WORLD METEOROLOGICAL ORGANIZATION

WMO AMDAR PANEL WORKSHOP ON AIRCRAFT OBSERVING SYSTEM DATA MANAGEMENT

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NEW, IMPROVED DATA MANAGEMENT FRAMEWORK FOR AIRCRAFT OBSERVATIONS

Review of WMO WWW AO Guidance Material and Recommendations for Updating

(Submitted by Frank Grooters)

SUMMARY AND PURPOSE OF DOCUMENT

Analysis of the relevant sections of the Manual and Guide to the GOS to determine deficiencies in relation to AO DM.
Changes and recommendations are proposed that might be necessary in light of a new or changed DM Framework.

ACTION PROPOSED

1. The Workshop is invited to note the information contained in the document.
2. The Workshop is invited to discuss, amend where necessary and present, for further action, the recommendations to the WMO AMDAR Panel and CBS ET-AIR.

References:

1. Guide to the Global Observing System, Edition 2010 (WMO No. 488)
2. Manual on the Global Observing System, Edition 2011 (WMO No. 544)
3. WMO Guide to Meteorological Instruments and Methods of Observation, 7th Edition (WMO No. 8)
4. Annex 3 to the Convention on International Civil Aviation – Meteorological Service for International Air Navigation, 16th Edition, 2007

THE GUIDE TO THE GLOBAL OBSERVING SYSTEM

1. The Guide to the Global Observing System (GOS), Edition 2010, contains one paragraph (Part III – The surface-based Subsystem, paragraph 3.4) referring to Aircraft Meteorological Stations (see Appendix 1).

2. This paragraph is a general description of an Aircraft Meteorological Station based on a revised text of the 1998 edition of the Guide, and includes besides text about AMDAR added at the revision, reference to AIREP, ASDAR and ACARS as Aircraft Observing Systems (AO).

3. Regarding the various sub-systems under AO, the Guide makes reference to other key material: the AMDAR Reference Manual (WMO No. 958) for the AMDAR System, the Guide to Meteorological Instruments and Methods of Observation (WMO No. 8) for Instrumentation and Data Processing, the Technical Regulations, vol. II (WMO No. 49) in relation to ICAO requirements for the selection of observing sites, and the Manual on the GOS (WMO No. 544) for the frequency and time of observation.

4. No reference is made to the Manual on the GTS (WMO No. 386) for Communication and the manual on Codes (WMO No. 306) describing the AMDAR code (FM42 Alphanumeric Codes and FM94 Binary Codes).

5. In the communications section reference is made to the use of the IDCS (for ASDAR) and aircraft VHF links, but not in connection to AMDAR.

6. It can be concluded that

a. the paragraph on Aircraft Meteorological Stations in the Guide to the GOS (Part III, 3.4)is outdated and insufficiently updated in the 2010 Edition;
b. this paragraph needs total re-writing, reflecting the current status of the AMDAR Programme;
c. the update should not be done without reviewing and updating the Reference Material referred to in the paragraph.

THE MANUAL ON THE GLOBAL OBSERVING SYSTEM, VOLUME 1-GLOBAL ASPECTS

7. In the Manual on the GOS, Volume I, paragraph 2.5 under Part III (Surface-based Subsystem) describes Aircraft meteorological Stations, totally in line with the Guide to the GOS.

8. As in the Guide to the GOS, this paragraph is outdated. It furthermore only follows and refers the requirements of the International Air Navigation, as stated in the Technical Regulations, Volume II (WMO No. 49) which is in fact a copy of the ICAO Annex III (Meteorological Service for International Air Navigation), see appendix 2.

9. This paragraph is mainly focusing on AIREPS, with the consequence that the description of the required elements is insufficient when AMDAR should be added as the missing observing system.

10. When AMDAR (and perhaps other non-WMO AO like ADS and Mode-S) would be included, update and additional information is also needed regarding Quality Monitoring and (HR) NWP requirements (resolution, thresholds).

11. It is advised that paragraph 2.5 Aircraft Meteorological Stations is re-written to reflect the current situation in Aircraft Observation Systems.

12. In addition it is also advised not to copy ICAO requirements as WMO requirements, but make reference to requirements expressed by other international organizations.

13. When updating/re-writing paragraph 2.5, also the relevant elements in paragraph 3 (Equipment and Methods of Observation, see Appendix 2) which are currently only for Surface Observations should be updated and enlarged to accommodate to AO.

