WORLD METEOROLOGICAL ORGANIZATION

WMO AMDAR PANEL
(Fifteenth Session)

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(14.X.2012)

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PROJECTS, PLANNING AND WORK PROGRAMME

Development and Maintenance of the Aircraft Observing System QMS

Data Impacts

(Submitted by Gilles Fournier)

SUMMARY AND PURPOSE OF DOCUMENT

Provides a progress report on the impact of AMDAR observations.

INFORMATION ITEM

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

WMO SPONSORED WORKSHOPS ON THE IMPACT OF VARIOUS OBSERVING SYSTEMS ON NWP

1. In document 4.4.9(2) Dr. Ralph Peterson provides a history of the results of studies on the impact of AMDAR observations on global Numerical Weather Prediction models. He concludes that results of studies show that although satellite microwave observations have the largest influence on 24 hours global forecasts with their global, all-weather coverage, AMDAR observations have become a critical component of operational NWP systems around the world. Although AMDAR data have their greatest influence in the areas and around the levels where they are most abundant, their impact on forecasts extends to 48 hours and beyond. Local impacts can be greater at shorter ranges in areas of higher data density.

2. WMO sponsored workshops are held every 4 years, the latest one, i.e. the fifth one, in Sedona, Arizona, USA on 22-25 May, 2012. The first workshop was held in Geneva in 1997 and the second one in Toulouse in 2000.

3. Presentations and final reports of last 3 workshops can be found at:

- (http://www.wmo.int/pages/prog/www/OSY/Reports/NWP-5_Sedona2012.html)
- (http://www.wmo.int/pages/prog/www/OSY/Reports/NWP-4_Geneva2008_index.html)
- (http://www.wmo.int/pages/prog/www/GOS/Alpbach2004/Agenda-index.html).

4. On the results of the Sedona workshop Mr David Helms provided the following general findings:

- AMDAR continues to increase in its contribution to predictability relative to all other observing systems, and now rivals satellite data (global IR and microwave sounders and GPS-RO) for total contribution to NWP predictability.
- AMDAR's impact to global model is increasing.
- AMDAR is contributing more observations (increasingly moisture), and the quality assurance and data assimilation systems are improving thereby making better use of AMDAR data.
- The studies show where the temporal and spatial gaps and redundancies are located.

5. In particular the presentation by Stan Benjamin et al. (2012), entitled 'Impact of upper-air and near-surface observations on short-range forecasts from NOAA hourly assimilation cycles (RUC and Rapid Refresh)' showed the results of extensive OSEs performed for a winter and two summer seasons using RUC/RAP for 3-12h forecast impact over the US. Among others, results from the study show that aircraft data are the most important observations overall for short-range forecasts in the troposphere (10-20% reduction for 6h forecast error for T/V/RH), but also that they are far from sole key observing system. For RUC OSEs, RAOBs are #2 importance overall while for RAP OSEs (with advanced satellite data assimilation (GSI)) there are broader contributions evident from various observing systems (GPS-PW, surface, RAOB. This presentation is available at http://www.wmo.int/pages/prog/www/OSY/Meetings/NWP5_Sedona2012/2a1_Benjamin.pdf.

6. A document on the outcome and recommendations of the Sedona workshop on the impact of various observing systems on NWP was presented at the seventh session of the Implementation/Coordination Team on the Integrated Observing System (ICT-IOS), held in Geneva on 18-22 June, 2012 (see http://www.wmo.int/pages/prog/www/OSY/Meetings/ICT-IOS7/documents/ICT-IOS-7-Doc.6.8_2_NWP_Workshop-outcome.doc). The document provided the preliminary report of

the workshop and observed that the series of WMO workshops on data impact has proved very successful providing substantial input for reviewing the Statements of Guidance for Global and High-resolution NWP, the Vision of the GOS for 2025 and the ET-EGOS IP.

STATUS OF DATA IMPACT PAPERS INVOLVING AMDAR

7. Mr David Helms also provided the following very useful "running" summary of sensitivity studies that include AMDAR, indicating that it is very difficult to do literature searches for AMDAR impacts as each researcher seems to use a difference acronym for AMDAR (ACARS, MDCRS, AIRCRAFT, AIREP, etc).

