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DATA QUALITY MANAGEMENT

AO Data Quality Management, Assessment of Current Practices and Recommendations for Improvement

(Submitted by Gilles Verner, lead, Brad Ballish, Xiaohua Yang and Jitze van der Meulen)

SUMMARY AND PURPOSE OF DOCUMENT

Summary of current situation regarding the framework and practices for Aircraft Observations Quality Monitoring and Management.

To define and recommend improvement and changes to the Data Quality Management and Monitoring Framework

ACTION PROPOSED

1. The Workshop is invited to note the information and discuss the issues identified in the document.
2. The Workshop is invited to consider the recommendations made in the document and to develop additional ones as required for improvement to the Aircraft Observation Data Quality Management Framework.

References:

1. MANUAL ON THE GLOBAL DATA PROCESSING SYSTEM, WMO NO. 485, VOL. 1 (2010) ATTACHMENT II.9, PROCEDURES AND FORMATS FOR EXCHANGE OF MONITORING RESULTS: http://www.wmo.int/pages/prog/www/DPS/Monitoring-home/mon-procedures.htm#Aircraft%20Data

2. Report of the Joint Meeting of the AMDAR Panel (14th Session) and CBS ET-AIR (3rd Session).

Background information

Monitoring of the quality of meteorological observations became an essential component of NWP data assimilation systems in the late 1980's. Even at that time, it was clearly demonstrated that comparisons of observations against NWP model background fields could be very useful in identifying various issues related to observational data quality. Initially many issues were identified with station metadata (such as errors in station location, elevation, and so on), or to data processing problems, or even to the data assimilation systems themselves. The key point here being the ability to data quality monitoring to detect problems, and hopefully with some further investigation, discussion and cooperation with partners such as data producers and managers, find a way to correct the issues in order to get better quality data and improve their utilization.

NWP Centres also quickly realized that exchange of monitoring information between them was also very beneficial as cross comparison is a very useful mechanism to confirm that the issue is with the data (or associated processing) and not the utilization or assimilation system. Also to coordinate the efforts in feeding back the information to data producers, a certain number of Lead Centres were designated by the WMO with the responsibility of monitoring the quality of specific types of data. Initially ECMWF was designated for the monitoring of radiosonde observations, the UKMO was designated for the monitoring of marine stations, and NCEP was designated for the monitoring of satellite and aircraft data. Later on, a few other Lead Centres were designated for monitoring the quality of land surface data.

Procedures and criteria for the quality monitoring, as well as for the exchange of the monitoring information between participating centres and data providers have evolved over the years, and have been well documented by the " WMO expert group on GDPS solutions for data quality monitoring " and are available on the WMO GDPS web site : http://www.wmo.int/pages/prog/www/DPS/Monitoring-home/mon-procedures.htm which also includes links to most data monitoring web sites. In addition the AMDAR Panel maintains some pages with information more specific to aircraft observations, such as reception statistics, links to monitoring pages and reports, web sites and viewers. The page can be found here: http://www.wmo.int/amdar/AMDARStatistics.html

Over the recent years, numerous examples of AO data quality issues have been discussed at various meetings, reports, in presentations, and so on. However there is no archive of such issues with associated diagnostics and corrective actions that have been taken to fix these issues. As part of a data quality management framework, it would be very useful if some tracking mechanism or simple archive of AO data issues could be maintained, for example through a wiki interface.

In preparation for this meeting a certain number of **Issues** with respect to AO Data Quality Management have been identified and are discussed below in more details. Where possible some **Recommendations** are also made to improve on those issues. A complete list of the issues as well as a summary of the exchange of information between participants is included as Appendix A to this document.

Current practices and framework for aircraft observations data quality monitoring and management.

1. Comparisons of aircraft observations against model background fields are done routinely by most NWP centres and should be considered as a critical part of aircraft observations QC. Various tools, including interactive (or not) web sites, are used at many centres. Information can be displayed in many forms, such as profiles, time series, phases of flight, by aircraft, by types of aircraft, by

AMDAR program, and so on. Such different displays are very useful to identify data issues, when they occur, and to assist in trying to resolve the issues being investigated. An important aspect for this to be more effective is having access to a variety of metadata information on the aircraft and programs. As an example, trying to match a specific data issue (e.g. wind errors) to a type of aircraft or avionics software can be quite challenging indeed as this information is not readily accessible.

2. Most centres also use these model-aircraft differences to compute various statistics, including list of suspect aircraft according to some criteria. Some standardized criteria have been established (see link above) but there are differences between centres in the criteria, time period for establishing or refreshing the list of suspect stations, and so on. Some of these differences are to be expected as NWP models and assimilation systems are all different and use observational data differently. And many centres provide a public web display of some of the monitoring information.

