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User Requirements for the AO DM Framework

International AO Data Access and Display Requirements & Functions for Data Users

(Submitted by William R. Moninger, NOAA/ESRL/GSD and CIRES, and Stewart Taylor, E-AMDAR Technical Coordinator)

Summary and purpose of document

We summarize the current situation in relation to Aircraft Observation data access and display and define perceived issues.

We define the functions and requirements of Data Users for international AO data access and display, particularly taking into account the requirements and needs of developing nations.

ACTION PROPOSED

1. The Workshop is invited to note the information contained in the document.

1. Current Situation

1.a. Brief survey of existing access and display systems

Many systems worldwide have been developed to provide access to and display of Aircraft Observations. We present here a partial list of such systems, to give an idea of their capabilities and their breadth.

- The NOAA/ESRL/GSD AMDAR display system (http://amdar.noaa.gov/), while not an operational system (because it is based in a research laboratory and not operationally supported) has been available since 1994. It provides plan views and soundings of AMDAR observations, and a variety of quality control information based on differences between the AMDAR observations and background fields from various models. The data display is used by operational and research forecasters in the US, Canada, Denmark, Dubai, Finland, France, Spain, Peru, Romania, Russia, Serbia-Montenegro, South Africa, Switzerland, the E-AMDAR program, and others. The QC statistics on the site have been primarily used in the US, most notably by the WVSS and TAMDAR programs. The display software as been adapted by the Korean Meteorological Agency and AirDat, the private company that operates TAMDAR sensors.
- In Canada, AMDAR soundings (ascent and descent--wind and temperature) are displayed on the NinJo system used by operational forecasters.
- The Canadian Meteorological Center also has a data monitoring portal for multiple kinds of data including AMDAR at http://collaboration.cmc.ec.gc.ca/cmc/data_monitoring/ (restricted access).
- Both the Bureau of Meteorology in Australia and the UK Met Office use, among other tools, a commercial product called "Visual Weather" from IBL (http://www.iblsoft.com/products/visualweather) to display data, including AMDAR.
- Australia also uses a display system for wind profiler and AMDAR data written in java by a 3rd party developer, although this system is not currently widely used.
- Australia uses a third system for quick, near-real-time display of AMDAR data overlaid or overlayable with radiosonde and wind profiler data in a time series of vertical profiles for a selectable (upper air) location.
- E-AMDAR (the European AMDAR program) uses a system developed for them by the Deutsch Wetterdienst, http://eucos.dwd.de/eamdar (with restricted access). This provides primarily statistics on which airports have recent AMDAR soundings and also provides graphical displays of sounding data.
- The above system will soon be replaced by an improved display system that will provide plan views and profiles (soundings) of AMDAR data worldwide for E-AMDAR aircraft. This will also maintain report statistics, so that aircraft that fail to report as contracted can be easily identified. Longer-term reporting statistics will be available to administrators.
- The US National Weather Service displays AMDAR data (plan view and soundings) on the AWIPS workstations used by forecasters. This is an integrated workstation, which allows the AMDAR data to be shown in context with other data sources and model forecasts.
- Many National Meteorological Services (NMSs) in developed countries now have integrated workstations for operational forecasters that include AMDAR data along with model forecasts and other data sources such as radiosondes and profilers. These systems allow AMDAR data to be seen in meteorological context, but are not always optimized for the display of AMDAR data.

1.b. Unmet needs

Although many AO access and display systems are operational in multiple countries, there remain unmet needs that limit the impact of aircraft observations.

- The most effective systems for displaying AOs are often not integrated with other meteorological information. Single-purpose display systems are often not used optimally in a busy forecast office.
- Integrated display systems provide meteorological context, but often do not display AOs easily or effectively.
- Multiple systems are used by multiple NMSs. A unified system, such as that used in the E-AMDAR participating nations, might provide economies.
- Less-developed countries that have poor infrastructure and limited bandwidth often cannot use existing access and display systems.
- Most systems used by forecasters do not provide any quality control information, so the forecasters cannot use this information in making forecast judgments. For instance, temperature bias information, especially in cases in which an aircraft is not so biased as to be blacklisted, would be helpful to forecasters using aircraft soundings to estimate thunderstorm potential.
- Systems that do provide QC information are not generally available to forecasters.
- QC monitoring is decentralized and inconsistent between QC centers.
- Multiple downlink formats (FM42, BUFR, ASDAR,AIREP/ADS etc.) are not easily used; common distribution would be simpler.
- New airlines are less likely to become data providers if they don't see a way that their data could provide better forecasts in their areas of operation. If their NMS has no access and display system available, and if an appropriate display system isn't available to airlines directly, airlines will be unlikely to see it in their interest to participate.