Model Impact Meta Study
Updated:
25 Sep 2012
Sensitivity Studies - Observing System Ranking

Author/Model	Sample Period	Domain	AMSU-A	AIRS	IASI	Cloud Drift Winds	Aircraft (AIREP/MDCRS)	RAOB (TEMP)	Buoy (drifting)	OSVW	Profiler	Radar (VAD)	GPS-Met	GPS-RO	Surface Land (Mesonet)
Benjamin/RUC	2007	CONUS	x	x	x	7	1	2	x	x	3	4	5	x	6
Benjamin/RAP	2011	CONUS	x	x	x	7	1	2	x	x	6	4	5	x	3
LaRoche/GEM 60hrs	2007	CONUS	3				1	2	x	x	x	x	x	x	x
LaRoche/GEM 60hrs	2007	N.America	3				2	1	x	x	x	x	x	x	x
Ratier/UKMET	unknown	N.Hemi	1-?	1-?	1-?	5	4	3	6						
Cardinali/ECMWF	2006-2007	Global	1	2	x	8	4	6	5	7	9	x	x	x	x
Cardinali/ECMWF-FEC	2011	Global	1	3	4	6	2	7	*	*	*	x	x	5	8
Cardinali/ECMWF-DFS	2011	Global	1	3	2	8	4	5	*	*	9	x	x	6	7
Ota/NCEP GSI-EnKF	2010	Global	2	6	4	7	1	3	9	*	x	x	*	5	8
Gelaro/GEOS-5	2007	Global	2	6	4	5	3	1							
Gelaro/NOGAPS	2007	Global	1			2	4	3		7					
LaRoche/GEM 60hrs	2007	N.Pacific	1				2	3	x	x	x	x	x	x	x

X = not assessed
Ranking outlier
* small or no impact

STATUS OF DATA IMPACT STUDIES INVOLVING ENVIRONMENT CANADA

8. At the Vertical Atmospheric Profiling Workshop of Environment Canada held in Toronto on 24-25 April, 2012, Stéphane Laroche (2012) provided a presentation entitled 'Observing System Experiments : Impact of Satellite, Radiosonde and Aircraft Data over North America'.

9. Results from an OSE study performed from 2007 data were reiterated. This OSE was presented in 2 articles of Atmosphere-Ocean of the Canadian Canadian Meteorological and Oceanographic Society in 2010 (Laroche, S. and R. Sarrazin (2010)).

10. The authors provided the following lessons learned from these OSEs and other Impact Studies:

a. In general, the information from most existing observing networks is not fully extracted in the Environment Canada data assimilation systems
b. Radiosonde and aircraft data are still the main observing networks that contribute to the short-range forecast skill over North America. However, less than 50% of these data are currently assimilated
c. Satellite radiances over land and sea ice areas provide little benefit to short-term EC forecasts, mainly because only channels not sensitive to surface characteristics are assimilated over these regions

11. The following proposed upgrades and improvements to Environment Canada's data processing for radiosonde and aircraft data were recommended:

a. Increased volume of data: selection of observations according to model levels
b. Revised observation error statistics (the revised observation errors are based on the method of Desroziers et al. (2005). In general, the authors found that the observation errors should be greater for radiosonde when the volume of data is increased. The new errors for aircraft data are now comparable to those for radiosonde. They were previously overestimated. This confirms that aircraft data are now as good as radiosonde data).
c. Revised rejection criteria for radiosonde data based on those used at ECMWF
d. Horizontal drift of radiosonde balloon taken into account
e. Bias correction scheme for aircraft temperature reports (warm biases of aircraft temperature observations are particularly important at the cruising level, reaching 0.5 to 1.0 C in average. Although temperature biases depend on the temperature probe, aircraft type and other factors, the authors consider a single bias correction profile for all aircraft temperature data. This approach has the advantage of being simple, and is able to capture the main part of this systematic source of errors).