3. It is the understanding of the authors of this document, that such comparisons between aircraft observations and model fields *are not* done anywhere *before* data are distributed on the GTS. It is debatable whether performing such comparisons before distribution should be done. There would be some problematic issues to take care of, such as contingency plans when the model fields are not available, or for occasions when the model quality is questionable. However, satellite agencies such as NOAA NESDIS and Eumetsat now regularly make use of NWP model fields in processing satellite measurements before distribution to users. A good example of this is the processing of satellite imagery for the generation of atmospheric motion vectors. And data quality flags are also distributed with the processed satellite data and may be used by users as they wish.

4. One important aspect of quality monitoring information is the regular feedback of the information to data producers, program managers, airlines, and other interested parties. This is essential in ensuring that issues with data will be corrected when they arise. Although this feedback is presently done to some degree (e.g. in Canada we provide a monthly summary to AC Jazz), a universally available (and interactive) data monitoring display system would be very useful to program managers, airlines and other clients. Ideally, such a display system would need to organize the contribution of monitoring information from multiple centres. As was mentioned by Xiaohua Yang*: " it would be great for global NWP modellers if the monitoring information from contributing global/LAM centers about aircraft data can get aggregated into a realtime guidance about aircraft data anomaly, and secondly such coherent report can be sent to airlines as feedback."*

5. Regarding the current monthly aircraft monitoring reports generated by many centres, some suggestions were to generate more frequent reporting and alerting, such as a daily report. As well longer term (greater than one month) statistical information would be useful.

6. Other features suggested for incorporation into the global data management system are:
   - An online database of all historical data, data metadata and system metadata.
   - An online database of all comparisons made against all references (NWP, radiosonde, etc); probably a statistical record would be adequate (e.g. daily means of differences).
   - A data processing and QC system for processing some data streams before provision on the GTS or within the database. Should it be in series or in parallel with the real-time data stream?

7. Here is a short list of some monitoring web sites from contributing centres:

http://www.wmo.int/amdar/AMDARStatistics.html/
http://amdar.noaa.gov/java/
http://amdar.noaa.gov/RR_amdar/
http://www.ecmwf.int/products/forecasts/d/charts/monitoring/conventional/aircraft/

http://collaboration.cmc.ec.gc.ca/cmc/data_monitoring/ (username: monitoring; password: CMC)
http://collaboration.cmc.ec.gc.ca/cmc/data_monitoring/CAMDAR/ (same username and password)

RECOMMENDATION: The new international Aircraft Observation Data Management Framework should:

- **Recognize comparisons of aircraft observations to NWP model background fields as a critical component of AO QC.**
- **Consider whether or not such comparisons should be done *before* AO data are exchanged on the GTS.**
- **Promote and support the development of a universally available (and interactive) AO data monitoring display system, for use by program managers, airlines, NWP centres and other clients.**
- **Consider more frequent reporting of monitoring reports and reject lists, including a daily report and possibly an alerting mechanism.**

Documentation of past, present and future issues with aircraft observations.

8. Such documentation would indeed be quite useful, not only through the monitoring of data (e.g. bugs in instruments, systematic position issues in SAA program, etc.) but also on the hardware side as well (e.g. the T sensor installed on DHC-8 and Q400, SAS stopped its deployment of AMDAR on DHC-8, AC Jazz added dual T sensor to bypass the OEM sensor). Also the issue with the smoothing algorithm, the truncation in processing systems such as Flight Data Management, etc. Also tracking issues with ADS data (e.g. recent s/w change at NAV CANADA resulting in missing data).

9. An archive with a QC flag system tagged to specific observations and preferably a data archive would be the ideal solution. At the least, a record of documented issues held by the designated global monitoring center is required and would be a natural candidate for doing this.

RECOMMENDATION: If an archive of Aircraft Observation is developed as part of the new AO Data Management Framework, consideration should be given to include records of documented aircraft data quality issues and associated corrective action.

"Continuous" monitoring and (semi-)automated QC alarm system, and experience from other data types.

10. Semi-automatic information exchanges about data counts, usage, quality etc. between various NWP and data management centres on a regular basis would be useful for all involved. Some of this information is available from monitoring web sites but is passive. However, should we also consider a near-real time system which would again semi-automatically spot potential data problems as they are made available to users and raise "alarm/event". For example, we can refer to a case last year when 24 hour old AO were sent by mistake. Formally all looked OK and analysis swallowed a good part of the old data. However, looking at the first guess departures there were a lot of "probably correct"/"probably incorrect" flagged data. In the confusion ECMWF blacklisted them for a few days. Such information could be exchanged (by an alert or otherwise) with others (and potentially a designated centre) in order to get the problem corrected.

