3.6

DEVELOPMENT OF THE CANADIAN AIRCRAFT METEOROLOGICAL DATA RELAY (AMDAR) PROGRAM AND PLANS FOR THE FUTURE

Gilles Fournier * and Stephen D. Holden **
Environment Canada, Canada

1. Introduction

Upper-air data are a critical input for numerical forecasting, climate and air quality models, and are important for weather forecasting and for validating satellite retrievals. There are a number of sources of upper-air data: radiosondes, satellites, ground-based weather radars, and wind profilers are currently operational upper-air observing systems. While automated aircraft reporting systems (such as AMDAR-capable aircraft), GPS Meteorology systems, aerosondes, dropwindsondes, ground-based doppler lidars, etc., are relatively new observing systems that are being developed and becoming operational. It must be noted that the AMDAR Program of the USA is called MDCRS (Meteorological Data Collection and Reporting System).

Currently, the core source of upper-air data is the global radiosonde network (www.wmo.int), which includes the Canadian radiosonde network operated by Environment Canada that currently consists of 31 regular radiosonde stations with balloon launches twice daily.

With the advances in weather modeling and computer capabilities, high resolution upper air observations are required, especially for mesoscale forecasting of high impact weather. Very cost effective automated meteorological observations from commercial aircraft are an excellent means of supplementing upper-air observations obtained by conventional systems such as radiosondes. According to the WMO AMDAR Reference Manual (2003), AMDAR systems have been available since the late 1970s when the first Aircraft to Satellite Data Relay (ASDAR) systems used specially installed processing hardware and satellite communications. Subsequently, by the mid-1980s, new operational AMDAR systems taking advantage of existing onboard sensors, processing power and airlines communications infrastructure were developed, requiring only the installation of specially developed software.

Today, Australia, New Zealand, South Africa, the European EUMETNET-AMDAR (E-AMDAR) group (UK, Netherlands, Germany, France, Sweden) and the US continue AMDAR operations with mature programs, and are improving and expanding them. Over the last 16 months, five new national programs have commenced routine operational reporting: Saudi Arabia, Hong Kong China, Japan, China, and Canada. These programs generate a daily exchange of over 180,000 observations on the Global Telecommunication System (GTS), with additional data (about 50,000 observations) generated by the US TAMDAR Great Lakes Fleet Experiment (www.airdat.com/tamdar/glfe.php), not yet exchanged on the GTS.

Countries that are developing or joining AMDAR programs include: Chile, Argentina, Finland, the Republic of Korea, United Arab Emirates, and the Russian Federation. Countries that are planning to develop or join AMDAR programs include: Oman, Egypt, Romania, Austria, Hungary, Czech Republic, Bulgaria, Ukraine, Spain, Iceland, Ireland, Brazil, India, Pakistan, Malaysia, and Mauritius. The European E-AMDAR Program is working with the ASECNA group of countries in central and west Africa, and with Madagascar to configure French aircraft that operate into most of the 15 countries. Data is already being provided for 2 non-ASECNA countries, Ghana and Nigeria. Additional data will also be provided over the southern Africa region by E-AMDAR under a special arrangement and Kenya has commenced discussions with E-AMDAR to provide additional targeted data. Australia has begun to investigate ways to provide targeted data in RA-V, including the South West Pacific area and Indonesia, and to assist with program planning and development.

In this paper, the development of the Canadian AMDAR Program will be described, issues encountered will be discussed, and plans for the future will be provided.

2. Historical Background

While the Canadian radiosonde network exceeds the World Meteorological Organization's (WMO) accuracy standards for aerological observations, it does not meet the recommendations for spatial and temporal coverage by upper-air land stations, and expanding the core network of radiosondes would not be cost-effective. As the best technology to provide such observations in the short-term and at relatively low risk is through the use of commercial aircraft, an operational AMDAR program is being developed in Canada and forms a cornerstone of the modernization of the Canadian Upper Air Observing Program.

* Corresponding author address: Gilles Fournier, Senior Environmental Monitoring Scientist, Atmospheric Monitoring and Water Survey Directorate, Meteorological Service of Canada, 373 Sussex Drive, Block E-124, Ottawa, Ontario, Canada K1A 0H3

** Corresponding speaker address: Stephen D. Holden, Upper Air, Lightning and Aviation Network Division, Atmospheric Monitoring and Water Survey Directorate, Meteorological Service of Canada, 4905 Dufferin St, Downsview, Ontario, Canada M3H 5T4

After a Business Case on the benefits of a Canadian AMDAR Program was presented to the Canadian air carriers in March 2000 (SYPHER: MUELLER International Inc. and Enviromet International Inc., 2000), the Meteorological Service of Canada (MSC) formed the Canadian AMDAR Program Implementation Team (CAPIT) to oversee all aspects of the development of the Canadian AMDAR Program. CAPIT membership includes NAV CANADA, Canadian air carriers (Air Canada Jazz, First Air, WestJet, Air Canada, some air carriers clients of AeroMechanical Services Ltd.), a representative from the US MDCRS Program, and the Technical Coordinator of the WMO AMDAR Panel. CAPIT is chaired by MSC.

While the AMDAR programs of the world started with the large national airlines that were operating systems already suited for AMDAR, Canada had to adopt a very different strategy as its main national airline, Air Canada, was restructuring, WestJet was concentrating on its business growth, and little of ARINC / SITA VHF networks extended north of 60N latitude. Thus Canada had to start the development of its national AMDAR Program using regional air carriers, having to deal with older aircraft, avionics and sensors, and no datalink in place. In that sense Canada has been breaking grounds in the development of an AMDAR Program involving regional air carriers. On the other hand, regional air carriers service much more communities than national airlines, fly shorter legs thus execute more ascents and descents in a day, and operate in the lower atmosphere where weather is occurring and largely over data sparse areas.

The approach taken with the airlines in Canada has been to present them with the benefits of AMDAR and to link the development of AMDAR systems to their operational interests as much as possible. Normally the airlines are interested in obtaining the following:

- better weather information and forecasts
- an aircraft system/sensor performance monitoring service
- enrolment in national Flight Data Management (FDM) Programs (FOQA in the US)
- movement messages OOOI (Out, Off, On, In)
- aircraft tracking (GPS positions)
- limited text messaging from cockpit

Then, the next step is to find out what datalink system is considered by an airline, never try to impose a system, rather adapt to it. Finally a partnership association for the development of an AMDAR system is developed, leading to an agreement for long-term provision of AMDAR data by the airline generally on a cost-recovery basis.

