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

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1. INTRODUCTION

With the advances in weather modeling and computer capabilities, high resolution upper air observations are required. 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, 12 countries operate operational AMDAR programs that generate a daily exchange of over 190,000 observations on the Global Telecommunication System (GTS), with additional data generated by the US TAMDAR Great Lakes Fleet Experiment (www.airdat.com) but not exchanged on the GTS. Another 29 countries are developing or planning national or regional AMDAR programs.

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. The Meteorological Service of Canada (MSC) created 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 AMDAR Program, and the Technical Coordinator of the WMO AMDAR Panel.

Canada started the development of its national AMDAR Program using regional air carriers, thus having to deal with older aircraft, avionics and sensors, and no datalink communications in place. The benefits are that regional air carriers service much more communities than national airlines thus covering more area, fly shorter legs thus executing more ascents and descents in a day, and operate in the lower atmosphere where weather is occurring and largely over data sparse areas.

3. AIR CANADA JAZZ

Air Canada Jazz (www.aircanadajazz.ca) is the largest regional air carrier of Canada. Since early 2000 Air Canada Jazz has been developing its datalink system based on Aircraft Communication Addressing and Reporting System (ACARS) and has accepted to accommodate the requirement to deliver AMDAR to the Meteorological Service of Canada. 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

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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, wind speed and wind 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, basic quality control and parsing of the data on the GTS.

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.

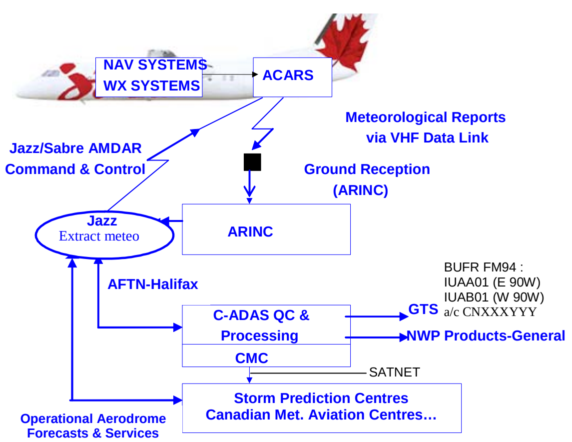

Figure 3.1 Schematic of the AMDAR data flow for the component of the Canadian AMDAR Program developed with Air Canada Jazz.

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 the GTS. Unfortunately 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 with DHC-8 Q400 aircraft operated by SAS (Scandinavia Airlines) before they were blacklisted.

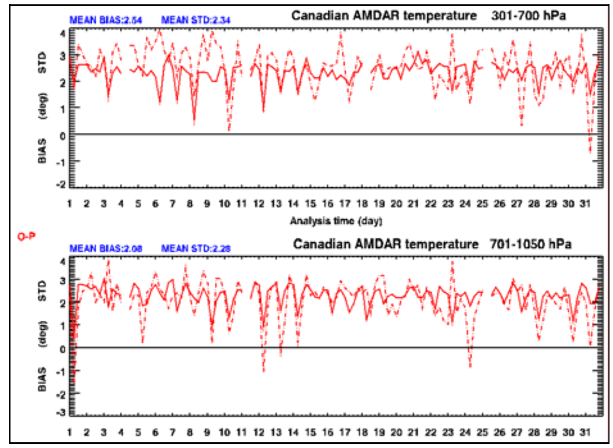

Figure 3.2 Observed minus first guess statistics for the Canadian AMDAR temperature in August 2002. A mean bias of +2.54C was observed between 301-700 hPa (upper graphic), and +2.08C between 701-1050 hPa (lower graphic).

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 all 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 in an optimum manner. They successfully used this fact in their business case to upgrade their DHC-8s with dual Spirent temperature probes, 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 have been used in the statistics).

