have recently undergone an ICAO Universal Safety Oversight Audit Programme (USOAP) have found that their quality-management initiatives and in particular certification under ISO 9001:2000, have not only complemented the USOAP but assisted in ensuring their success in meeting the demands of these audits.

The adoption of a quality-management approach to the delivery of aviation

weather services has a positive impact on the NMS that translates into significant safety and economic benefits for the aviation industry.

## Challenges in the provision of aviation meteorological services

### Efficiency of services

Aviation has been feeling the effects of the economic and political crises and has become a focus of attention as an economic sector that is both contributing and exposed to all facets of climate change. Significant efforts to reduce costs within the airline industry have triggered demands for comparable measures on the side of service providers to aviation, from air traffic services, airports and ancillary services to aviation meteorology. NMSs thus have the difficult task of demonstrating that their net benefit in terms of reduced operating and planning costs, environmental impact and passenger/crew safety and comfort outweighs the cost they are



*Rapid air traffic growth in various regions in the past decade has increased the vulnerability of air traffic management to disruption by weather.*

charging to the industry, the taxpayers or any combination thereof.

As part of the air traffic services chain, NMSs are affected by a wide-spread trend to restructure airspace to larger units. They need to find their optimal “niche” between globalized products, e.g. those provided by WAFS, national and regional warning services such as SIGMET/AIRMET and low-level graphic products of significant weather, and the emerging aerodrome-oriented specialized products for such diverse questions as wake vortex predictions and dedicated warnings of lightning or snow/freezing precipitation, for which commercial providers are increasingly offering bespoke services.

The world of aeronautical meteorological service delivery is changing and many of the developing and smaller nations are finding it increasingly difficult to keep up with the pace of technology and change. In response to the relentless drive from the aviation customer to increase efficiency, some NMSs have opted to centralize their aviation forecast production, whilst others have preferred to retain their airport

meteorological offices in order to maintain close customer relations with air traffic management, airline, pilot and airport management users.

Three main strategies are employed by the WMO Aeronautical Meteorology Programme to assist Members in



*The ability of pilots to receive weather information uplinked to the cockpit will be crucial to achieving a common operating picture among all aviation stakeholders.*

adapting and responding to these changes:

- Coordinate the development of new ATM-oriented products and the exchange of know-how with all Members through the work of the Expert Team on the New Terminal Forecast (see section “Advances in techniques and quality of services” above);
- Develop jointly with the aviation community and ICAO ways to gather, use and disseminate meteorological information to minimize the burning of fuel, carbon dioxide output and contrails/cirrus generation to mitigate the effects of climate change;
- Ensure, through the work of dedicated expert teams, that Members have access to current training material and curricula to ensure proper qualification of staff, that they operate a recognized quality-management system, again by using snowballing and exchange of guidance and documentation, and that they have access to guidance on customer relations and consultation.

Flexibility will be key to continued service provision in an economic environment characterized by rapidly changing conditions. Fuel prices, emissions-trading schemes emerging in some regions and environmental restrictions at some airports all result in the need to maintain close liaison between all stakeholders so that services can be quickly adapted to changing constraints.

The traditional global consultation process on the basic requirements for services to aviation driven by ICAO in cooperation with IATA and WMO, involving many levels of decision-making bodies, may prove to be a little slow in responding to such rapid changes and will benefit from more informal additional arrangements for rapidly evolving requirements.

NMSs will also need to consider carefully which services they can offer themselves under a commercial agreement, and where specialized contractors from the private sector may be able to provide expertise and services in cooperation with the NMS. On the other hand, only global coordination will ensure that duplication of efforts is avoided,



*Thunderstorms are a major weather element that needs to be addressed by the new terminal forecast.*

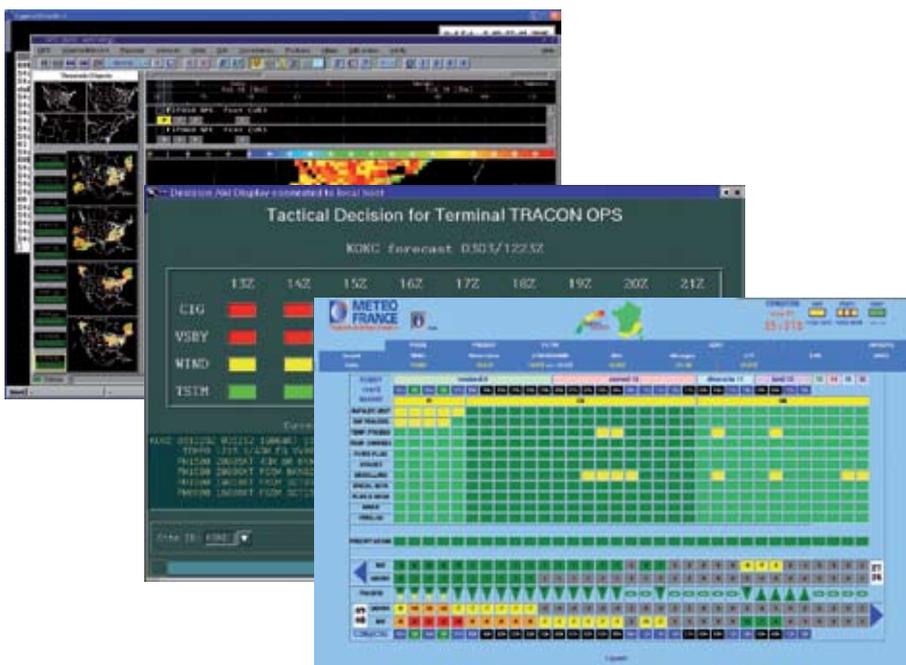
common standards are adhered to and grand plans are subjected to a reality check in all areas and at different levels of development!