THE MANUAL ON THE GLOBAL OBSERVING SYSTEM, VOLUME I1-REGIONAL ASPECTS

14. In Volume II of the Manual on the GOS, the Regional requirements of the various observing systems are described.

15. Only for three Regions and for Antarctica AMDAR is mentioned as a required (or encouraged) observing system and under different headings (see Appendix 3).

16. For RA-I (Africa) a clear requirement is given, which is missing for (parts of) RA-III (South America) and RA-V (mainly Central America and the Caribbean) either as “needed because of missing Radiosonde data” or as “supplementary data to Radiosonde data”.

17. The Manual on the GOS, Volume II, should also be updated, with the assistance (or with requirements provided by) the Regions concerned. It is advised that for RA-II (Asia), RA-IV (North and Central America, Caribbean) and RA-VI (Europe) specific requirements are added for the regions above the Polar Circle as a contribution to the WMO Polar Activities.

18. It should be noted that Australia is providing regularly AMDAR data from Antarctica during the Summer period.

Appendix 1: Guide to the GOS – Aircraft Meteorological Stations

PART III (III-57)
3.4 **AIRCRAFT METEOROLOGICAL STATIONS**

3.4.1 **General**
An aircraft meteorological station is an aircraft in flight from which meteorological data are obtained by utilizing instruments and equipment installed for navigational purposes. The measured data can be supplemented by the observation of visual, weather phenomena and by subjective or objective assessments of turbulence and icing. When compiled into reports, they constitute a vital part of the global database. The reports are of particular value over areas where other upper-air data are scanty or lacking. They can provide information on atmospheric phenomena such as wind, temperature and turbulence along horizontal and vertical profiles on a much smaller scale than do other routine observing systems. Thus, they also constitute a valuable source of information for the issuing of reports on significant weather phenomena and for special investigations and research. The collection and evaluation of post-flight reports is also an invaluable data source. Subject to timely receipt, processing and dissemination, they can be of use for forecasting purposes. Over recent years it has become evident that valuable meteorological data can be obtained from large areas of the world by collecting data from aircraft fitted with appropriate software packages. To date the predominant sources of automated aviation data have been from aircraft-to-satellite data relay (ASDAR), and more recently, from aircraft equipped with aircraft communication addressing and reporting systems (ACARS).

Aircraft communication addressing and reporting systems (ACARS) transmit data between aircraft and ground stations via radio and satellite communication systems. Such systems offer the potential for a vast increase in the provision of aircraft observations of wind, temperature and humidity.

The various systems—ASDAR, ACARS—are collectively named AMDAR, which stands for aircraft meteorological data relay. They are making an increasingly important contribution to the observational database of the World Weather Watch of the World Meteorological Organization. It is envisaged that AMDAR data will inevitably supersede manual air reports (AIREP).

AMDAR systems operate on aircraft which are equipped with sophisticated navigation and other sensing systems. There are sensors for measuring air speed, air temperature and air pressure. Other data relating to aircraft position, acceleration and orientation are available from the aircraft navigation system. The aircraft also carry airborne computers for the flight management and navigation systems, by which navigation and meteorological data are computed continuously and made available to the aircrew at the flight deck.

In AMDAR systems, the data are further processed and fed automatically to the aircraft communication system for transmission to the ground, or alternatively, a dedicated processing package can be used on the aircraft to access raw data from the aircraft systems and independently derive the meteorological variables. In addition, these facilities are used to compile and transmit meteorological reports in real time. The messages contain wind speed and direction, air temperature, altitude, a measure of turbulence and the aircraft position.

The source data for meteorological observations require significant correction and complex processing to yield meteorological measurements representative of the free airstream in the vicinity of the aircraft. Although the data processing involved is complex, errors in reported wind and temperatures are comparable with those of radiosonde
systems. AMDAR observations can thus provide high-quality single-level data in cruise and detailed profile data up to cruise levels.

AMDAR observations where made can meet the resolution and accuracy requirements for global numerical weather prediction. Observations are restricted from commercial aircraft to specific air routes at cruise level and profile data are only available on climb or descent in the terminal areas. AMDAR observations are not made at standard times, and significant gaps in observations arise owing to the normal flight scheduling.

AMDAR profiles can be very useful for local airfield forecasting and are available during flight operations. This can be especially important during severe storm events.