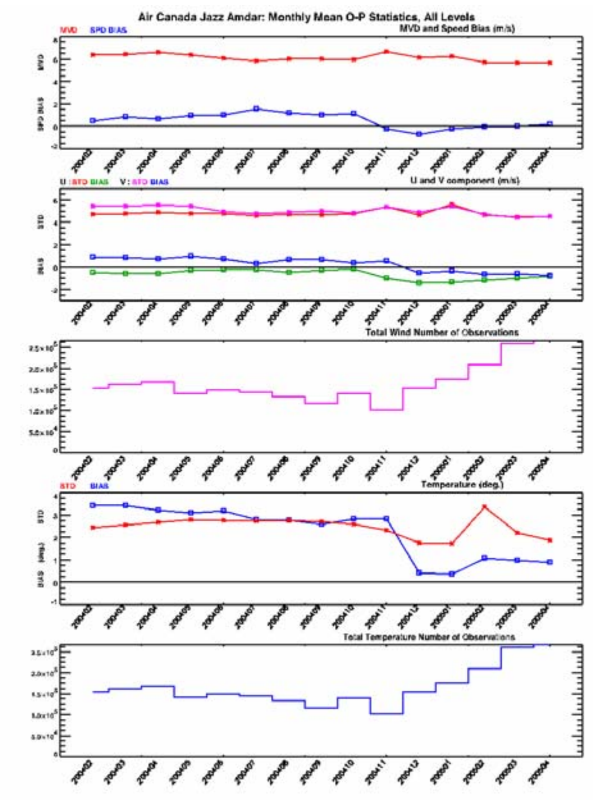

Figure 3.3 Observed minus first guess mean monthly statistics from February 2004 to April 2005 for the Canadian AMDAR temperature and wind generated by Air Canada Jazz' DHC-8 aircraft.

By 4 November 2005, 41 DHC-8 aircraft were upgraded. At this pace it is expected that the full fleet of 67 DHC-8 aircraft of Air Canada Jazz will be upgraded by July 2006.

Then CMC recently uncovered a clear dependency of the statistics of the data generated by Air Canada DHC-8 aircraft on the phase of flight (i.e. whether the aircraft is ascending, descending, or at cruise level). Figure 3.4 shows a positive bias in the temperature during ascent, a lower positive bias enroute and a negative bias during descent. As this situation results in a negative impact from the DHC-8 reports on the overall statistics of BUFR messages assimilated in the CMC operational analysis program, CMC has decided to stop assimilating the data generated from the DHC-8 aircraft until the situation is resolved.

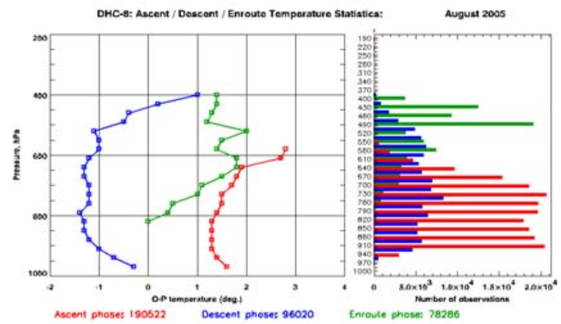

Figure 3.4 Observed minus first guess statistics according to phase of flight for the Canadian AMDAR temperature generated by Air Canada Jazz' DHC-8 aircraft in August 2005.

CMC then looked for a similar behavior in the data they receive from other programs, including the fleet of CRJ aircraft from Air Canada Jazz and the US AMDAR Program. No such behavior could be found.

Such behavior could potentially 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. This issue was also presented to the Science Sub-Group of the WMO AMDAR Panel at its second meeting on 4 October, 2005 (WMO AMDAR Technical Coordinator, 2005). The document demonstrates from simulation data that there is a strong possibility that biases are introduced as a direct result of applying the smoothing function suggested by WMO and that the severity of the bias depends on the actual sampling interval of the data provided, and the assumed sampling interval and averaging period used by the function. Consequently the Science Sub-Group of the WMO AMDAR Panel was charged with further studying the case and reviewing alternative smoothing algorithms with a view to minimising the impact on data quality.