2. A potentially improved system

In considering how to improve access and display systems, it is important to carefully identify the potential user classes, who may have different needs. These include

- Weather forecasters in high-infrastructure nations
- Weather forecasters in low-infrastructure nations
- Airline weather departments
- Airline dispatchers/operations
- Aircraft Observation data managers

2.a. Weather forecasters in high-infrastructure nations

As the survey in part 1 suggests, these weather forecasters are currently well-served. It is unlikely that any kind of new, internationally-centralized AMDAR display system would be adapted, because forecasters and their managers generally want integrated display systems, and have invested major resources into developing and deploying such systems.

On the other hand, these forecasters do not have ready access to aircraft QC information, and this information has been requested by those operational forecasters most familiar with AMDAR data. If a new AO data distribution format could be developed and implemented that included QC information, that would facilitate providing this information to forecasters. In this regard, we may want to consider centralizing QC operations; this is discussed in section 4.

2.b. Weather forecasters in low-infrastructure nations

It is difficult for those in developed nations to imagine the limited infrastructure available to airlines and NMSs in less-developed countries in the Middle East and Africa. Often only very limited (dial-up speed) internet service is available. Even power is only available some hours of the day at some locations. Repair services for computers and networks are often very limited. Nonetheless, we would like airlines in developing nations to participate in the AMDAR program for at least two reasons: 1) increased global AO coverage will improve global weather forecasts, to the benefit of all, 2) increased AO coverage will improve local forecasts in the countries that participate, providing local benefits.

AO access and display systems that require broad bandwidth are non-starters in the developed world. Also, systems that require major resources on the ground are not likely to be adapted. So, a careful balance between local and remote processing must be considered.

The most easily-used kind of AO display is probably aircraft soundings from local airports. If international infrastructure were in place, aircraft soundings could simply be faxed or emailed to local weather forecasters, and even trained airline dispatchers. (This is in fact what was done in the US in the early days of the AMDAR program.)

The management issues involved in even this, however, are non-trivial. It would require an international agency with the ability to 1) receive the AO data from the participating airline, 2) process the data into traditional sounding format (not a trivial task), and 3) send the soundings to the appropriate recipients in a timely manner (which requires maintaining an up-to-date list of recipients).

A solution that assumes slightly more infrastructure on the ground would be to develop a system that could display AO data distributed by satellite. Such a system, targeting African countries, was proposed in 2007 by NOAA/ESRL/GSD at the request of the then AMDAR Technical Coordinator. The system was not adapted at that time because the target countries could not justify the cost. Nonetheless, the proposal describes in some detail the issues that would need to be addressed in implementing a system that could be useful in low-infrastructure nations. The proposal in included in Appendix 1.

More recently, “cloud computing” is receiving increasing attention. It is possible--but by no means assured--that cloud based systems might allow countries with low infrastructure to display AO data. Cloud systems allow computing tasks to be uploaded to remote servers, and this has advantages in countries that have little compute power available. Simple displays could be developed that would not tax bandwidth limitations. However, most cloud-based systems currently available are very bandwidth intensive, and could not easily be adapted to low-bandwidth situations. Many discussions of cloud-based systems suggest that good connectivity is critical. However, one African entrepreneur suggests the cloud would allow continued data processing even when local power is unavailable, which could be a huge advantage. It is worth considering cloud-based solutions, while keeping in mind their many risks in a low-bandwidth environment.