3. AMDAR Development with Air Canada Jazz

Air Canada Jazz (www.flyjazz.ca) is the largest regional air carrier of Canada. In early 2000, Air Nova, which was later amalgamated with three other regional air carriers to form Air Canada Jazz, began the development of a datalink program based on Aircraft Communication Addressing and Reporting System (ACARS) for the management of its fleet of DHC-8 100 aircraft. It was then timely to approach Air Nova with a request to investigate the possibility to implement an AMDAR capability using the Canadian AMDAR specifications. The Canadian AMDAR specifications are based on ARINC 620 Supplement 4, with version 3 for ascent and version 2 for descent and en-route data (www.arinc.com).

The work started promptly with the development of the Canadian AMDAR specifications into Universal Avionics Systems Corporation's (UASC) UniLink, the avionics of the Air Canada Jazz' DHC-8 aircraft. The first aircraft loaded with the datalink system began reporting in the fall of 2001 but, unfortunately, the data received at the Canadian Meteorological Centre (CMC) could not meet all AMDAR requirements because the system could not handle the analog nature of the DHC-8 100 model. As the problem could be partly resolved through software, UASC was subsequently contracted to upgrade the UniLink software and first data were received by CMC in mid-June 2002.

AMDAR data (pressure, temperature, and wind speed and direction) were reported to CMC from 21 DHC-8 100 aircraft servicing eastern Canada through the Aeronautical Fixed Telecommunication Network (AFTN) operated by NAV CANADA. Meanwhile, CGP Associates Ltd., a company from UK that had developed the European EUMETNET – AMDAR Data Acquisition System (E-ADAS) was contracted to develop the Canadian – ADAS (C-ADAS). C-ADAS has been operational at CMC since mid-July 2002 for real time acquisition of the Canadian AMDAR data, data format handling and transformation, and basic quality control.

Figure 3.1 presents the current architecture of the AMDAR system that was developed with Air Canada Jazz. It can be noted from this figure that CMC receives the data directly from Air Canada Jazz and that there is provision for a feedback mechanism between CMC and the airline.

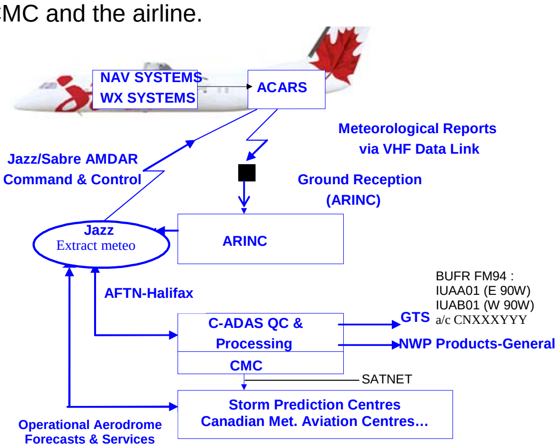

Figure 3.1 Schematic of the AMDAR data flow for the component of the Canadian AMDAR Program being developed with Air Canada Jazz

CMC had been evaluating the Canadian AMDAR data to make sure they were of adequate quality before assimilating them in the Canadian Numerical Weather Prediction (NWP) models and making them available to the world through GTS. Unfortunately, since the beginning of data acquisition, an unacceptable positive temperature bias of 2-4C had been observed with the Canadian data generated by the 21 original DHC-8 100 aircraft (Figure 3.2). The same type of temperature bias was also observed by the European E-AMDAR Program with DHC-8 Q400 aircraft operated by SAS (Scandinavia) before they were blacklisted.

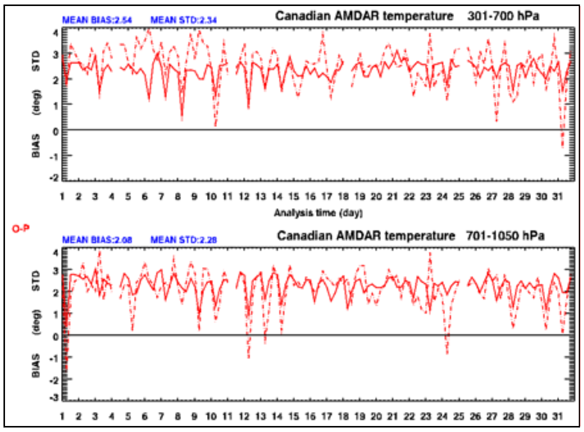

Figure 3.2 Observed minus first guess statistics for the Canadian AMDAR temperature in August 2002. A mean bias of +2.54C was observed between 301-700 hPa (upper graphic), and +2.08C between 701-1050 hPa (lower graphic).

A deeper investigation pointed to compounded sources for this issue:

- the type of OEM temperature probe of the DHC-8 aircraft that is flat, i.e. the OEM sensor does not protrude into the airstream, and
- the location-exposure of the sensor that is flashed mounted under the wing root of the aircraft

The DHC-8-100, -200, -300, and Q400 aircraft are equipped with a Norwich Aero Model 103-00034 Static Air Temperature sensor. This sensor is a dual bulb design, such that one sensor is tied to Air Data Computer (ADC) #1 and the other one to ADC #2. Because of the way wind is calculated from an aircraft, the temperature bias also led to a certain degradation of the wind data.

As temperature is used in aircraft fuel flow management system, Air Canada Jazz was not operating its fleet of DHC-8 aircraft under optimum conditions. They then successfully used this fact in their business case to Air Canada to upgrade their DHC-8s with new dual Spirent temperature probes, new Spirent dual digital air data computers, and Universal Avionics Systems Corporation's UniLink UL-70x. Air Canada Jazz also used the fact that CMC was capable of providing an aircraft system/sensor performance monitoring service to consolidate their involvement in the Canadian AMDAR Program.