While the Science Sub-Group of the WMO AMDAR Panel works towards finding a long-term solution, the issue with the DHC-8 fleet of Air Canada Jazz has to be urgently resolved and CAPIT is currently working with Universal Avionics to find an alternative interim solution that could be applied to the next annual release of the Unilink UL-70X software scheduled for August 2006. To achieve this goal Universal Avionics need to have requirements defined by the end of January 2006.

Air Canada Jazz also operates a 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 reached 25 CRJ-200 aircraft contributing to the Canadian AMDAR Program since 11 May 2005. Figure 3.5 shows that the temperature data provided by the fleet of CRJ aircraft are of excellent quality. Same is true for wind data.

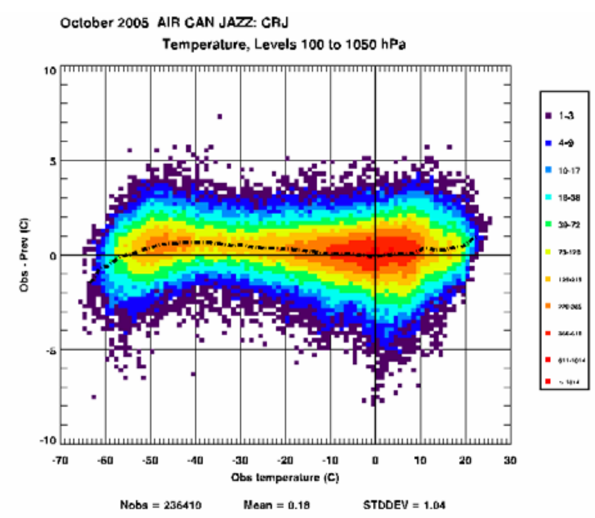

Figure 3.5 Density plot of innovations of temperature for all data from all levels for Air Canada Jazz CRJ-200 aircraft in October 2005.

As of 4 November 2005, Air Canada Jazz operates a fleet of 12 brand new CRJ-705 model aircraft. This will increase to 15 aircraft by the end of December 2005 with an option for 8 more in the short term. A contract is being worked out between Air Canada Jazz and Rockwell-Collins, its avionics provider for the CRJ aircraft, with the support of the Meteorological Service of Canada, to make the ACARS/AMDAR applications common across the CRJ-200 and CRJ-705 fleets. In the standard configuration of the CRJ-705, parameters such as pitch and roll angles are not provided. These parameters are used for quality control of the wind and may eventually be used as input to turbulence algorithm. The contract with Rockwell-Collins include the processing of roll and pitch angles but physical wiring between the Flight Management System (FMS) and the CMU 900 systems is necessary before the data becomes available to the ACARS/AMDAR software.

Further some of the 25 CRJ-100 from Air Canada have been transferred to Air Canada Jazz and Air Canada Jazz will be acquiring 8 CRJ-200 aircraft from Independence Air in the coming months. However it is unlikely that the CRJ-100 will be upgraded for datalink capability and plans regarding the 8 CRJ-200 from Independence Air are not yet known. Therefore by mid-2006 Air Canada should be operating around 67 CRJ aircraft from which at least 48 will contribute to the Canadian AMDAR Program on an operational basis.

The following are milestones that were reached in 2005:

- 4 January 2005: beginning of Canadian AMDAR data distribution on the GTS and internal SATNET circuit
- 12 January 2005: Canadian AMDAR data are being displayed as tephigrams on NOAA's Global Systems Division of the Earth System Research Laboratory (ESRL/GSD) AMDAR web (amdar.noaa.gov) since then
- 22 February 2005: an AMDAR Business Case (Sypher:Mueller International Inc., 2005) on benefits to aviation submitted to NAV CANADA seeking their contribution to enhance the Canadian AMDAR Program with the reporting of icing and turbulence
- 15 March 2005: CMC implemented the 4D-Var Global Weather Analysis System
- 4 November 2005: 61 Air Canada Jazz aircraft reporting AMDAR on the GTS (25 CRJ + 36 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 critical 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 developed to reduce unnecessary duplications and associated communication costs (MacKay, 2002). This system will be operated by Air Canada Jazz in coordination with CMC. The C&C system is about to become fully operational. 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 will use these basic rules and will automatically send 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 3-fold after 15 March 2005, i.e. with the passage from 3D-Var to 4D-Var Global Weather Analysis System.