2.c. Airline weather departments

Fewer and fewer airlines have airline weather departments. Those that still do are generally major airlines in developed countries. Their needs are similar to those of other weather forecasters in developed countries, which have been covered in 2.a. The airline forecasters, of course, have more focus on en-route and terminal weather and therefore can use tools that are more aircraft-centric than the general weather workstations used by NMS forecasters. Icing and turbulence information is of particular interest to these forecasters, and systems that can display these data are of great value.

2.d. Airline dispatchers/operations

For airlines that do not have weather departments, the task of gaining benefit from aircraft observations falls to the dispatch/operations department. Often, particularly in less-developed nations, dispatchers have some limited meteorological duties and training. Aircraft soundings can be of use in these situations; more detailed meteorological information may not be needed and may even be distracting. Finding the most appropriate products to use in situations in which airlines have limited meteorological expertise available will require working with the specific potential users of aircraft data display systems. Designing a system without such input is unlikely to be successful.

Another AO-related task that sometimes falls to dispatchers/operations is noting which aircraft fail to provide data, or provide erroneous data. The tools they need for this task are discussed in section 2.e.

2.e. Aircraft Observation Data Managers

Those who monitor AMDAR data for availability and quality need tools with quite different attributes than what is needed by weather forecasters. The tools must make it easy to identify mal-performing aircraft and provide information on the kind(s) of errors. Often long-term (days or weeks) statistics are used to reveal subtle errors. The needs for AO Data Managers are discussed in more detail in Document 6: AO Data Quality Management, Assessment of Current Practices and Recommendations for Improvement", so won't be discussed further here.

3. Technologies to leverage (with advantages/disadvantages of each)

3.a. "Cloud computing"

Cloud computing offers the opportunity to upload compute-intensive tasks to the "cloud"--servers maintained and operated by private companies such as Amazon and Google. In developed countries with good connectivity, it may be feasible to take advantage of this technology. On the other hand, AO processing in developed countries is currently performed by NMSs, which generally have very good access to compute power. The compute cycles needed to process, QC, distribute, and display AO data are so tiny compared to the cycles needed to perform NWP, that compute power is simply not a limitation as far as AO is concerned. Moreover, the traditional management style of most NMSs suggests that adapting cloud computing might be a hard sell.

For developing countries, cloud computing suffers from serious bandwidth limitations, but may offer some advantages in terms of reliability of data storage and "back-end" compute power. However, in general, developing countries will have to rely on AO data processing and distribution provided by organizations--either NMSs or other--in developed countries.

In summary we are dubious about the potential of this technology to make a major contribution to AO processing and display in the near future.

3.b. The Java programming language and Java applets

The NOAA/ESRL/GSD AMDAR display was an early application of a java applet. The display has been successfully used for over 15 years, suggesting that deploying java applets was a good choice. Indeed, the java display has been successfully adapted by other organizations without difficulty.

However, the newest web-based displays generally do not rely on java. In fact, Apple Computer, maker of iPads and iPhones, is hostile to java (as well as to flash). Thus, java applets do not operate on these platforms. Also, Google has chosen to adapt dhtml ("dynamic html", aka javascript, or html5) for their interactive web products such as Google maps.

This suggests that java may be near end-of-life as a display medium. (The java *language* on the other hand, as opposed to java *applets,* continues to be used widely for back-end data processing applications.)

New display systems should probably use dhtml or its equivalents rather than java.

3.c. Commercial systems

Commercial products provide the advantage of off-loading the development of processing and display systems from often overworked NMS staff. Moreover, the companies developing these products can leverage the needs of multiple forecast providers; if the potential base of users is large, companies can spend deeply to develop sophisticated systems.

The Bureau of Meteorology in Australia and the UK Met Office report positive experiences, for instance, with a commercial product called "Visual Weather" from IBL (http://www.iblsoft.com/products/visualweather).

These systems are likely to focus on a broad need, such as the display of weather data, rather than a narrow need, such as a portal to facilitate AO data management--there are many more weather forecasters than there are AO data managers.

Whether commercial systems can be usefully deployed depends more on the culture of the NMS than on the system itself, we believe.

Commercial systems that have a low-budget/low-connectivity option may be useful in developing nations that begin to participate in the AMDAR program. Whether a business case can be made for producing such a system for developing nations is an open question.