11. Similarly there were recent events with ADS data in the North Atlantic, where data counts dropped, came back and dropped again. This was caused by two different issues but specific contacts were needed to identify and fix the problems, as data producers were not aware of the issues. It is to

be expected that monitoring centres and program managers will still need to be proactive and contact data producers in order to fix data issues (availability, quality, etc.).

12. Presently, most if not all NWP systems perform a significant amount of data QC and screening as part of their data assimilation system. We can therefore assume that NWP systems do not rely heavily on external or upstream QC systems. That being said, there are certainly improvements that can be made to pre-GTS-transmission QC systems.

13. Is it conceivable and feasible to have centres that are mandated to carry out international QC of aircraft data and then provide the data to data users? Data Users could elect whether to take the "raw" stream (i.e. from the GTS as they do now) or the QC'd stream. The QC'd stream could be pulled rather than pushed.

RECOMMENDATION: Semi-automatic near real time monitoring information such as data counts, missing data, higher than normal rejects by the assimilation system, etc. should be exchanged regularly (monthly or more frequently as required and agreed to) between designated centres and data managers (and/or producers). This could include and Alarm/Event system.

RECOMMENDATION: Consideration should be given to the designation of centres to carry out international QC of Aircraft Observations (WMO and ICAO), possibly before insertion on the GTS.

Standardization of aircraft observations (WMO and ICAO) reporting processes, practices, distribution (codes), monitoring, etc.

14. During such discussion, it must be recalled that ADS (and other ICAO sources of data such as with MODE-S datalink) data is an ICAO-owned and sourced data set. Theoretically, it should be transmitted from aviation to meteorology in the standard ICAO format that this data is transmitted in and then, for the process of transmitting it on the GTS, it could conceivably be decoded and re-encoded into something more appropriate to meteorology such as BUFR. If we were to move to a centralized data processing system, then we could more rigidly standardize both the process and the data format. Any rules should be based on the same rules as for AMDAR data, which ensure that the data is traceable to a source and an aircraft system. Whilst we don't necessarily need to prevent data being put on the GTS, we could at least develop a standard that would allow data users to know that it has the WMO stamp-of-approval.

15. It is conceivable that ADS (and other ICAO sources of aircraft) data might be data that could be managed by just 1, 2 or 3 international data processing centres prior to GTS transmission. This would certainly allow better quality control. According to ICAO regulation, it is the WAFCs that have responsibility for receiving and transmitting data on the GTS but this is not necessarily practical to enforce. And their mandate would not include decoding, QC and re-encoding. If we wanted them to do this, we would probably have to resource it. Otherwise, we could ask that they retransmit to another centre in the ICAO format where it would be processed, QC'd, and reformatted into standard WMO format (BUFR). It would be important that enough metadata be available to the processing centre as to enable appropriate QA/QC processes as discussed before.

16. It is probably not possible to standardize everything between WMO and ICAO aircraft observations. For example, the ICAO air to ground data formats are an ICAO matter only. As long as WMO knows the format, and that the metadata information required for QA/QC processes, as well as the reporting mechanisms to fix data issues, are established and well known, then we would have

gone a long way in improving the ICAO aircraft observation data management issues. But it is probably quite feasible to develop and establish an aircraft observation data processing model that could be applicable to both WMO and ICAO aircraft observations.

RECOMMENDATION: That the data processing model developed as part as the Aircraft Observation Data Management Framework be established in such as way as to accommodate the processing and distribution of WMO and ICAO observations.

RECOMMENDATION: That distribution of ICAO automated aircraft observations on the GTS be done using WMO approved format (BUFR) with an appropriate template (similar to the AMDAR ones) for clear identification of the source of the data (ADS, MODE-S, Aircraft ID, etc.).

Data quality issues of smaller regional type aircraft (e.g. turboprop) and expansion of AMDAR into regional carriers.

17. Expansion of AMDAR into smaller regional carriers would be very, very beneficial. Not only would we get more data over less travelled routes and remote locations, but also as they take off and land a number of times on a daily bases we would get vertical profiles as well. In Canada we were expecting tremendous impacts when we first established the AMDAR program with regional carriers. However we found the hard way that the situation with smaller aircraft could be quite different from that of larger jet aircraft.