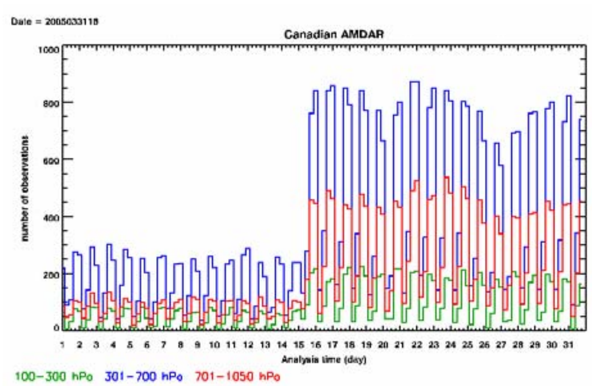

Figure 3.6 Histogram for the month of March 2005 of the amount of Canadian AMDAR data assimilated (green: 100-300 hPa levels; blue: 301-700 hPa levels; red: 701-1050 hPa levels).

Figure 3.6 tells 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 2007. 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 currently little source of upper air data.

About three 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 statistics, graphs and histograms such as figures 3.2 to 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's ESRL/GSD AMDAR web (amdar.noaa.gov) respectively show a map of sets of AMDAR observations received at ESRL/GSD from the fleet of 61 Air Canada Jazz aircraft and a tephigram representation of an ascending aircraft departing Whitehorse. The ESRL/GSD web is an extremely powerful real-time aircraft AMDAR 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 ESRL/GSD only from Canadian aircraft source over a period of 24 hours on 4 November 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 establishes that, for the selected period of 24 hours, 260,295 aircraft observations were received worldwide, from which 25,006 were generated from Canadian aircraft, while 3,078 are displayed. It is noted from Figure 3.7 that some of the Air Canada Jazz aircraft, mostly the CRJ aircraft, fly transborder routes. The profile on Figure 3.8 was obtained by clicking on the Whitehorse airport.

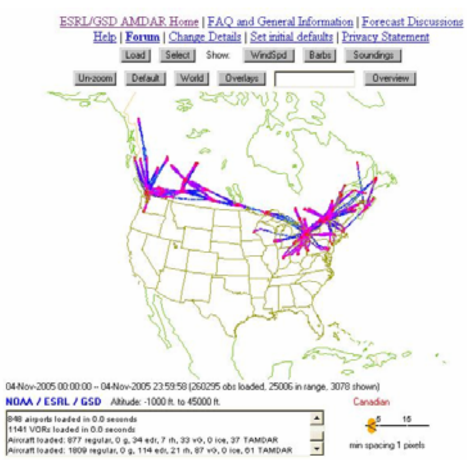

Figure 3.7 Map obtained from ESRL/GSD web displaying Canadian data received from all levels over a period of 24 hours on 4 November 2005.