Air Canada Jazz started to upgrade their DHC-8 aircraft in August 2004 at a rate of 2-3 per month and CMC began using data only generated by the upgraded DHC-8 aircraft in December 2004. Figure 3.3 presents the evolution of temperature and wind statistics for all levels for the DHC-8 aircraft from February 2004 to April 2005. The top graph presents monthly evolution of wind statistics while the second graph from the bottom presents monthly evolution of temperature statistics. These graphs show significant reductions in temperature and wind biases starting in December 2004, when the upgraded DHC-8 aircraft became available (note that, starting in January 2005, only data from upgraded DHC-8 aircraft are used in the statistics).

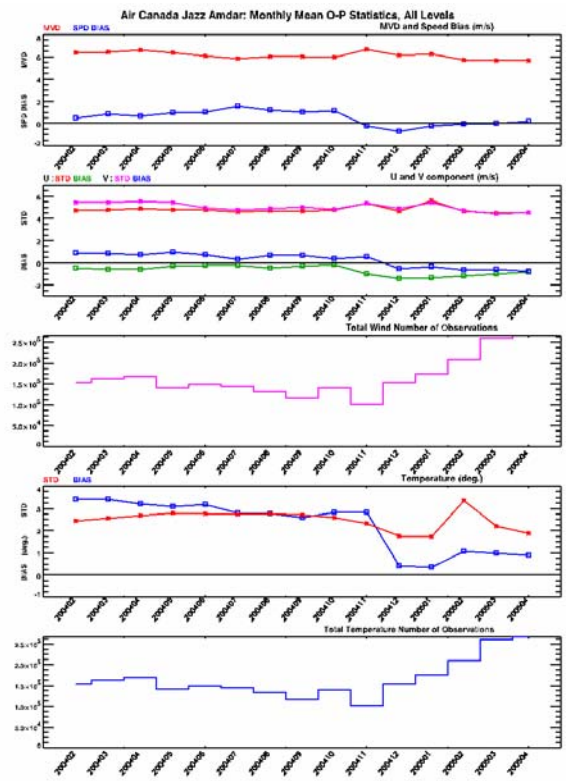

Figure 3.3 Observed minus first guess mean monthly statistics from February 2004 to April 2005 for the Canadian AMDAR temperature and wind generated by Air Canada Jazz' DHC-8 aircraft.

By 11 May 2005, 28 upgraded DHC-8 aircraft were contributing to the Canadian AMDAR Program. It is expected that the full fleet of 67 DHC-8 aircraft of Air Canada Jazz will be upgraded by November 2005.

The fact that the monthly mean statistics of temperature data from the upgraded DHC-8 aircraft showed a slow deterioration from January to April 2005 prompted CMC to conduct a deeper analysis of the statistics. In April the average temperature bias was 0.9C versus 0.4C for January. The results showed not only a seasonal dependency (still to be confirmed) of the statistics, but a clear dependency on the phase of flight (i.e. whether the aircraft is ascending, descending, or at cruise level). In January the average temperature bias for data captured during ascent, descent and en-route phases were respectively 0.6C/-0.5C/0.9C against 1.5C/-0.9C/1.4C. These differences seem to be more acceptable in January than in April. CMC then looked for a similar behavior in the data they receive from other programs. These include the fleet of CRJ aircraft from Air Canada Jazz and the US MDCRS Program. No such behavior could be found. It would be interesting to have a look at the TAMDAR GLFE data generated by the 64 Saab 340 aircraft but the phase of flight is not provided in the data stream.

CMC is working jointly with Air Canada Jazz to find the source of the differences. Such behavior could be associated with delays in response time of the Spirent temperature probe, the existence of a time lag between the reported time of measurement and the actual temperature measurement, or the temperature smoothing algorithm in the vertical coded in the UniLink software.

Meanwhile the results of a temperature probe comparison study contracted out to AeroMechanical Services Ltd. (2005) became available on 10 February, 2005. AeroMechanical Services (AMS) tested three candidate temperature probes with the objective to select one that could eventually be deployed with their Automated Flight Information and Reporting System (AFIRS/Uptime) system that is described in section 5. These probes were installed on the government of Alberta DHC-8 aircraft that is also equipped with a Goodrich/Rosemount temperature probe and the original OEM Norwich temperature probe of the DHC-8 aircraft. Results were compared against both the Goodrich/Rosemont probe measurements (Figure 3.4) and radiosonde sounding measurements.

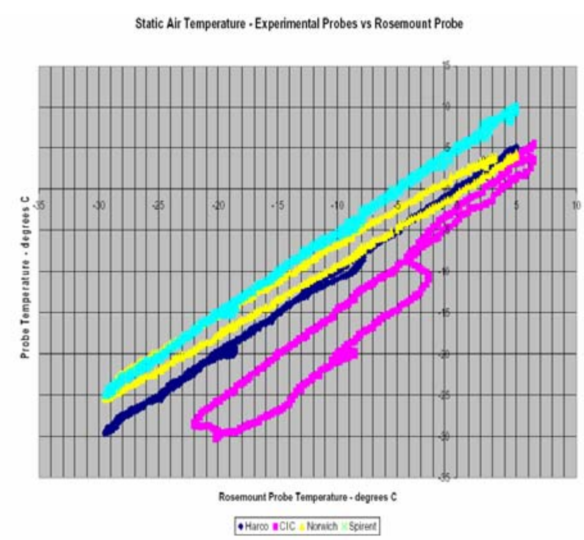

Figure 3.4 Comparison of Static Air Temperature values from Experimental probes against the Goodrich/ Rosemount probe

Figure 3.4 reveals that the worst of the three tested probes was the Spirent probe with the average difference from the Goodrich/Rosemount probe being in excess of 3C. As seen in Figure 3.4, the Spirent probe shows a strong positive bias but a linear response to temperature. AeroMechanical Services made the hypothesis that much of the poor performance of the Spirent probe was likely the result of the non-linear nature of the thermister sensing element used. Unfortunately, these results were not available at the time Air Canada Jazz selected a system to upgrade their DHC-8 aircraft in 2002.