For further details concerning AMDAR, please refer to the *Aircraft Meteorological Data Relay (AMDAR) Reference Manual* (WMO‑No. 958).

3.4.2 **Instrumentation and data processing**

The type of sensors used and their siting on board the aircraft are determined by the manufacturers and depend on the type of aircraft. For details concerning instruments, measurement and data processing on board aircraft, reference should be made to Chapter 3, Part II, of the *Guide to Meteorological Instruments and Methods of Observation* (WMO‑No. 8).

3.4.3 **Site selection**

The selection of observing sites is prescribed by the reporting procedures promulgated by the International Civil Aviation Organization and national aviation authorities. See [C.3.1.] 5, Volume II, *Technical Regulations* (WMO‑No. 49). These generally lead to an accumulation of data at reporting points fixed at intervals of 10° longitude or latitude along major air routes, with most altitudes being between the upper standard pressure levels, 300 hPa and 150 hPa.

Observations related to specified weather phenomena should be made wherever these phenomena are encountered.

Data obtained automatically during ascent or descent are related to the predetermined pressure increments and refer to the vicinity of the aerodrome of departure or arrival. However, owing to the geographical separation of sectors used for
approach and take-off and to the differences in descent and climb rates, systematic differences are to be expected.

3.4.4 **Observing and reporting procedures**

The observational data requirements to support international air navigation are contained in Volume II of the *Technical Regulations* (WMO‑No. 49). Details on the frequency and time of observations are given in 2.5.5 and 2.5.11, Volume I, Part III of the *Manual on the Global Observing System* (WMO‑No. 544).

3.4.5 **Communications**

ASDAR data are transmitted from the host aircraft via the International Data Collection System on board the Meteorological Geosynchronous Satellite System (METEOSAT, GOES-E, GOES-W, GMS). Ground stations are located in the USA, Japan and Europe where the received data are encoded into WMO AMDAR code and injected into the Global Telecommunication System.

The standards for aircraft VHF data-links have been established for ACARS and adopted by SITA (AIRCOM), ARINC, Air Canada (ACARS) and Japan (AVICOM). These five compatible systems provide coverage over most of the land areas of the globe through a network of remote ground stations.

Airlines operating international routes have contacts with appropriate service providers; for instance transatlantic operations require contracts with SITA, ARINC and ACARS. ACARS/AIRCOM is used mainly for automation of key airline applications such as maintenance, engine monitoring, flight operations and logistics support. Meteorological data are readily attached to down-linked messages and can be controlled by ground command or on-board programming. The data formats for down-linking meteorological reports through ACARS/AIRCOM are not standardized globally.

3.4.6 **Personnel and training**

Making meteorological measurements and observations on board the aircraft is a part of pilots' training in which National Meteorological Services should cooperate as far as possible.

3.4.7 **Quality standards**

For safety reasons, operators generally apply very high quality standards for measurements and reports. The quality of air reports has been found to be comparable with radiosonde data. For a single level, the reports are much more accurate than satellite wind and temperature data.

Systematic errors noticed during the evaluation of observations received at meteorological offices need to be identified; the malfunctioning unit should be located if possible, and the operator notified.

Procedures should be developed by the National Meteorological Services together with national airlines for continuously monitoring adherence to established reporting procedures, the quality of the reports and the adequacy of dissemination methods.

Appendix 2: Manual on the GOS, Vol. I – Aircraft Meteorological Stations

Manual on the GOS
Volume I, Part III, Surface Based Sub-System, (III-7)

2.5 **Aircraft meteorological stations**

General

2.5.1 Each Member shall arrange for observations to be made by aircraft of its registry operating on international air routes and for the recording and reporting of these observations.

Note: Further information on aircraft observations and reports may be found in the Technical Regulations (WMO-No. 49), Volume II – Meteorological Service for International Air Navigation, Part 1, [C.3.1.] 5.

2.5.2 Members accepting responsibility for collecting aircraft reports for synoptic purposes shall promptly make these available, in agreed code forms, to other Members.

2.5.3 Members should give special consideration to the use of an automated aircraft meteorological observing and reporting system.

2.5.4 Aircraft reports shall, at a minimum, satisfy the requirements of International Air Navigation (for details see the TechnicalRegulations (WMO-No. 49), Volume II – Meteorological Service for International Air Navigation, Part 1, [C.3.1.] 5).

Location and composition

2.5.5 The following aircraft observations shall be made:
(a) Routine aircraft observations during en-route and climb-out phases of the flight; and
(b) Special and other non-routine aircraft observations during any phase of the flight.