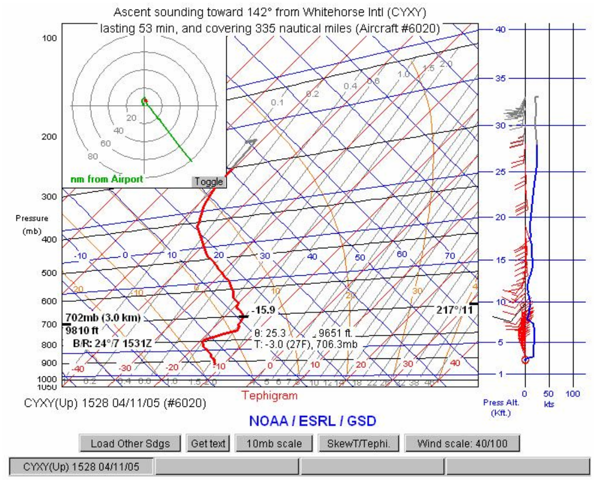

Figure 3.8 Tephigram representation of a sounding obtained from an aircraft departing Whitehorse airport.

4. FIRST AIR

With its fleet of 19 aircraft, First Air (www.firstair.ca) is the largest regional air carrier servicing the Canadian Arctic. Figure 4.1 shows that First Air operations provide significant coverage in the data sparse north of 60N area. 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 current 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 the north to Canada and the fact that it is a dramatic data sparse region, the Meteorological Service of Canada committed more resources to develop a proof-of-concept (POC) 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 viable and technically manageable 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.

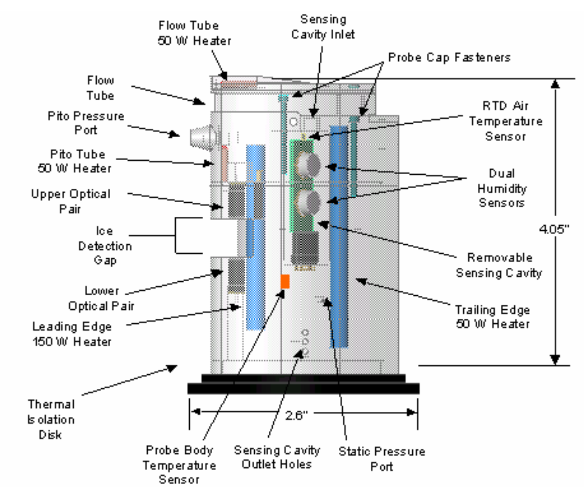

Figure 4.2 Schematic of the TAMDAR unit and its sensing components (taken from AirDat LLC web site www.airdat.com).

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.

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. The system installed on the test B727 provides data to CMC (Figure 4.3) but there have since been numerous certification and technical difficulties that delayed completion of Phase 3.

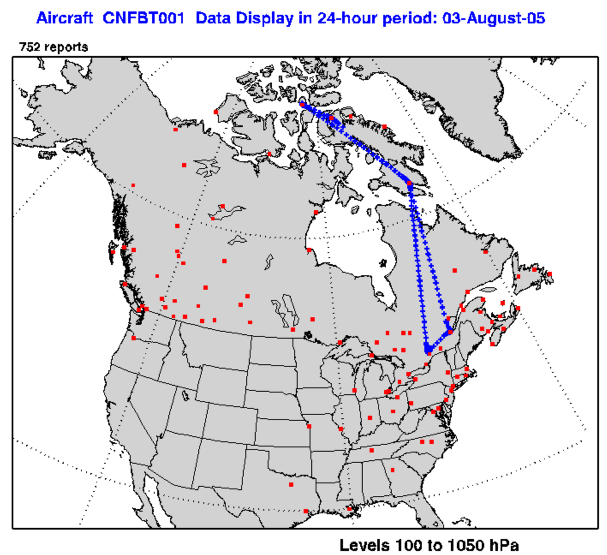

Figure 4.3 A typical daily scheduled route (here northern destinations include Iqaluit, Nanisivik, and Resolute) for the test B727 that provides AMDAR data to CMC. The data has not been verified by CMC yet because the TAMDAR unit needs to be calibrated first.

The 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 flown on a commercial passenger aircraft
- Transport Canada certification of the TAMDAR unit 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
- failure of transmission on the test aircraft

The certification aspect is now behind but First Air now wants to decommission the B727 on which the proof-of-concept system is installed within the next two months. The system will be transferred to one of the two B737-200 aircraft that First Air recently acquired so more integration difficulties are still possible. Then the TAMDAR unit will have to be calibrated by AirDat LLC before CMC will look at the quality of the data generated from the proof-of-concept system.