Air Canada Jazz also operates a rapidly growing fleet of Canadair Regional Jet (CRJ) aircraft. An original fleet of 10 CRJ-200 was upgraded with Collins' CMU 900 and appropriate datalink and AMDAR software, and has been providing AMDAR data since April 2004. The fleet of AMDAR-capable CRJ aircraft has been increasing with time with 25 CRJ-200 aircraft contributing to the Canadian AMDAR Program by 11 May 2005. Figure 3.5 shows that temperature data provided by the fleet of CRJ aircraft are of excellent quality. Same is true for wind data. Further planned acquisitions of 25 CRJ-100 aircraft from Air Canada by Christmas 2005 and 8 CRJ-200 aircraft from Independence Air in the fall of 2005 will need a major upgrade. In addition, the first two of 15 brand new CRJ-705 aircraft were expected to be delivered by the end of May 2005.

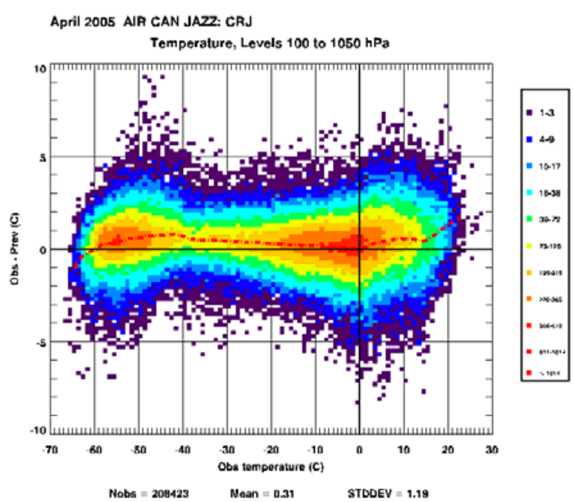

Figure 3.5 Density plot of innovations of temperature for all data from all levels for CRJ aircraft

The following are milestones reached up to now in 2005:

- 4 Jan 2005: beginning of Canadian AMDAR data distribution on the GTS and internal SATNET circuit
- 12 Jan 2005: Canadian AMDAR are being displayed as tephigrams on NOAA FSL web (acweb.noaa.fsl.gov) since then
- 3 Feb 2005: Air Canada Jazz / Sabre (www.sabre.com) Command and Control (C&C) system began operation
- 22 Feb 2005: an AMDAR Business Case

(Sypher:Mueller International Inc., 2005) on benefits to aviation submitted to NAV CANADA

- 15 Mar 2005: CMC implemented the 4D-Var Global Weather Analysis System
- 11 May 2005: 53 Air Canada Jazz aircraft reporting AMDAR on GTS (25 CRJ + 28 upgraded DHC-8)

On the GTS, the Canadian AMDAR messages are distributed by CMC as BUFR FM94 messages with the following headers in conformity with WMO guidelines:

- IUAA01 CWAO (for data 90W and east)
- IUAB01 CWAO (for data west of 90W).

Each aircraft is uniquely identified by an aircraft identifier of the form CNXXXYYY where XXX are 3 alphabetic characters defined by CMC and YYY is a number.

Another very important component of the Air Canada Jazz AMDAR system is the fully automated AMDAR data Command and Control (C&C) system (Figure 3.1) that was implemented to reduce unnecessary duplications and associated communication costs (MacKay, 2002). This system uses the Sabre flight reservation system and is operated by Air Canada Jazz in coordination with CMC. The basic rules of the C&C system are the following:

- only one aircraft within reports ascent data for each airport per hour
- a descent should never eliminate an ascent, but an ascent can disable a descent
- only one aircraft will report descent data per 2 hours per destination
- ability to permanently request mandatory reporting of ascent or descent from a station
- ability to specify that the last flight per calendar day will always report ascent and or descent data, regardless if it falls within the specified window
- ability to specify range of flight numbers to disable totally (e.g. test flights)
- diversion information should disable further data feed
- modular programming to allow changing of parameters without major re-programming (i.e. ability to change time specifications, etc.)
- ability to create a table of airports where auto disabling can be specified by time (to avoid duplication with other airlines)
- ability to indicate an encrypted aircraft ID, unique to that aircraft, that is controlled by Air Canada Jazz
- ability to transmit in ARINC 620-4 format to CMC
- ability to accept an external signal for manual AMDAR data on/off selection from an external source (for future enhancement)

The Command and Control system uses these basic rules and automatically sends uplink commands to aircraft to enable/disable reporting for specific phases of flight. This system has the potential for targeting AMDAR observations based on meteorological conditions. The C&C rules can be adjusted to fit requirements, such as those of the NWP system.

CMC reached an important milestone on 15 March 2005 when they implemented the 4D-Var Global Weather Analysis System in their operations. Figure 3.6 is a histogram showing that the amount of Canadian AMDAR data assimilated in the global NWP model increased almost 4-fold after 15 March 2005, i.e. with the passage from 3D-Var to 4D-Var Global Weather Analysis System.

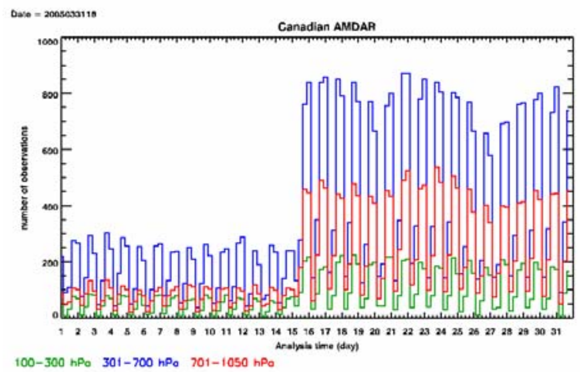

Figure 3.6 Histogram for the month of March 2005 of the amount of Canadian AMDAR data assimilated (green: 100-300 hPa levels; blue: 301-700 hPa levels; red: 701-1050 hPa levels)

Figure 3.6 says a lot about the value of AMDAR as a unique source of in-situ upper air data in the troposphere. In March 2005 there were about 45 aircraft contributing data mostly south of the 55N latitude. This fleet is increasing to reach over 130 aircraft by April 2006. It also says a lot about the weight the NWP assimilation will give to AMDAR data generated from north of 55N (sections 4 and 5) where there is little source of upper air data.