3.d. Open source software -- "google code" and similar systems

The open source approach, in which software is generally produced by a geographically-dispersed set of developers, has been very successful in the last 10-20 years in developing inexpensive (usually free) but substantial applications. Examples include the Mozilla Firefox browser, the MySQL database, the Linux operating system.

For systems not tightly integrated with forecaster workstations (and hence with individual NMS software), such as AMDAR data management and perhaps QC systems, the open source development model ought to be considered. At best, this model could result in internationally-sharable software that could be used by data managers in both developed and developing nations.

A positive aspect of this kind of development model is that AMDAR is in its essence an international program, benefiting NMSs and airlines world-wide. Information sharing among nations is already excellent; it would not be a big technical step to share code and code development.

A negative is that the open source culture is somewhat foreign to the culture of government agencies, such as NMSs. This is less true than it was 10 or 15 years ago, but may still be an issue. Whether resources could be made available to staff to develop systems that are not be under the direct control of the NMSs remains a question. WMO support could be critical here.

Another aspect of open source development is that it requires strong management so that development stays focused and projects don't bog down in mutual hostility or 'fork' into multiple, incompatible software versions.

4. How to implement an improved system

4.a. Centralized approach

A centralized approach might involve a central location (or a few) to 1) receive raw data as downlinked from aircraft, 2) remove obvious bad data 3)add some QC information to the remaining data, and 4) redistribute the data--probably over GTS. The central location might also provide a web-based data monitoring portal. It would probably not provide a centralized integrated forecaster workstation.

Advantages of a centralized approach are the following

- economies of scale
- easy to bring on new airlines--they know to whom to send their data
- common QC; a single reject list to be used worldwide
- Model-based QC could use a single model, providing more QC uniformity
- central source for answers to QC questions
- Some QC information could be distributed along with the data--something forecasters have asked for

Disadvantages are the following

- Broad buy-in needed
- Individual NMSs may not want to give up control
- Most NWP operators want to perform their own QC; in the past they have explicitly wanted access to un-QCd aircraft data
- Latency may increase, particularly for getting back to local airports (if the data have to go through a centralized QC process)
- Potential single point of failure (either data flow failure or QC judgment failure)

As a European-wide centralized system, E-AMDAR has been a notable success. This program is in a position to receive, QC, and redistribute data from less-developed countries worldwide. Whether their portfolio can be expanded to do this is a question that needs to be addressed. This program has already expanded their system to process IAGOS BUFR messages.

4.b. Decentralized/Incremental approach

Worldwide, a decentralized approach is the status-quo, and will certainly remain so unless new resources can be applied. That is likely to be difficult in the current economic climate. One can imagine that the E-AMDAR system might be *gradually* expanded to handle data from newly participating airlines based in less-developed countries, and assimilating those data into the existing E-AMDAR processing at relatively minimal expense. However, the E-AMDAR portfolio would have to be amended to allow this, which would require buy-in from the current nations participating in E-AMDAR.

The NOAA/ESRL/GSD proposal for a display system target to developing countries could be revisited. However, funds are not likely any more readily available now then they were in 2007.

It might be feasible to tax all the current AMDAR producing nations a small amount, and to use those funds to develop an open-sourced AO data management system that would include distribution of QC information along with the data, and a repository of longer-term QC information. The system could be operated with linked and redundant systems at the major AMDAR QC centers (NOAA, E-AMDAR, CMC, etc.). Developers would be comprised of staff at the major AMDAR centers, and other interested parties. Therefore management buy-in at those centers would be required. In this sense, this approach is like a centralized one. But the development and ultimate “ownership” of the resulting system would be decentralized.

5. Conclusion

Current Aircraft Observation data access and display systems do a very good job of making AO data available to forecasters and data managers in developed nations. Nonetheless there is room for improvement. These are detailed in section 1.b, and in brief are

- Quality control is not always consistent between nations
- QC information is not available to forecasters in real-time
- Few or no AO systems are available for use by nations that don't have good internet connectivity or other computer infrastructure.

We suggest several ways in which the situation might improved, and invite readers to consider these.

Appendix 1.