18. On the quality side, the Canadian experience with AC Jazz regional jet aircraft data was very good and was similar to data from major carriers. However, with data from their turboprops the story was very different. The issue was a strong temperature bias due to the temperature sensor being mounted on the fuselage, which eventually was corrected by the airline (Jazz added dual T sensors to bypass the OEM sensor). A further problem was that biases differed depending on the flight phase (ascent vs descent). The belief was that it was because the avionics software uses the data averaging values typical for jet aircrafts which have different ascending and descending rates from the turboprops. However, since this issue could not be easily corrected as well as other issues related to funding eventually resulted to the removal of data from the turboprops from the Canadian AMDAR program.

19. In Canada we still believe that fixing this issue as well as the T sensors on DHC-8 and Q-400 aircraft would be a great achievement and would help to contribute to the expansion of AMDAR into remote locations. With the right navigation and T sensor system, and the right data processing, the data quality of large jet and regional aircraft should be comparable. It would be very beneficial if other experience in dealing with issues of regional carriers or smaller aircraft could be shared.

RECOMMENDATION: Further experience and studies with data quality aspects from smaller airplanes and regional carriers are needed. Current AMDAR programmes could be encouraged to perform (as permitted) trials with smaller airplanes.

How to perform aircraft track-checking?

20. What is the best way to perform aircraft track-checking. For example, different centers all said their QC did not work well with the group track-check errors we were having with South African aircraft. Besides position errors, we need smart codes to detect stuck data.

21. The Australian system used an algorithm that calculated an aircraft "apparent velocity" and then identified anomalous or unrealistic aircraft velocities. It tended to find the same errors identified by NCEP.

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Appendix –A

Information collected before the Meeting on subject 6:

AO Data Quality Management, Assessment of Current Practices and Recommendations for Improvement

1) Consider model-aircraft differences, accumulated over days, weeks, months, generated at NOAA/GSD and perhaps other centers (Bill)

- I had suggested considering using model background fields as a critical part of AMDAR QC. This is done at several centers; here is an overview of what we do in this regard here at GSD.

We have a number of tools that compare aircraft data with model background fields. Some of the tools are restricted to those people who have access to our real-time AMDAR display at http://amdar.noaa.gov/java/. If you want access and don't have login credentials, let me know and I'll provide them.

At http://amdar.noaa.gov/RR_amdar/ we present statistics from matched differences between AMDAR data and 1h forecasts from the Rapid Refresh model (which became the operational RAP model at NCEP this past May 1st).

We present data for all altitudes, and for 3 altitude bands: surface to 710 hPa, 700 - 301 hPa, and 300 hPa and above. The data are interactively sortable, so aircraft having the largest differences with the model background field can easily be identified.

We also provide time-series data for individual aircraft. This has enabled us to see exactly when data from a particular aircraft went bad, and also identify particular circumstances (such as ascents or descents) when data disagree with the model.

Also linked from this page is http://amdar.noaa.gov/RR_amdar/view/, which shows a plan view of aircraft data in the RR domain, compared with model background fields. The data on this page can be displayed in a variety of ways. In particular, AMDAR and model vector wind difference barbs can be shown. These can clearly reveal occasional bad data points, such as the one shown by the cursor: the aircraft with GSD ID 8476 is showing a 122 kt difference with the RAP background field due, probably, to an incorrect wind direction (reported as from 7 degrees when the model is reporting a wind from 180 degrees) (figure amdar2.gif, attached). AMDAR wind barbs themselves can be displayed (amdar1.gif, attached), as can model wind barbs. These can reveal large-spatial-scale model-AMDAR differences, which are generally due to the model mis-locating synoptic weather patterns.

We have a similar set of pages showing differences between AMDAR and GFS data. Whereas the RAP produces hourly analyses and background fields, the GFS produces these only four times a day. So, we compare AMDAR data with GFS 3-h forecasts at 3, 9 15, and 21 UTC. We use a +/- 60 minute window from the valid time, so we're not able to compare AMDAR data taken at all times with GFS forecasts. Nonetheless, because the GFS is a global model, we can compare aircraft with the model background world-wide.

Using 7-day RAP-AMDAR statistics, we generate AMDAR reject lists every day. These daily-updated reject lists were used operationally in the RUC model (predecessor to the RAP), and are

currently updated periodically for the RAP.

We believe the on-going, automatic generation of AMDAR-model statistics, and the automatic generation of reject lists, has been helpful in improving model performance. We also believe that interactive tools such as those described here can be helpful in the ongoing monitoring of aircraft quality. (Bill Moninger)

- Thanks Bill, very useful information and great displays. Your site is still used by Canadian meteorologists for real-time displays. (Our functionality with the Ninjo workstation should be available soon, if it isn`t already).

Concerning the use of NWP model fields, is anyone aware of a Centre or data processing system which does some comparisons of Aircraft measurement against NWP fields BEFORE distributing the data on the GTS? In your opinion is this something that should be considered (or even feasible), assuming that it would not result in unecessary delays in data distribution.