About 21/2 years ago CMC's Data Assimilation group integrated the monitoring of AMDAR data into their data monitoring operations. CMC established two internal web sites from which QA/QC statistics, graphs and histograms such as Figure 3.6 can be obtained. CMC runs on-going statistics on the number of observations received, data distribution, number of observations assimilated, innovations (MVD and biases; U, V, T Biases and STD), QC data rejections and reasons for rejections, data quality for individual aircraft, fleet, aircraft type, and airline, list of aircraft with suspect data, etc. One of the internal web site processes data from the various components of the Canadian AMDAR Program while the other processes data from all international AMDAR programs.

Figures 3.7 and 3.8, obtained from the NOAA FSL aircraft data web (acweb.noaa.fsl.gov) respectively show a map of sets of AMDAR observations received at FSL from the fleet of 53 Air Canada Jazz aircraft and a tephigram representation of an ascending aircraft departing Whitehorse. The FSL web is an extremely powerful real-time aircraft data display tool. Almost everything is selectable for display by the user: the region, the date, time, period, the source of data, the type of sounding representation (Skew-T or Tephigram), the levels, and the type of observations. Figure 3.7 displays data received at FSL only from Canadian aircraft source over a period of 24 hours on 18-19 May 2005, from all levels (color corresponds to level source of data according to vertical ruler on the right). The statistics provided at the bottom of the map says that, for the selected period of 24 hours, 272,068 global aircraft observations were received at FSL, from which 22,587 were generated from Canadian aircraft, while 3,274 are displayed. It is noted from Figure 3.7 that some of the Air Canada Jazz aircraft, mostly the CRJ aircraft, fly transborder routes. Figure 3.8 was obtained by clicking on the Whitehorse airport on Figure 3.7.

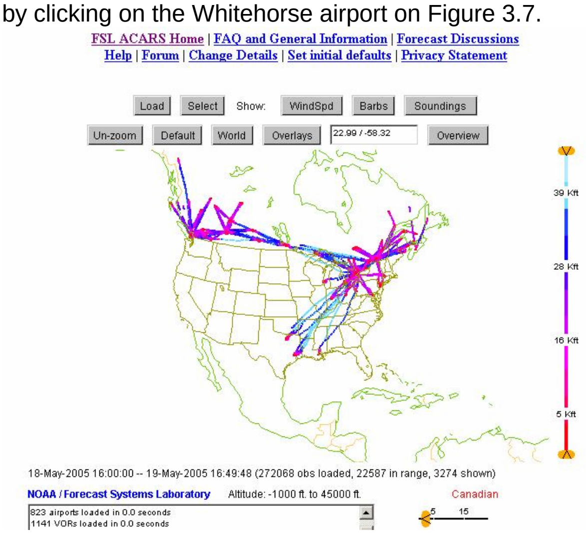

Figure 3.7 Map obtained from FSL web displaying Canadian data received at FSL from all levels over a period of 24 hours on 18-19 May 2005

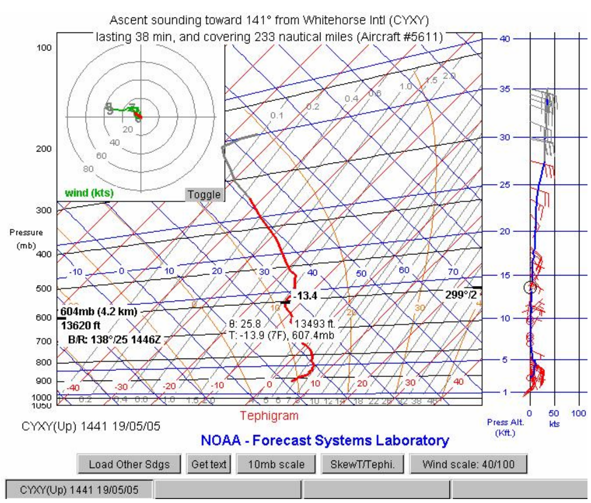

Figure 3.8 Tephigram representation of a sounding obtained from an aircraft departing Whitehorse airport

4. AMDAR Development with First Air

With its fleet of 16 aircraft, First Air (www.firstair.ca) is the biggest regional air carrier servicing the Canadian Arctic. Figure 4.1 shows that First Air operations provide significant coverage in the data sparse area north of the 60N latitude. A certain number of the high arctic locations get daily, or close to daily service. There is no conventional VHF datalink network extending in this area. This is where the satellite communications technology comes into play.

Figure 4.1 Map showing First Air scheduled route structure, providing significant coverage in the sparse north of 60N area (taken from www.firstair.ca)

It is in mid-2002 that the development of a non-ACARS alternative AMDAR system for First Air began. It was timely because, as First Air operates mostly north of 60N latitude, i.e. in a region out of VHF communication coverage, they had been investigating a way to track their aircraft fleet using satellite communications.

Given the strategic importance of northern Canada and the fact that it is a dramatic data sparse region, Environment Canada committed more resources to develop a proof-of-concept system for First Air. However, given the fact that First Air operates a mixed fleet of old aircraft, the risk was relatively high so that the development work has been proceeding by phases. Phase 1, an analysis of the feasibility to develop an AMDAR capacity out of First Air fleet, was completed by April 2003. It is then that it was realized that it would not be economically and technically possible to upgrade each aircraft for proper meteorological sensing and that the relatively low cost TAMDAR package (Figure 4.2), that had been developed jointly by NASA and a private company, Optical Detection Systems, Inc., now AirDat LLC (www.airdat.com), with its promise to be easily adaptable to various aircraft configurations and requiring minimal certification, would be the best candidate to provide the required meteorological data across the First Air fleet. The TAMDAR unit is a self-contained box which can be mounted on the inside wall of the cockpit with the sensor protruding out and measures temperature, relative humidity, pressure, icing, peak and median turbulence and, when combined with GPS, wind speed and direction. The icing report indicates only the presence of icing, not the rate or droplet size.