2.5.6 Routine air reports shall contain the following meteorological elements:
(a) Air temperature;
(b) Wind direction and speed;
(c) Turbulence;
(d) Aircraft icing;
(e) Humidity (if available).

In addition, reports of any volcanic activity observed by the flight crew shall be included.

2.5.7 Special aircraft reports shall be made whenever any of the following conditions are observed:
(a) Severe turbulence;
(b) Severe icing;
(c) Severe mountain wave;
(d) Thunderstorms, with or without hail, that are obscured, embedded, widespread or in squall lines;
(e) Heavy dust storm or heavy sandstorm;
(f) Volcanic ash cloud;
(g) Pre-eruption volcanic activity or a volcanic eruption;

In addition, in the case of transonic and supersonic flights:
(h) Moderate turbulence;
(i) Hail;
(j) Cumulonimbus clouds.

2.5.8 Routine aircraft observations should be made at the designated air traffic services/meteorological (ATS/MET) reporting points.

Note: Lists of designated ATS/MET reporting points are prepared by and available from International Civil Aviation Organization (ICAO) Regional Offices.

Frequency and timing of observations

2.5.9 When automated observing and reporting systems are available, routine observations should be made every 15 minutes during the en-route phase and every 30 seconds during the first 10 minutes of the flight.
2.5.10 When voice communications are used, routine observations shall be made during the en-route phase in relation to those air traffic services reporting points or intervals:
(a) At which the applicable air traffic services procedures require routine position reports; and
(b) Which are those separated by distances corresponding most closely to intervals of one hour of flying time.

2.5.11 Observations shall be made by all aircraft of meteorological conditions encountered during the take-off or approach phases of flight, not previously reported to the pilot-in-command, which in his opinion are likely to affect the safety of other aircraft operations.

2.5.12 Observations shall also be made by aircraft:
(a) If a meteorological office providing meteorological service for a flight makes a request for specific data; or
(b) By agreement between a Meteorological Authority and an operator.

1. Equipment and Methods of Observation

3.3.2 Atmospheric pressure

3.3.2.1 Barometric readings shall be reduced from local acceleration of gravity to standard (normal) gravity. The value of standard (normal) gravity (symbol gn) shall be regarded as a conventional constant. gn = 9.806 65 m/s

3.3.2.2 The hectopascal (hPa), equal to 100 pascals (Pa), shall be the unit in which pressures are reported for meteorological purposes.

Note: One hectopascal (hPa) is physically equivalent to one millibar (mb) and thus no changes are required to scales or graduations made in millibars in order to read them in hectopascals.

3.3.2.3 Atmospheric pressure shall be determined by a suitable pressure measuring device of uncertainty specified in the Guide toMeteorological Instruments and Methods of Observation (WMO-No. 8), Part I, Chapter 1, Annex 1.B.

3.3.2.4 In order for mercury barometer readings made at different times and at different places to be comparable, the following corrections should be made:
(a) Correction for index error;
(b) Correction for gravity;
(c) Correction for temperature.

3.3.2.5 Whenever it is necessary to compute the theoretical local value of the acceleration due to gravity, each Member shall follow the procedure given in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part I, Chapter 3, Annex 3.A.

3.3.2.6 Atmospheric pressure at a station shall be reduced to mean sea level, except at those stations where regional association resolutions prescribe otherwise.

3.3.2.7 The results of comparisons of national and regional reference standard barometers shall be reported to the Secretariat for communication to all Members concerned.

3.3.2.8 Regional comparisons of national standard barometers with a regional standard barometer shall be arranged at least once every 10 years.

3.3.2.9 Reference standards for comparison purposes may be provided by a suitable pressure measuring device that, generally, shall be of the highest metrological quality available at a given location or in a given organization from which measurements made there are derived.

3.3.2.10 In calibration against a standard barometer whose index errors are known and allowed for, tolerances for a station barometer stated in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part I, Chapter 3 should not be exceeded.

3.3.3 Air temperature

3.3.3.1 One of the following three main types of thermometer shall be used:
(a) Liquid-in-glass thermometer;
(b) Resistance thermometer;

(c) Thermocouples.
All temperature shall be reported in degrees Celsius.