12. A statement that was made at the Vertical Atmospheric Profiling workshop was that satellite data will become less valuable as the grid spacing of the NWP models decreases – more ground-based and airborne data will be needed.

13. It is interesting to note that many methods, other than OSE and OSSE, that diagnose the impact of assimilated observations on a given analysis or forecast now exist. They include Degrees of Freedom for Signal (DFS), Analysis Sensitivity, and Adjoint-Based Procedures. Each has its specific pros and cons and is usually complementary to each others. For example OSEs are used to estimate the data impact in a forecasting system, whereas the DFS calculations are used to assess the impacts of various observing systems on analyses. Despite of that, Lupu, C. et al (2012) investigated whether DFS calculations show some agreement with results obtained from OSEs, using the OSEs performed at the Meteorological Service of Canada (MSC) for the period of January and February 2007 interested in the evaluation of the North American observing networks (see Laroche, S and R. Sarrazin (2010)). The DFS was thus used as a diagnostic to estimate the amount of information brought by subsets of observations in the context of OSEs. In particular, it was demonstrated that on the short-range forecast, DFS and OSEs provide a somewhat comparable assessment of the impact of radiosonde or aircraft observations. However, the variation of the DFS percentages and forecast impacts (FIs) from one region to another agrees better for the aircraft data. The results also show that removing some observation types from the assimilation system influences the effective weight of the remaining assimilated observations, which may have an increased impact to compensate for the removal of other observations. The response of the remaining observations when a given set of observations is denied is illustrated comparing DFS calculations with the observations' impact. DFS

show how observing system data can be complimentary (or redundant). DFS also show how the high temporal resolution of aircraft data is better exploited by 4DVAR assimilation systems than 3DVAR.

STATUS OF PANEL ACTIVITIES ON DATA IMPACT

Impacts and Benefits Document for Aviation (Work Programme Task 5.1.2)

14. The AMDAR Panel Management Group and the Secretariat has again approached several potential consultants with the Statement of Work to develop an AMDAR Impacts and Benefits to Aviation document, seeking to address this important task, however, a suitable and willing contractor is still yet to be found to undertake the work.

15. **Recommendation**: The Aircraft-based Observations Programme should again seek to address the undertaking of this work in 2013.

Impact Studies Assessment (Work Programme Task 5.1.4)

16. The AMDAR Panel (Session 14, 2011) determined that the Panel should support and fund the commissioning of a paper summarizing the historical and current status of AMDAR data on meteorological applications or applications areas. During late 2011 through the first quarter of 2012, a Statement of Work was developed for this task and the Secretariat developed a Special Services Agreement (SSA) contracting Dr Ralph Petersen from the University of Wisconsin in May 2012. An extract from the SSA, which describes the scope of the work is provided in Appendix I.

17. Associated with this task, Dr Petersen also agreed to contribute to the Fifth WMO Workshop on the Impact of Various Observing Systems on NWP, Sedona, May 2012, under Session 2, Regional Forecast Impact Studies on Impact of AMDAR Aircraft Observations. The abstract for the presentation made is provided below:

> S3 AMDAR, Dr Ralph Petersen from the University of Wisconsin.
>
> ABSTRACT
>
> Over the past two decades the Aircraft Meteorological Data Relay (AMDAR) Programme has rapidly and consistently grown as it has expanded from producing several thousands observations of wind and air temperature over a limited coverage, to one that now produces nearly three hundred thousand observations per day with considerably enhanced and expanded global coverage and includes a growing number of moisture observations. Such a growth in the output of a particular observing system has had a significant and evolving impact on NWP systems and operational forecasting applications that has been tested and gauged at various times over this period. This talk will present a summary of the results and conclusions of the observing systems tests and applications assessments of AMDAR data and make recommendations for future work in this area.

18. Dr Petersen also recently contributed an article to the AMDAR Panel Newsletter summarizing some of the impact material being analysed under the SSA: https://sites.google.com/a/wmo.int/amdar-news-and-events/newsletters/volume-4-october-2012#TOC-Feature-Technical-Article---Summary-of-Recent-Studies-on-the-Impact-of-AMDAR-data-in-NWP-Forecasts

RECOMMENDATION FOR FUTURE DATA IMPACT STUDIES

19. The Panel to continue to monitor and review publications and activities associated with AMDAR data impact studies: this is an on-going activity.