It is still hope that flight test, i.e. Phase 3 of this development contract, 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 targeted aircraft, by April 2006 and April 2007 respectively.

The aircraft proposed for reporting AMDAR data are:

- two B727 aircraft
- five B737 aircraft, and
- eight ATR-42-300 aircraft

A further difficulty was 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 was 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 4.4 presents the overall architecture of the alternative AMDAR system based on the ISAT/TAMDAR/Internet system being developed with First Air. The Iridium LEO satellite constellation is used. Satellite communications is provided by SkyTrac Systems Ltd. of Penticton, British-Columbia.

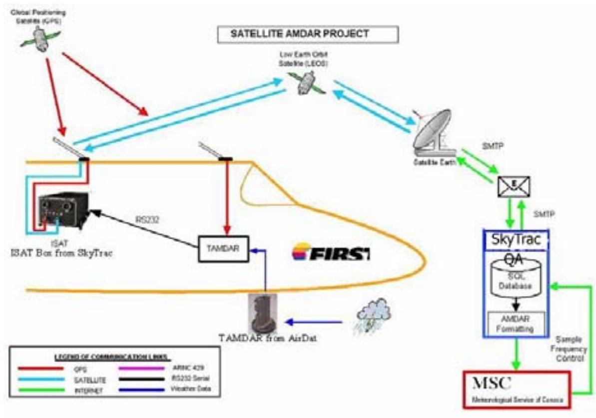

Figure 4.4 Schematic of the AMDAR data flow for the component of the Canadian AMDAR Program being developed with First Air.

It was hoped that the First Air aircraft equipped with TAMDAR units could participate in the TAMDAR Great Lakes Fleet Experiment (GLFE) but this could not be possible due to the delays enumerated above. The Canadian Meteorological Center (CMC) has participated in a limited way to the TAMDAR Great Lakes Fleet Experiment (GLFE). CMC began receiving TAMDAR data on December 16, 2004 and monitoring the wind and temperature data in terms of quality, availability and usefulness in the forecast process. The results of monitoring by CMC confirm the TAMDAR data are generally of good quality except for some concerns about a small positive wind bias (Zaitseva, 2005).

Finally there is an additional challenge when dealing with aircraft operating in the northern domestic airspace. These aircraft are required to fly on either true north headings or destination grid headings, rather than magnetic headings. In practice it seems that only destination grid navigation is used for commercial aircraft as the direction to true north changes fairly rapidly in the high latitudes as the lines of longitude converge. In addition magnetic compass navigation becomes very unreliable in the high latitudes. Not only can the north magnetic pole move by as much as 80 km per day but large magnetic variance, magnetic dip (the lines of magnetic force pointing into the earth) can also be significant. This is anticipated to play an important role in degrading the wind reported from the Arctic area and investigations on how to best eliminate or mitigate this are being pursued.

5. 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.

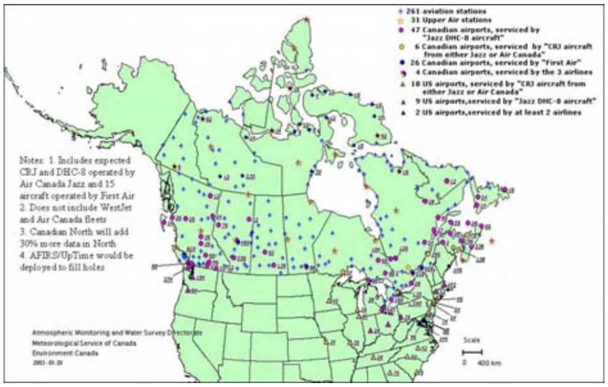

Figure 5.1 Projected weekly frequencies of aircraft ascent and descent soundings once Air Canada Jazz and First Air AMDAR Program components are fully developed and operational. A small aircraft icon represents an airport part of MSC's Aviation Surface Weather Network, a star a Canadian radiosonde site, 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 had 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 dedicated system being developed with 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.