### Regional and global cooperation in the provision of services to aviation

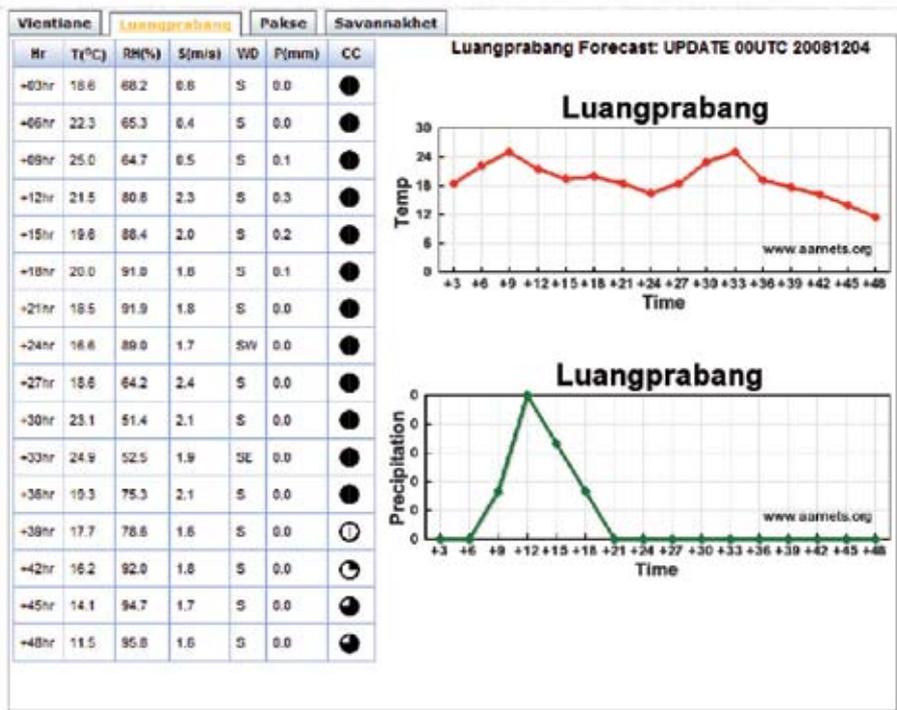
When it comes to efficient and effective delivery of services,

economies of scale are always to be considered a prime option. The development of new techniques involving complex and costly technology on a purely national basis may not bear economic scrutiny for many smaller and developing countries but, even for larger NMSs, cooperation with partners in the same region, a leading research and development institution or an industrial partner may be the best way to achieve results fast, affordably and compliant with international standards of quality and integrity.

Historically, regional air navigation service alliances such as Eurocontrol for western and central/south-eastern Europe or the Agency for Air Safety in Africa and Madagascar have driven enhanced cooperation in their area of influence, especially among providers of meteorological services. The challenge of congested air space has accelerated the integration of services across national boundaries or agencies and undertakings such as NextGen (Next Generation Air Transport System) in the USA or SESAR (Single European Sky ATM Research) in Europe are setting de facto standards in service delivery that will require other regions to collaborate closely if they do not wish to become marginalized by



*Prototype NTF products under development*



smaller and developing country Members can benefit from techniques and products generated on a regional basis for national applications (see sample product tailored for Lao People’s Democratic Republic to the left).

### Conclusion

The relationship between aviation and meteorology spans more than a century. Serving aviation was the single most important factor in the formation of NMSs. This long-standing and successful relationship is comfortable but perhaps consequently dangerous. Newer and fresher issues continue to grab the attention of decision-makers and bureaucrats. There is a need, however, to continue to focus on maintaining and continuously improving meteorological service to this important client.

TAF guidance for four Lao airports provided by the Asian Aviation Meteorology Website (<http://www.aamets.org/>)

such large regional blocks and see their traffic from and to such regions jeopardized.

NMSs are thus in the process of forming alliances and cooperation

agreements needed as “single voice of meteorology” in such regional undertakings, and laudable pilot projects such as the Asian Aviation Meteorology Website (<http://www.aamets.org/>) are examples of how