20. Study the benefits to meteorological applications of a wider deployment of water vapour sensing within the AMDAR programme, as well as those of TAMDAR systems and of ADS-B (Mode S), and conduct further impact studies on human forecasting and other aircraft data users such as aviation operators. These would also support business cases with aviation partners.

References:

Benjamin, S., E. James, H. Lin, S. Weygandt, S. Sahm and B. Moninger, 2012: Impact of upper-air and near-surface observations on short-range forecasts from NOAA hourly assimilation cycles (RUC and Rapid Refresh), presentation given at WMO workshop on the impact of various observing systems on NWP, Sedona, May 2012 (http://www.wmo.int/pages/prog/www/OSY/Meetings/NWP5_Sedona2012/2a1_Benjamin.pdf)

Desroziers, G., L. Berre, B. Chapnik and P. Poli, 2005: Diagnosis of observation, background and analysis-error statistics in observation space, *Q.J.R. Meteorol. Soc.*, 131, 3385-3396.

Laroche, S. and R. Sarrazin, 2010: Impact Study with observations assimilated over North America and the North Pacific Ocean on the MSC global forecast system Part I: Contribution of radiosonde, aircraft and satellite data. *Atmos. Ocean*, 48, 10-25.

Laroche, S. and R. Sarrazin, 2010: Impact Study with observations assimilated over North America and the North Pacific Ocean on the MSC global forecast system Part II: Sensitivity experiments. *Atmos. Ocean*, 48, 26-38.

Laroche, S. and R. Sarrazin, 2012: Observing System Experiments: Impact of Satellite, Radiosonde and Aircraft Data over North America. An internal presentation provided at the Vertical Atmospheric Profiling Workshop of Environment Canada held in Toronto on 24-25 April.

Lupu, C., P. Gauthier, and S. Laroche, 2012: Assessment of the Impact of Observations on Analyses Derived from Observing System Experiments. *Monthly Weather Review*, Volume 140, Issue 1, 245-257.

Proposal to Document the Impact of AMDAR data

Dr Ralph Alvin Petersen, Principal Investigator (PI)

Abstract

This project proposes to provide a published documentation that will summarize the history, quality, use and impact of data obtained from the Aircraft Meteorological Data Relay (AMDAR) Program. It will include as much of the historical data impact material as possible with the intent of providing a strong and reasonably definitive background document that can be referenced in the literature and by potential new users of the AMDAR systems. The documents will provide background material on the program, highlight the most important results already available and include discussion of the value of water vapor observations. It also will include information obtained by the PI from a variety of sources while he is representing the utility of AMDAR at the Fifth WMO Workshop on the Impact of Various Observing Systems on NWP.

Background

Over the past two decades the Aircraft Meteorological Data Relay (AMDAR) Program has rapidly and consistently grown as it has expanded from producing several thousand observations of wind and air temperature over a limited coverage, to one that now produces nearly three hundred thousand observations per day with considerably enhanced and expanded global coverage, including a growing number of moisture observations. Such a growth in the output of a particular observing system has had a significant and evolving impact on NWP systems and operational forecasting applications that have been tested and gauged at various times over the past two decades. This effort will provide a summary of the results and conclusions of the observing systems tests and applications assessments of AMDAR data and suggest recommendations for future work in this area.

Proposed Documentation Scope

In the 1980, two separate programs were established to collect meteorological observations from commercial aircraft with the objective of improving weather forecasts, especially those which affected aviation operations. In the US, a mechanism was established to provide observations already being collected internally by participating airlines through the Aircraft Communications Addressing and Reporting System (ACARS). The data were intended primarily for use in Numerical Weather Prediction (NWP) models, both on regional and global scales. By the late 1990s, the North American Observing System study group performed an evaluation of the value of automated aircraft reports relative to and as a supplement for rawinsonde observations over the U.S. The results of that study also identified the need to include moisture data in addition to the temperature and wind reports included in the aircraft data.