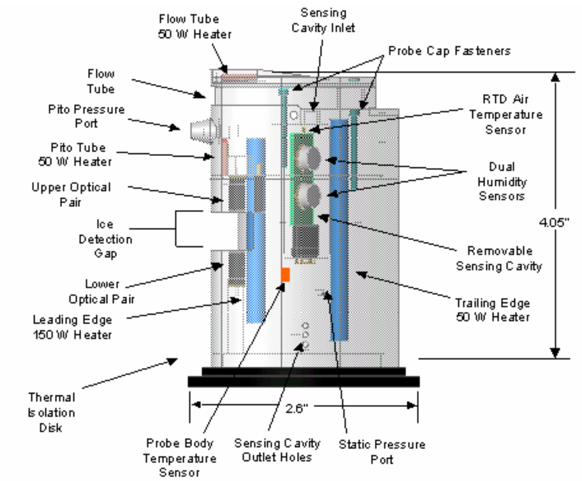

Figure 4.2 Schematic of the TAMDAR unit and its sensing components (taken from AirDat LLC web site www.airdat.com)

CAPIT selected the TAMDAR option and Phase 2, the development of a proof-of-concept system integrating together TAMDAR, ISAT satellite communications, some of the avionics of the aircraft and the Internet was completed by April 2004. The system worked on the ground and was subsequently installed on the test B727 aircraft ready for Phase 3 (i.e. in-flight testing) to proceed. There have since been numerous certification and technical difficulties that delayed completion of Phase 3. These difficulties, that have been resolved one by one over longer than anticipated periods of time, were, in chronicle order:

- FAA certification of the TAMDAR unit to be flown on a commercial passenger aircraft
- Transport Canada certification of the TAMDAR unit to be flown on a commercial passenger aircraft
- GPS format mismatch between aircraft GPS and TAMDAR systems
- mismatch between TAMDAR and ISAT data rates (to conform to ISAT data rate, TAMDAR is now operating at 1 sequence / 3 sec instead of 1 sequence / sec)
- failed TAMDAR unit while the spare available for replacement was not certified
- lost a few more weeks due to a wiring issue
- the test B727 aircraft is now operating out of Montreal instead of Ottawa, which creates an access problem as First Air's engineering facility is in Ottawa
- there was a major failure of Skytrac service, and then the Iridium satellite network itself
- failure of transmission on the test aircraft

The certification aspect is now behind us and we are confident that the remaining technical problems will soon be resolved so that test flight, i.e. Phase 3, can be completed in the next few months.

Once CMC has demonstrated through Phase 3 flight test that the data are of adequate quality, and pending the availability of appropriate funding, the plan is to proceed with Phases 4a and 4b, i.e. deployments on 8 aircraft and then the 6 remaining aircraft, by April 2006 and April 2007 respectively.

The aircraft proposed for reporting AMDAR data are:

- four B727 aircraft (three combined passenger-freight models and one full freighter)
- three B737 combined passenger-freight aircraft, and
- eight ATR-42-300 aircraft

A further difficulty is that, as Canada is only acquiring TAMDAR units, not the data service from AirDat LLC, and TAMDAR unit's basic real-time QA is performed at AirDat's ground-based TAMDAR data centre in North Carolina, there is a requirement for Canada to develop and implement its own basic real-time QA system for TAMDAR data before these data can be assimilated in the NWP system and distributed on the GTS.

Figure 4.3 presents the overall architecture of the alternative AMDAR system based on ISAT/TAMDAR/Internet being developed with First Air. The ISAT LEO satellite constellation is used. Satellite communications is provided by SkyTrac Systems Ltd. of Penticton, British-Columbia while InteliSys Aviation Systems, Inc. operates a 24/7 Network Control Centre in Shediac, New Brunswick where the AMDAR data will be received, processed and transmitted to CMC and the data Command and Control commands will be performed.

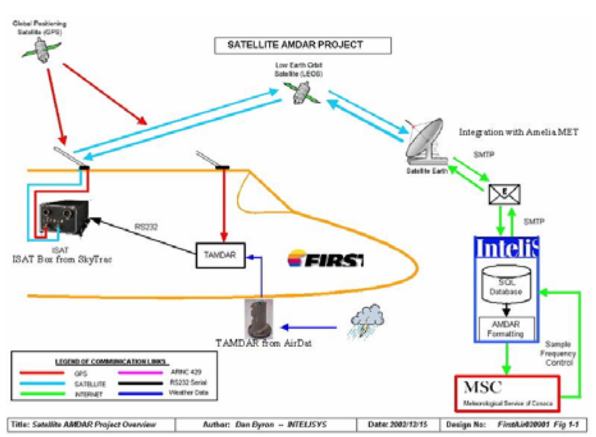

Figure 4.3 Schematic of the AMDAR data flow for the component of the Canadian AMDAR Program being developed with First Air

5. AMDAR Development with AeroMechanical Services Ltd.

An investigation of the coverage that Air Canada Jazz and First Air will provide (Figure 5.1) leads to the realization that there will still be huge areas not covered between southern and northern Canada. This is the area were only the smaller regional air carriers operate and where VHF datalink communication is rarely available.

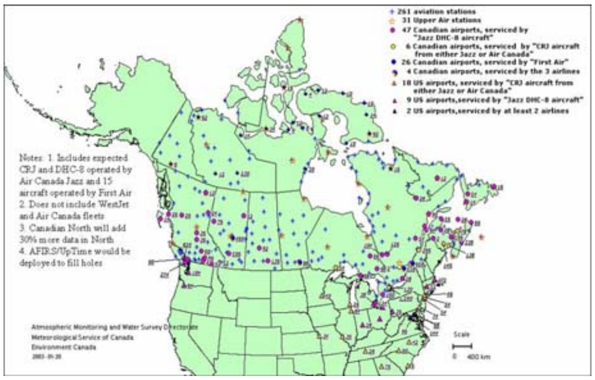

Figure 5.1 Projected weekly frequencies of aircraft ascent and descent soundings once Air Canada Jazz and First Air AMDAR Program components are fully operational. A small aircraft icon represents an airport part of Environment Canada's Aviation Surface Weather Network, a star a Canadian radiosonde site, and a colored circle an airport from which AMDAR soundings will be generated by Canadian aircraft

In December 2002, AeroMechanical Services (AMS) Ltd. of Calgary, Alberta (www.amscanada.com) was contracted to develop a Proof-Of-Concept alternative AMDAR system based on their Automated Flight Information Reporting System (AFIRS) / Uptime service for smaller regional air carriers with a goal to eventually fill AMDAR data gaps in Canada. This system has been developed in partnership with Transport Canada, and the Program on Energy R&D (PERD) of Natural Resources Canada who are interested in reducing aircraft fuel emission through improved weather monitoring and forecasting.