When we implemented the Canadian AMDAR system here a few years ago, we did comparisons against NWP fields for a few months before we decided to distribute the data, and some data issues were corrected or improved before distribution. But once the distribution started on the GTS, those data that were disseminated on the GTS were distributed before the comparisons against NWP fields. I am assuming that it is a similar situation for other AMDAR programmes. (Gilles Verner)

- I'm not aware of anyone making comparisons with model background fields *before* data are distributed on GTS. That strikes me as problematic. You'd have to have contingency plans for when the background field isn't available at all, or when it's from several hours before (as sometimes happens, at least here, if the previous run didn't occur). More insidious, you'd have to plan for occasions when the model is badly out of whack.

I'm much more comfortable with daily, weekly, or longer AMDAR-model statistics. For those, transient model problems are less of a problem.

As I mentioned, we do update our reject lists every day, based on 7-day statistics. These could certainly be applied to AMDAR data before it is distributed. (Bill Moninger)

- In my opinion, the ideal aircraft obs global data management system would include the following features:

1. An online database of all historical data, data metadata and system metadata.

2. An online database of all comparisons made against all references (NWP, Radiosonde, etc) - probably a statistical record would be adequate (e.g. daily means of differences).

3. An online set of data quality flags for each observation and parameter able to be set and re-set by external QC systems.

4. A universally accessible data monitoring display system, which would require a data quality control backend.

5. A data monitoring display system available to programme managers and airlines.

6. A data processing and QC system for processing some data streams before provision on the GTS or within the database.

The question is: how much of this is practical or feasible now and in the future?

If we could have an online data processing and archive, should it be in series with the real-time data stream or in parallel? (Dean Lockett)

- Dean's list is quite comprehensive and well thought. I guess the main point here is to organise such in a global, coordinated way, (many of these, pts 1-4, already exist in some fashions, aren't they). For most of the points, my feeling is that these are 'good to have' but mostly un-essential.

About the last question, I guess it is more practical for the latter: parallel, so that NWP centers will continue to use their existing data stream (via GTS?), but adding a well-coordinated, 'universal' QC information source for aircraft data for real time quality flagging. How much shall such QC flagging do is up to debate/discussion though.

nr 5 above seems important to me, because feedback information about systematic bias, short-term anomaly can result in timely detection and correction of instrumental/calibration error.

How to organise the contribution of multi-centers is unclear to me. Probably one can start with some well-functioned monitoring facilities at some global centers such as NOAA/NCEP, ECMWF and CMC to see how good the monitoring information match each other. But in principle, it is probably important not to attach a universal QC information to any particular NWP model. Leave eg. the part concerning model first guess check etc to models themselves to handle.

I am however a bit skeptical about nr 6. If we can assure models with good monitoring either via internal or external QC monitoring/statistical training, a real time QC before GTS entry may not be that necessary. (Xiaohua Yang)

2) Is there a need to keep track of (some) examples of AMDAR data issues and how they have been identified or corrected? This could be useful for new programmes. (Gilles)

- An archive with a QC flag system tagged to specific observations and preferably a data archive would be the ideal solution. At the least, a record of documented issues held by the designated monitoring center is required. (Dean Lockett)

- Yes, very much so, not only through the monitoring of data (e.g. bugs in instruments, systematic position issues in SAA program) but also on the hardware side as well (e.g. the T sensor installed on DHC-8 and Q400, SAS stopped its deployment of AMDAR on DHC-8, Jazz added dual T sensor to bypass the OEM sensor. Also the issue with the smoothing algo, the truncation in processing system such as Flight Data Management…). Also what about tracking issues with ADS data (e.g. recent s/w change at NAV CANADA resulting in missing data). (Gilles Fournier)

- A global QC system on aircraft data would be natural candidate for doing such.

On one hand, regular/periodic monitoring report is generated out of input from contributing NWP centers, and on the other hand, interaction with data providers are activated and documented to tract handling of such exchange. (Xiaohua Yang)

3) Information content (humidity etc) (Drasko)

- Item covered under Doc. 5, issue 5 (additional elements) (Gilles Verner)

4) Relevant experiences and practices for other observational data types? (Xiaohua)

- Does anyone know of an online universally available data sources? I believe that some "research" datasets are managed globally, e.g. GAW ozone? (Dean Lockett)

- No experience from my side. . (Xiaohua Yang)

5) Experiences and practices about aircraft data usage, monitoring and report at global NWP centers (ECMWF, NCEP...) and at the various data management centers (EUMETNET-E-amdar...)? (Xiaohua)