3.3.3.2 An instrument height of between 1.25 and 2.0 m above ground is considered satisfactory to obtain representative air temperature measurements. However, at a station where considerable snow cover may occur, a greater height is permissible or, alternatively, a moveable support can be used allowing the thermometer housing to be raised or lowered in order to keep the correct height above the snow surface.

3.3.3.3 Thermometer screens should be constructed so as to minimize radiation effects and at the same time allow free influx and circulation of air.

3.3.3.4 Thermometers should be checked against a reference standard instrument every two years.

Note: The required uncertainties are given in the Guide to Meteorological Instruments and Methods of Observation (WMO No.8), Part I, Chapter 1, Annex 1.B.

3.3.3.5 For psychrometric purposes, thermometers shall be read to at least 0.1°C.

3.3.4 Humidity
Note: Definitions and specifications of water vapour in the atmosphere are given in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part I, Chapter 4,Annex 4.A.

3.3.4.1 In surface observations, at temperatures above 0°C values of humidity should be derived from the readings of a psychrometer or other instrument of equal or better accuracy.

3.3.4.2 If forced ventilation of psychrometers is used the airflow past the thermometer bulbs should be between 2.5 m/s and 10 m/s.

3.3.4.3 In surface observations the height requirements for humidity measurements shall be the same as for air temperature measurements.

3.4 **UPPER-AIR OBSERVATIONS**

3.4.1 At an upper-air synoptic station, atmospheric pressure, temperature and humidity (PTU) observations shall be made by means of a radiosonde attached to a fast-ascending free balloon.

Note: For detailed guidance on the radiosonde and balloon techniques, see the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8), Part I, Chapters 12 and 13.

3.4.2 Computations of upper-air observations shall be based on the relevant definitions of physical functions and values of constants given in the Technical Regulations (WMO-No. 49), Volume I – General Meteorological Standards
and Recommended Practices, Appendix A.

3.4.3 At an upper-air synoptic station, upper-wind observations should be made by tracking of the fast-ascending free balloon by electronic means (e.g. radio theodolite, radar or NAVAID).

Note: At stations where the skies are generally clear, upper
winds may be determined by optical tracking of a balloon.

3.4.4 Each upper-air station should have an appropriate manual of instructions.

3.4.5 Each upper-air synoptic station shall promptly report on any changes of the types of radiosonde and windfinding systems in operational use to the Secretariat for communication to all Members at least on a quarterly basis.

3.4.6 International comparisons of widely used radiosonde types shall be made at least once every four years.

3.4.7 New radiosonde types should be compared with sondes accepted as having the most stable and accurate performance before adoption for operational use.

3.4.8 At a meteorological reconnaissance aircraft station, electronic means (NAVAID) should be used when a vertical profile of upper winds is to be determined by means of a dropsonde.

Appendix 3: Manual on the GOS, Vol. II – Regional Aspects

Region I (Africa)

1.4. AIRCRAFT METEOROLOGICAL DATA RELAY PROGRAMME
Facing the degradation of the state of the network of upper-air stations in Africa, and in order to significantly increase the number of upper-air reports for the purpose of improving forecast quality, each Member of the Association is requested to urge its national airlines to join a regional or sub-regional aircraft meteorological data relay (AMDAR) programme.

Region II (Asia)

2.1.3 Upper-air synoptic observations

Region III (South America)

Region IV (North America, Central America, Caribbean)

4.1.3 Upper-air synoptic observations

Region V (South-west Pacific)

5.1.3 Upper-air synoptic observations

5.4 OTHER IN SITU OBSERVING SYSTEMS
5.4.2 AIRCRAFT METEOROLOGICAL DATA RELAY PROGRAMME
In order to significantly increase the number of upper-air reports for improved analysis and forecasts, Members of the Association are requested to explore opportunities for obtaining reports from their national airlines as part of regional or subregional aircraft meteorological data relay (AMDAR) programmes.

Region VI (Europe)

6.4 OTHER IN SITU OBSERVING SYSTEMS
6.4.2 AIRCRAFT METEOROLOGICAL DATA RELAY PROGRAMME
Members of the Association are strongly encouraged to become actively involved in the aircraft meteorological data relay (AMDAR) programme, either directly, or through a shared programme such as E-AMDAR, and thus support an important element of the Global Observing System (GOS).

Antarctic

7.1.3 Upper-air synoptic observations

7.6 AIRCRAFT REPORTS

Members are encouraged to arrange for making, recording and distributing in real time observational reports from all flights to/from and within the Antarctic.