Proposed Statement of Work for a
Stand-alone AMDAR data ingest system and display
NOAA / Earth System Research Laboratory / Global Systems Division
2 November 2007

Background

The WMO AMDAR panel wishes to provide a mechanism by which all countries may display AMDAR data for use by government weather forecasters. Although many countries already have this capability, existing systems require high bandwidth connections to the internet. Many countries lack this infrastructure, and are therefore currently unable to display AMDAR data effectively.

For more than a decade the Global Systems Division (a branch of NOAA's Earth System Research Laboratory) has operated a system to process and display world-wide AMDAR data. The display part of this system is internet-based, and thus requires a broadband connection to work effectively.

In response to a request by the AMDAR Technical Coordinator, we have prepared this statement of the work required to adapt this display system, and its underlying processing, as a stand-alone system. AMDAR data would be received by a system external to the one we propose to build, and these data would be ingested by our system for decoding and display.

The initial customers for this system would be the ASECNA group of countries in Africa. We have been in touch with Dr. Diarra M'Piè, Director of the ASECNA Meteo Service, who has provided much helpful information about the target environment for the system.

In order to minimize costs, we plan to build a system that is as similar as practical to the one we run here.

Overview

We propose to build a system that has the following properties.

- It runs on the Windows XP operating system—required by ASECNA.
- The input is: raw AMDAR data in both FM-94 (BUFR) and FM-42 (text) format from a separate, but locally-networked, ingest system (probably ASECNA's "PUMA" or "SADIS" system). ASECNA is currently receiving text AMDAR data, and expects to start receiving BUFR data shortly.
- The decoding and processing software will be adapted from our existing software and will be written in the C and C++ programming languages.
- This software will use "Cygwin," a system that runs on Windows XP and provides many of the necessary libraries and subroutines expected by our software, which runs here at GSD under the linux operating system.
- The output is: an AMDAR display similar to that currently available on GSD's web-based AMDAR display (http://amdar.noaa.gov/java/).

Tasks

1. Create a stand-alone version of GSD's existing AMDAR data ingest system. This system reads raw AMDAR data in both FM-94 (BUFR) and FM-42 (text) format, and produces "raw" data files in netCDF format. The system is currently tightly embedded in a much larger data processing system, and will need to be detached and reconfigured as a stand-alone package. Also, it uses a locally

built, old, and inflexible BUFR decoding package that is no longer actively supported at GSD. We will therefore adapt a new BUFR decoder that is already running here at GSD for a separate application. The system uses the C and C++ computer languages.

- 1a. Create the stand-alone package and decode FM-42 (text) data.
- 1b. Add decoding of FM-94 (BUFR) data.

2. Acquire and set up a computer running Windows XP that is as similar as possible to the target machine(s) running at ASECNA as a “test-target”.

3. Install Cygwin on the test-target computer. This will allow us to port our linux-based decoding and quality control software to Windows XP with minimal difficulty. Cygwin is an open-source product, and available free. The cost covers staff time to install it and configure it appropriately.

4. Port the decoding package created in task 1 to the Cygwin environment.

5. Port GSD’s existing Quality-Control and reformatting code to the Cygwin environment. This software takes the raw netCDF files as input and outputs files in a special binary format expected by the java display software. This program is written in the C computer language.

6. Convert the GSD AMDAR java display applet into a stand-alone java program running on the test target computer. Add automatic data loading and refreshing.

7. Create a Windows-XP “install package” so that the package, consisting of
   - The decode software
   - The QC and reformatting software
   - The java display application can easily be installed on the target computer at ASECNA. We will automate the installation of Cygwin as much as possible, and provide appropriate instructions.

8. Have a member of the ASECNA technical staff visit GSD for two weeks for hands-on experience with the system.

9. Have a member of the GSD technical staff travel to an ASECNA office to help with the initial installation of the system. The installation would be supervised by the ASECNA staff member mentioned in Task 8.

10. Provide one year of technical support for the system by GSD. After one year, any necessary updates, for instance to decode new data types such as water vapor and turbulence, could be provided as funds become available.

11. Configuration and project management. Provide documentation, coordination, ongoing communication with ASECNA, deal with institutional budget issues, etc.

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