- It was great to read the information that Bill provided about your AO data display/monitoring system. The community I work on, (HIRLAM and ALADIN LAM modelling consortia in Europe) have been working with assimilation of AO data but I am not aware of any detailed work and actions so far to take into account of quality monitoring per aircraft. As Dean seem to suggest, the NOAA system seem to be quite unique in its extensive coverage and functionality about tracking of AO data delivery and quality status. European modellers are well aware of the observation data monitoring webpage hosted by ECMWF, http://www.ecmwf.int/products/forecasts/d/charts/monitoring/conventional/aircraft/

which provides a near-real time information about data coverage and averaged analysis diagnosis (in terms of departures between model guess and observation, between observation and final analysis etc.), but these displayed information, to my knowledge, are only averaged ones, not per aircraft to be of direct applicability for QC purpose in data assimilation. On the other hand, out of daily statistics it is of course feasible to use information similarly derived as in the NOAA site to make the monitoring information directly useful in data assimilation. Drasco may clarify whether this is already the daily practice at ECMWF. In the LAM consortia I work, we have similar real time monitoring about AO data coverage and analysis diagnosis (these are unfortunately not accessible via internet), and our assimilation system does have the infrastructure to absorb monitoring information via blacklisting etc., but personally I am not aware of such work done about AO in our system. It is inspiring to learn about the NOAA AO monitoring system. I'm interested to see if my system can make use of such publicly available information, or develop something similar in our own system. (Xiaohua Yang)

- I believe that most if not all NWP Centres are doing a similar type of monitoring of aircraft data (and of all other types of data that are assimilated), including some form of data blacklisting of aircraft that do not meet some criteria. There are probably some differences in the criteria, time period for establishing or refreshing the list of suspect stations, and so on. And many Centres provide a public web display of some of the monitoring information.

Here at CMC we do this on a monthly basis, and have done so for some years now. We do have a monitoring web site on the public web but it needs to be password protected for internal reasons. The web site is: http://collaboration.cmc.ec.gc.ca/cmc/data_monitoring/ the username is: monitoring and the password is: CMC (in upper case).

The main pages shows links to data coverage charts for our various assimilation runs (global and regional, short cut-off and long cut-off, some with a distribution by model time step in the 4D-Var), and then we have links for data quality monitoring for the various data types that are assimilated. Of particular interest for this meeting is the link to the monitoring of aircraft data. That page

includes all kinds of comparisions against model first guess, daily time series, monthly averages, list of suspect aircraft (by month), monitoring by codes (AMDAR, BUFR, AIREP, ADS), by AMDAR program (e.g. E-AMDAR, MDCRS, etc), by aircraft, by airline, by phase of flight, with about one year of results on-line. The blacklisting for data assimilation is updated once a month.

However, our monitoring web site is passive, contrary to the GSD site provided by Bill, which has quite extensive interactive displays and monitoring capabilities, which is quite useful indeed. (Gilles Verner)

- I was anticipating some inventories and I am already quite satisfied with the information exchange concerning monitoring activities at NOAA, CMC and ECMWF. As already expressed in previous email, it would be great for global NWP modellers if the monitoring information from contributing global/LAM centers about aircraft data can get aggregated into a realtime guidance about aircraft data anomaly, and secondly such coherent report can be sent to airlines as feedback.

These said, I am not sure whether or not a mechanism of such kind does already exist, especially at AMDAR/E-amdar/ACARS programme level etc. Apology if such indeed is already the case. (Xiaohua Yang)

- (Semi)-Automatic information exchanges about data counts, usage, quality etc. Between various NWP and data management centres on a regular basis would be useful for all involved. However, should we also look for a (near)-real time system which would again (semi)-automatically spot potential data problems as they are made available to users and raise "alarm/event". Here, I refer to a case last year when 24 hour old AO were sent by mistake instead. Formally all looked OK and analysis swallowed a good part of it. However, looking at the first guess departures there were a lot of "probably correct"/"probably incorrect" flagged data. In the confusion we blacklisted them for a few days. (Drasko Vasiljevic)

- Agreed, Also occasional daily contacts as needed when specific issues arise. Example the exchange between some Centres recently when there was a sudden decrease in the availability of ADS data over the Northern Atlantic. Data producers were unaware of the issue until they were contacted. (Gilles Verner)

6) Can all aircraft data programmes (WMO AMDAR and ICAO AIREP/ADS) share common reporting processes and practices, including codes? (Gilles)

- Standardisation is continuing but it is difficult to standardise all aspects end-to-end. For instance, should we be standardising air to ground data formats? It makes sense to standardise data exchange formats certainly. Exchange of metadata will need to be standardised as should monitoring data if we want to exchange it. (Dean Lockett)