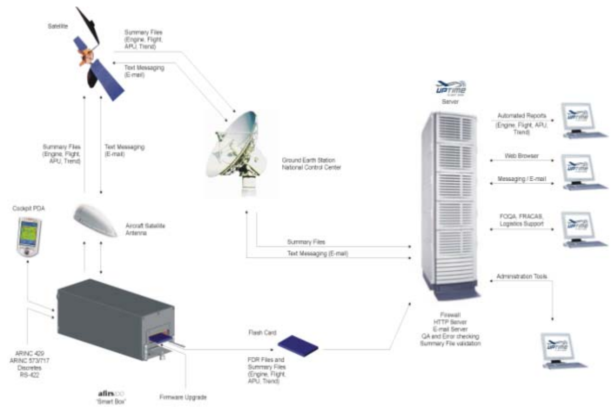

Figure 5.2 Schematic of the AeroMechanical Services AFIRS/Uptime architecture as component of the Canadian AMDAR Program being developed with the smaller air carriers.

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 by the end of March 2006 with deployment on up to six B737-200 combi aircraft from Canadian North servicing the Arctic (www.cdn-north.com).

AMDAR data from 2 DHC-8 aircraft from HawkAir servicing part of British Columbia and from 2 B737-200 from Canadian North servicing the Arctic have been communicated to CMC (Figure 5.3) but are of very poor quality. The challenge is that the smaller air carriers operate older aircraft, avionics, navigation, communications and sensing systems. Therefore the only way to be successful in deploying AMDAR on the smaller air carriers using the AMS AFIRS/Uptime system would be to enhance AFIRS/Uptime with low-cost and reliable sensing components. This is the intent of a submission to the New Canadian Search and Rescue (SAR) Initiatives Fund for a three-year project that would also develop the capacity by

CMC to process and assimilate moisture data provided by aircraft.

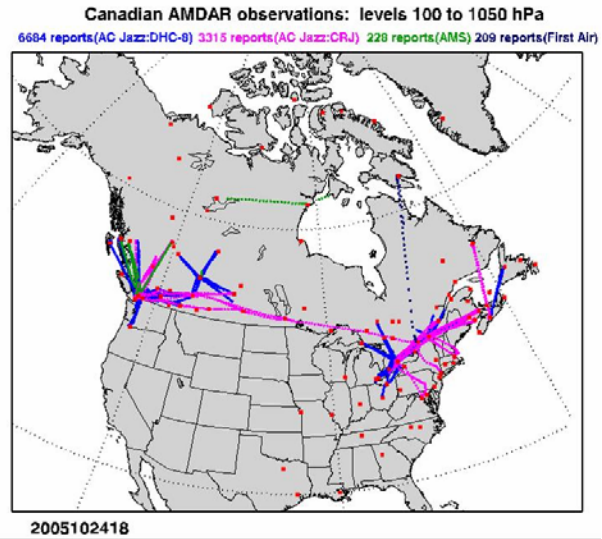

Figure 5.3 Canadian AMDAR data received by CMC over a 6-hour window centered at 18 UTC on 24 October 2005. Data from aircraft equipped with AMS AFIRS/Uptime system are in green.

Once reliable and good quality data are produced from the AMDAR system based on the enhanced AFIRS/Uptime system, the Meteorological Service of Canada will establish a long-term agreement with AeroMechanical Services for the provision of AMDAR data from the clients that will operate over otherwise data sparse areas. 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, the Meteorological Service of Canada and Transport Canada.

The challenge with wind obtained from aircraft operating in the northern domestic airspace described in section 4 above also applies to some clients of AMS, such as Canadian North. In the context of the SAR NIF proposal, AMS intends to partner with a professor from the Department of Geomatics of the University of Calgary working on precision inertia reference devices using MEMS technology (microelectric gyros and accelerometers), with the intend to solve the problem of heading in the high latitudes.