About the same time, the WMO began development of the AMDAR program and a necessary mechanism to follow up the previous Aircraft to Satellite Data Relay (ASDAR) program. While the ASDAR program relied on observations transmitted from aircraft by specialized communications systems, the AMDAR program built upon experiences primarily in the U.S., Australia and Europe to facilitate the collection of automated meteorological observations taken on commercial aircraft without the need for special instrumentation.

The two efforts now fall under the umbrella of the WMO AMDAR program. Although a number of studies have been made discussing the accuracy, utility and impact of these data reports to both operational forecasting and NWP, no single pier-reviewed paper exists which can be used as a standard reference by researchers and potential new users of the AMDAR systems and their data.

The Principal Investigator (PI) proposes to compile such a document to be published in a refereed American Meteorological Society (AMS) journal and possibly in the WMO bulletin, as well as future issues of the AMDAR Newsletter. This will include collecting results from research efforts conducted by the PI and other scientists in the US and global NWP and aviation forecasting communities. The PI will also demonstrate the utility of the AMDAR data at the upcoming 5th WMO Workshop on the Impact of Various Observing Systems on NWP. A detailed outline of the proposed paper is discussed in the next section.

The PI's experience in assessing the accuracy and representativeness of automated aircraft observations in previous field programs (e.g., WVSS-I and WVSS-II evaluation, ARM-CART Winds, AERI, etc.) makes him an excellent candidate for this task. In addition, the PI has been actively involved in establishing, supporting and evaluating the AMDAR program from its inception. Most recently, the PI lead the US assessment of the automated water vapor sensing program, which is seeing increased operational use in the US and Europe.

Proposed Documentation Outline

Impact of AMDAR Wind, Temperature and Moisture Data in Operational Forecasting

Submit to:

AMS Bulletin (Including Cover?) and possibly WMO Bulletin (Including Cover?)

1 History of operational AMDAR data provision
  - a. ASDAR
    - i. Objective – Data for FGGE – WWW
  - b. Other Pre-AMDAR Panel data collection efforts
    - i. ACARS
      1. Objective – Improve NWP Wind / Temp Forecasts for Aviation
      2. Cooperation between private (airlines) and public (NWS) sectors
    - ii. Other efforts (Australia, UK, Germany)
  - c. AMDAR Panel Era
    - i. E-AMDAR
    - ii. Expansion to Southern Africa, Asia, South America
    - iii. Adding Water Vapor observations

2 Current status
  - a. Airline/Aircraft/Coverage examples
  - b. Quantity
    - i. En-route
    - ii. Ascent/Descent
  - c. Quality
    - i. Chamber Tests
    - ii. CIMSS co-locations (Wind/Temp/Water Vapor)
    - iii. NCEP / E-AMDAR operational Quality Control results

3 Uses
  - a. Subjective Forecaster Use
    - i. Aviation and General Forecasting
      1. Web-based Display Systems
  - b. Objective NWP Use
    - i. Data Assimilation
      1. Traditional “on time” use
      2. Continuous “off time” use

4 Subjective Impact Assessments
  - a. NWS Forecaster applications
  - b. AMDAR Panel evaluations

5 NWP Impacts
- a. Removal of all AMDAR Data
  - i. Zapitockny results and previous ECMWF Data Denial Tests
    1. Regional and Global assessments
  - ii. RUC Impacts (past and recent)
  - iii. Recent ECMWF Impact Evaluations
- b. Removal of Ascent/Descent Data
  - i. Short-Range Forecasts
    1. Compare Ascent/Descent data impact to en-route data only
    2. Show impact of data relative to changes in model
- c. Comparison with other wind observing systems
  - i. Regional OSSE assessing impact of moisture flux observations
  - ii. Impact vs. Cost of different observing systems

6 Future
- a. Program Expansion
- b. New Observations
  - i. Turbulence(?)

7 Summary
- a. Recap
- b. Future Applications