- That would be best but harmonization between WMO and ICAO is the major challenges as data clients are different. Is it ICAO that would have to move towards WMO's requirements or the opposite? (Gilles Fournier)

- Let me remind about MODE-S data. I am optimistic about potential of such data, so some kind of forward-looking planning/guidance from WMO side would be desirable to avoid confusion in the future. (Xiaohua Yang)

7) Can we come up with rules for putting ADS data on the GTS? (Brad)

- It must be recalled that ADS data is an ICAO-owned and sourced data set. Theoretically, it should be transmitted from aviation to meteorology in the standard ICAO format that this data is transmitted in and then, for the process of transmitting it on the GTS, it could conceivably be decoded and re-encoded into something more appropriate such as BUFR. If we were to move to a centralised data processing system, then we could more rigidly standardise both the process and the data format. Any rules should be based on the same rules as for AMDAR data, which ensure that the data is traceable to a source and an aircraft system. Whilst we don't necessarily need to prevent data being put on the GTS, we could at least develop a standard that would allow data users to know that it has the WMO stamp-of-approval.

ADS (and other ICAO sources of aircraft) data might be data that could be managed by just 1, 2 or 3 international data processing centres prior to GTS transmission. This would certainly allow better quality control. According to ICAO regulation, it is the WAFCs that have responsibility for receiving and transmitting data on the GTS but this is not necessarily practical to enforce. And their mandate would not include decoding, QC and reencoding. If we wanted them to do this, we would probably have to resource it. Otherwise, we could ask that they retransmit to another centre in the ICAO format where it is processed and QC'd. (Dean Lockett)

- Again, MODE-S is an interesting potential data source that needs some attention from WMO side, I think. (Xiaohua Yang)

8) "Continuous" (or as it happens) data screening and monitoring (Drasko)

- This has to be balanced against the need to provide aircraft data in as near-to-real time as possible. But, there are certainly improvements that can be made to pre-GTS-transmission QC systems.

Do NWP systems rely heavily on external, upstream QC systems?

Is it conceivable and feasible to have centres that are mandated to carry out international QC of aircraft data and then provide the data to data users? Data Users could elect whether to take the "raw" stream (i.e. from the GTS as they do now) or the QC'd stream. The QC'd stream could be pulled rather than pushed. (Dean Lockett)

- I am not aware of 'centres that are mandated to carry out international QC of aircraft'.

In general I don't think the systems I am familiar with can be said to rely 'heavily' on external/upstream QC as formulated by Dean. Our assimilation algorithm assumes a universal observation error statistics for aircraft data and a screening procedure perform gross check about measurement data (location, height, time, data category, thinning, black or grey-listing etc.), which is followed by model first guess check, and multiple steps during minimisation including steps on bias correction, variational quality control etc. (Xiaohua Yang)

9) Consider differences in data quality between large jet aircraft and smaller regional type aircraft (e.g. turboprops). Expansion of AMDAR into smaller regional carriers may be quite beneficial in some areas. (Gilles)

- Impacts would be tremendous. Access to TAMDAR and fixing T sensor on DHC-8 and Q400 would be great achievement contributing a lot to this. With the right navigation and T sensor system, and the right data processing, the data quality of large jet and regional should be comparable. (Gilles Fournier)

- I am unfamiliar with this topic but Gilles advice sounds reasonable! (Xiaohua Yang)

- The data quality difference may be an issue and that is certainly something to be addressed perhaps by assigning different obs errors. Expansion of AMDAR into smaller regional carriers would be very, very beneficial. Not only would we get more data but also as they take off and land a number of times on a daily bases we would get vertical profiles (sonde like) too. (Drasko Vasiljevic)

- My comment was based on our experience in Canada with Regional Carriers. We were expecting significant benefits from expansion of the AMDAR programme into less travelled routes, hoping to obtain very useful vertical profiles at more remote locations (in Canada you don't have to go too far to be remote). Also regional aircraft often fly at lower altitudes than jet aircraft, making their flight level data quite useful, even on more frequently travelled routes.

With AC Jazz we found out that their regional jet aircraft provided very good data (similar to data from major carriers), however the story was quite different for their turboprops. The major issue was related to a strong temperature bias which was finally traced back to the way the temperature sensor (which had of course been calibrated and evaluated in the lab) was mounted on the fuselage. This was eventually corrected (by the airline, not the aircraft manufacturer), but then although the global biases were quite small, we realized that biases were quite different between various phases of flight (similar amplitude but different sign between ascent and descent). We believed that this was caused by the avionics software, as the vertical averaging of data used values typically used by jet aircraft, which climb (and descent) at different rates than turboprops. Fixing this would have required an update to the avionics which was never done. And today we no longer receive any data from the turboprops.