6. OTHER AMDAR DEVELOPMENT ACTIVITIES

Members of the Canadian AMDAR Program Implementation Team (CAPIT) have been very active in conducting Science & Technology activities and impact studies relevant to the development of the Canadian AMDAR Program, in promoting AMDAR to various interest 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. This section provides an update on some activities additional to the development of the basic Canadian AMDAR Program.

NAV CANADA (www.navcanada.ca) have studied the AMDAR Business Case on aviation benefits that was submitted to them on 22 February 2005 and are now seriously considering the possibility to contribute to the enhancement of the Canadian AMDAR Program starting on 1st September 2006. The Business Case is seeking a contribution for the development and on-going costs associated with enhancing the Canadian AMDAR Program with the reporting of turbulence and icing, and its expansion over remote areas. If NAV CANADA makes the decision to contribute, the plan for the first year is to implement turbulence and icing reporting from the CRJ-200 and CRJ-705 aircraft from Air Canada Jazz, and to develop an AMDAR capacity, including the reporting of icing and turbulence, out of three new flight inspection aircraft that NAV CANADA is in the process of acquiring. These aircraft are very attractive to the Canadian AMDAR Program as they spend most of their time (around 70%) at low level around Canadian airports in various locations. It is anticipated that the new aircraft will have datalink and SATCOMM capabilities and that TAMDAR units will be used. Over the coming years development associated with NAV CANADA will gradually diminish while operations associated with the life cycle management of dedicated systems and data communications will increase.

Another important recent development is the enrollment of WestJet Airlines Ltd. (www.westjet.ca) in the Canadian AMDAR Program. WestJet is a rapidly growing low-fare Canadian airline operating across Canada. WestJet started operations in 1996 with three B737-200 aircraft and is now operating a fleet of 57 B737 aircraft, mostly Next-Generation (NG) aircraft, to 35 destinations in North America. The fleet should grow to up to 94 B737-NG aircraft in 3-5 years. The B737-NG aircraft are being deployed with an upgraded Honeywell FDAMS/ACMS system on which the AMDAR software would have to be developed. The WestJet AMDAR system will be based on ACARS as with Air Canada Jazz (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 (www.sabre.com) flight reservation system such that the same AMDAR C&C that was developed for Air Canada Jazz could potentially 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 (www.aircanada.com) is also a member of CAPIT but, because of major internal difficulties, they have not been able to join the development of the Canadian AMDAR Program. Air Canada is the largest 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 ERJ-175 and 45 ERJ-190 in the short-term 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.

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.

7. SUMMARY

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 data communication fronts:

- a conventional ACARS-based VHF datalink (Air Canada Jazz, and later WestJet, Air Canada…)
- an alternative AMDAR system based on LEO ISAT/TAMDAR/Internet for First Air
- an alternative low-cost AMDAR system based on AeroMechanical Services Ltd. AFIRS/Uptime datalink 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 temperature and wind data from 61 aircraft from Air Canada Jazz are being distributed on the GTS and CMC assimilates the data from the 25 CRJ-200 aircraft into its NWP models. The AMDAR-capable fleet is expected to increase to over 130 aircraft by April 2007, which will include a mixed fleet of 15 aircraft from First Air covering northern Canada. Efforts to enhance the AFIRS/Uptime datalink system with proper sensing components and to enroll more air carriers such as WestJet and Air Canada are being actively pursued.

The First Air aircraft equipped with TAMDAR units has not participated in the TAMDAR Great Lakes Fleet Experiment (GLFE) due to delays largely of technical nature. However the Canadian Meteorological Center (CMC) has been participating in a limited way and has confirmed that the TAMDAR data are generally of good quality except for some concerns about a small positive wind bias (Zaitseva, 2005).

8. ACKNOWLEDGEMENTS

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