AMS had been developing the AFIRS/Uptime system (Figure 5.2), an autonomous flight information collection and reporting system suitable for the smaller air carriers that cannot afford datalink systems such as ACARS or the one being developed for First Air. The on-board AFIRS system records flight data, generates data reports and automatically transmits them to the AMS Uptime Flight Data Centre, which then relays them via a communications network to the aircraft operator's flight operations base. There is no upfront and maintenance costs to the client who pays per flight hour data fees.

Again, owing to the risks inherent in developing new technologies, a phase approach was used to develop an AMDAR capacity out of the AFIRS/Uptime system. Phase 1 work, capabilities studies and AMDAR testing and qualification, was successfully completed by April 2003. Then Phase 2, initial implementation involving 4 DHC-8 aircraft was completed by April 2004. Phase 3, implementation of AMDAR on a client air carrier with AFIRS/Uptime, is expected to be completed in a few months with deployment on five B737-200 combi aircraft from Canadian North servicing the Arctic.

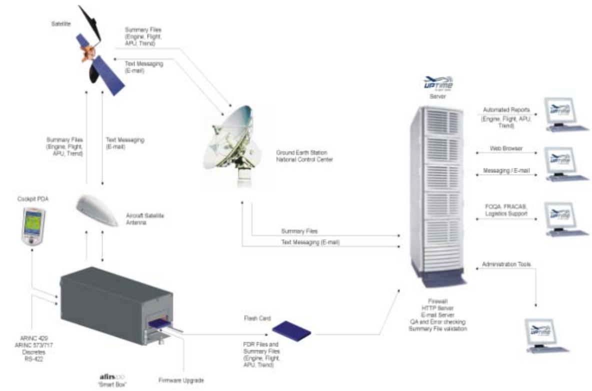

Figure 5.2 Schematic of the AeroMechanical Services AFIRS/Uptime architecture as component of the Canadian AMDAR Program being developed with the smaller air carriers

Once data from Canadian North become available CMC will test its quality before the aircraft are allowed to contribute to the Canadian AMDAR Program and a long-term agreement with AMS for the provision of AMDAR data from that fleet can be established. AMS' marketing model is particularly attractive to their clients as data fees will be shared by the various users of the data, namely the client airline, Environment Canada and Transport Canada.

6. Other AMDAR Development Activities

Members of the Canadian AMDAR Program Implementation Team (CAPIT) have been very active in conducting S&T and impact studies relevant to the development of the Canadian AMDAR Program, in promoting AMDAR to various interested groups on the national and international scenes, in facilitating the transfer of knowledge and developed technologies to the AMDAR community at large, and in encouraging other Canadian air carriers to join the Canadian AMDAR Program.

WestJet Airlines Ltd., a rapidly growing low-fare Canadian airline operating across Canada, has recently shown its interest in joining the Canadian AMDAR Program. WestJet started operations in 1996 with three B737-200 aircraft and is now operating a fleet of 54 B737 aircraft including 38 Next-Generation (NG) that should grow to 54 B737-NG aircraft by the end of 2005. The B737-NG aircraft are being deployed with an upgraded Honeywell FDAMS/ACMS system on which the AMDAR software would have to be developed. Currently the members of CAPIT from WestJet are compiling the information needed to convince WestJet's Executive Team to join the Canadian AMDAR Program. The WestJet AMDAR system will be a conventional ACARS-based AMDAR system (Figure 3.1) except that it is SITA, not ARINC, that is their aircraft data service provider. Like Air Canada Jazz, WestJet's routes and destinations are mostly located south of the 55N latitude with a few transborder routes. Development of the Canadian AMDAR on multiple airlines servicing similar areas is critical to reducing dependency on a specific unique airline. Also, compared to Air Canada Jazz, WestJet would provide enroute data generally from higher altitudes and soundings at two more locations. Like Air Canada Jazz, WestJet uses the Sabre Holdings Corporation (www.sabre.com) flight reservation system such that the same AMDAR C&C that was developed for Air Canada Jazz could be used for WestJet as well. The possibility to fully integrate the AMDAR data C&C functions of both airlines will be investigated.

Air Canada is also a member of CAPIT but, because of major internal difficulties, Air Canada has not been able to join the development of the Canadian AMDAR Program. Air Canada is the biggest domestic and international airline of Canada. On 30 September 2004, Air Canada and certain of its subsidiaries emerged from creditor protection under the Companies' Creditors Arrangement Act (CCAA) and implemented its consolidated Plan of reorganization, compromise and arrangement. The purpose of the Air Canada's Plan, together with its new business strategy, was to restructure its capitalization, operations and cost structure. An important component of the Plan is the implementation of a fleet renewal program to achieve the appropriate number, size and mix of aircraft for Air Canada's route network. As Air Canada plans to acquire new modern Embraer regional jet (ERJ) aircraft to service its domestic and North American routes, CAPIT decided to concentrate its effort on these new acquisitions. Currently the ERJ CMP software is not fully developed and will enter service in standard message sets. As the software matures, modifications (i.e. customized message sets) will be accomplished to enable airline specific features such as AMDAR. No timeline for the development of AMDAR is available from Air Canada yet.