We had another experience with a small company and they also had significant, although different, data quality issues.

I am not certain that such issues can be easily corrected using a NWP bias correction scheme, or by assigning different observation errors in the data assimilation system. Especially when the data are in remote locations.

I would be interested in learning about the experience from other AMDAR programmes in dealing with data issues of regional carriers. I do believe that if such issues can be fixed (or bias corrected, etc) that there is much to gain by expanding AMDAR into regional carriers. (Gilles Verner)

10) (Semi-)Automated QC alarm system (Drasko)

- It has always been assumed this was a national program responsibility, however, if global or international systems could have this feature it would certainly be useful - particularly for new programs or for countries with limited resources. Additionally, if QC is international, information can also be provided to those countries receiving data through an arrangement for data provision with another program. (Dean Lockett)

- Agreed. And this may be best done by pulling together monitoring information at multi-centers. At minimum, NWP centers can inject information about aircraft data in suspision into own system to prevent undesirable impact. (Xiaohua Yang)

11) What are optimal criteria for when an aircraft should be added to the reject-list? (Brad)

- We will probably need to summarise what criteria are being used by those centres that do monitoring - NCEP, ECMWF, CMC, KNMI, Meteo France and others? (Dean Lockett)

- For aircraft monitoring reports, I am still following the plans we developed around 2002 at a WMO meeting at the ECMWF. I usually do not have time to look at reports from other centers. I have seen the French report with just one vertical level. I am sure there are many different styles of reports. The standard one that I am following has a problem that it often lists aircraft as suspect because they had a small number such as one gross report out of a small number such as 20 reports total in one month. Often aircraft with small numbers of wind reports are listed as suspect, but I make a statement such as "but there were too few reports to be sure of a real problem". Therefore, I think we need more complex rules based on counts and stats so that I do not need to make such statements. In addition, are the standard rules too lenient for when an aircraft's stats are suspect? Right now, a temperature bias needs to be at least 2.0 degrees to be considered suspect. Should we make this limit smaller? What is an optimal reject-list criterion for temperature biases? If we can decide on that, then that decision should affect the suspect standards. (Brad Ballish)

- This probably is best left to a working group consisting of experts at contributing centers. (Xiaohua Yang)

12) What is the best way to perform aircraft track-checking. For example, different centers all said their QC did not work well with the group track-check errors we were having with South African aircraft. Besides position errors, we need smart codes to detect stuck data. (Brad)

- The Australian system used an algorithm that calculated an aircraft "apparent velocity" and then identified anomalous or unrealistic aircraft velocities. It tended to find the same errors identified by NCEP. (Dean Lockett)

13) All participants should review in advance the monthly aircraft monitoring reports we all make. What is good and bad about what is done now, and how can we improve them or even standardize them for easy comparisons? (Brad)

- More frequent reporting and alerting would be useful, e.g. a daily report.

Long term (i.e. greater than 1 month) statistical information would be useful. (Dean Lockett)

- This is very good point. I just checked my own consortia and found the last blacklist data for aircraft data had its last entry in year 2009. Something quite silly and shameful I admit. The first thing I'd do now is gather information from NCEP/CMC/ECMWF to update our system, and work on our own regular updating from now on.

For this community, it would be great if indeed active players like global NWP centers start to exchange regular/automated monitoring information to enable a central composite of 'universal' aircraft QC report for all to access, including those of data providers. (Xiaohua Yang)

- OK for standardization, that would help review by all participants, as long as there is an agreement on what is essential to present. (Gilles Fournier)

14) What visual graphics/diagnostics can be utilised for data monitoring? (Brad)

- Long-term plots of bias for sensor drift detection would be useful.

Aircraft-to-aircraft comparison of bias as a plot can be useful (done by KNMI for E-AMDAR).

Aircraft-to-aircraft comparison would be useful.

Aircraft-to-radiosonde comparison would be useful and offer a triangulation of comparison information. (Dean Lockett)

- These all sounds quite fine, but suitable for long term calibration-type studies, not immediately suitable of daily application in NWP, I assume. (Xiaohua Yang)

15) We really need to develop a system for documentation of both historical and future problems with aircraft data. People doing climate studies get negative impact from past problems that no one publicly documented. For example, when we had hundreds of day old AMDAR reports from Australia, most people know nothing about it or how to figure these things out. Maybe we should have a website for this purpose? (Brad)

- See comment above. (Dean Lockett)

- Agree. So this argue again for some kind of 'univeral' information centers under WMO umbrella, probably. (Xiaohua Yang)