7. Plans for the Future

The priorities for the period of April 2005 to March 2006 are:

- transferring completed AMDAR Program components to operations
- expanding AMDAR capability on all CRJ aircraft to be acquired by Air Canada Jazz
- upgrading all DHC-8 to AMDAR capability
- testing and implementing an improved performance temperature probe for the DHC-8 aircraft
- assuring the Air Canada Jazz / Sabre C&C system works on 100% of Air Canada Jazz AMDAR data
- completing flight test of ISAT/TAMDAR/Internet proof-of-concept system on First Air B727 test aircraft
- developing a real-time basic QA system for Canadian TAMDAR data
- depending on results of flight test and pending availability of appropriate funding, deploying ISAT/TAMDAR/Internet system on 8 aircraft from First Air
- developing an agreement with First Air for long-term provision of AMDAR data on a cost-recovery basis
- developing an AMDAR Program component with the B737 NG aircraft of WestJet
- studying the possibility of combining Air Canada Jazz and WestJet C&C functions (both airlines use the same Sabre flight reservation system)
- developing an agreement with WestJet for long-term provision of AMDAR data on a cost-recovery basis
- completing development on Canadian North using the AMS AFIRS/Uptime system
- testing AMDAR data obtained from Canadian North
- depending on results from test, developing an agreement with AMS for long-term provision of AMDAR data from Canadian North on a multi-user cost sharing basis
- expanding deployment of AMS AFIRS/Uptime systems as required
- testing selected temperature probe to be deployed with AMS AFIRS/Uptime system
- continuing efforts to enroll Air Canada, targeting new Embraer aircraft acquisitions
- continuing the monitoring of the performance and progress of TAMDAR such as through participation the TAMDAR Great Lakes Fleet Experiment (GLFE) and THORPEX initiatives
- completing national AMDAR data archiving system
- defining and developing AMDAR performance indicators to be used in Life Cycle Management (LCM) operations
- developing a Business Case to management of Environment Canada on the value of expanding AMDAR to other aircraft parameters such as relative humidity, icing, and turbulence
- assuring that the AMDAR specifications are well captured in the upcoming version of the Canadian forecaster Ninjo workstation
- assuring that the Canadian AMDAR Program is strongly considered in the development of the Canadian and International 10-year implementation plans of GEOSS (Global Earth Observing System of Systems)
- developing a long-term strategic plan for the emerging integrated Upper Air system within the context of GEOSS

The priorities for the period of April 2006 to March 2007 are:

- transferring completed AMDAR Program components to operations

- expanding AMDAR capability on all CRJ aircraft to be acquired by Air Canada Jazz
- pending availability of appropriate funding, procuring and implementing ISAT/TAMDAR/Internet systems on remaining 6 aircraft from First Air
- continuing expansion of WestJet AMDAR Program component using their B737 NG aircraft
- depending on feasibility, developing a common C&C for AMDAR data optimization between Air Canada Jazz and WestJet
- contracting Collins to upgrade the Air Canada Jazz CRJ AMDAR software for the transmission of icing YES/NO data
- upgrading C-ADAS system to receive and use icing data and use new international BUFR code to transmit icing YES/NO on the GTS
- supporting the development of an AMDAR Program component from Air Canada's Embraer jet aircraft (it is noted that Air Canada uses LIDO, the same flight dispatch system that is used by European EUMETNET E-AMDAR for the command and control of AMDAR data so that the same system could potentially be used to C&C AMDAR data generated by Air Canada aircraft
- pending availability of funds, expanding deployment of AMDAR capability on AMS client air carriers equipped with AFIRS/Uptime (AMS fleet to be managed for maximum returns according to the on-going funds available to this component of the AMDAR Program)
- pending availability of funding from NAV CANADA, designing, developing and managing aviation-related (icing, turbulence) S&T projects for the expansion to the monitoring of icing and turbulence
- developing a capacity at CMC to receive, decode/encode, process, assimilate, test and validate, and disseminate aircraft-based relative humidity (RH) or mixing ratio, icing and turbulence data
- conducting impact studies of Canadian AMDAR data
- if economically viable and funding is available, expanding Canadian AMDAR Program to procure aircraft-based relative humidity (RH) or mixing ratio observations
- designing and developing an AMDAR data targeting system
- upgrading the Canadian AMDAR specifications to latest version of ARINC 620 (Version 4, Supplement 5 or higher)
- upgrading on-board AMDAR software to the updated Canadian AMDAR specifications (i.e. ARINC 620 Ver. 4, Suppl. 5 of higher)
- assuring that the Canadian AMDAR Program plays a central role in the Canadian contribution to GEOSS

If the above listed tasks can be completed within the targeted timelines then it is expected that most components of the Canadian AMDAR Program will be operational by April 2008. By then the Canadian AMDAR Program will be a critical component of the Canadian Composite Upper Air Observing System, of the Canadian GEOSS, and of the international GEOSS.

8. Conclusion

Very cost effective automated meteorological observations obtained from commercial aircraft are an excellent means of augmenting upper-air observations required by modern weather forecasting systems. The Canadian AMDAR Program Implementation Team (CAPIT) was formed to oversee all aspects of the development of the Canadian AMDAR Program.

The development of AMDAR in Canada has been proceeding on three fronts:

- a conventional ACARS-Based VHF Datalink (Air Canada Jazz, and later WestJet, Air Canada…)
- an alternative AMDAR LEO ISAT/TAMDAR/Internet system for First Air
- an alternative low-cost AMDAR system based on AeroMechanical Services Ltd. AFIRS/Uptime system using LEO ISAT for the smaller regional air carriers

Progress has been slow and difficult but issues are being addressed one by one. Today good temperature and wind data obtained from 53 aircraft from Air Canada Jazz are being assimilated and distributed on the GTS. This fleet is expected to increase to over 130 aircraft by April 2006. To service the data sparse north, the First Air proof-of-concept system is about to be tested before deployment proceeds on 15 aircraft while AMS AFIRS/Uptime system is about to be tested on 5 aircraft from Canadian North. Efforts to enroll more air carriers are being actively pursued.

REFERENCES

WMO AMDAR Reference Manual. (2003). WMO-No. 958, Geneva (www.wmo.int).

SYPHER: MUELLER International Inc. and Enviromet‌ International Inc. (2000). Aircraft Reporting of Meteorological Data in Canada.

AeroMechanical Services Ltd. (2005). An AMDAR Temperature Probe for the DHC-8 Aircraft. Report 1118-3b, Calgary.

SYPHER: MUELLER International Inc. (2005). Canadian AMDAR Program – A Business Case for Contributions from NAV CANADA, Ottawa.

MacKay, Anthony. (2002). Power Point presentation, WMO AMDAR Panel Workshop on AMDAR Science and Technology, Toronto. September 31 – October 1, 2002.