



Agenda Item 5: Exchange of OPMET information in the CAR/SAM Regions

**ANALYSIS OF THE PROPOSED TRANSITION FROM TRADITIONAL ALPHANUMERIC
CODES TO BUFR IN CAR/SAM STATES**

(presented by the Rapporteur of the COM/MET Task Force)

SUMMARY

This working paper contains an analysis carried out by the COM/MET Task Force on the impact that the introduction of the BUFR code would have on CAR/SAM States/Territories. This analysis presents the complexities involved in such process and the most relevant aspects to take into consideration in order to carry out the proposed transition, with emphasis on WMO and ICAO responsibilities.

References:

- Report of the AERMETSG/7 meeting (May 2005)
- Final report of GREPECAS/13 (November 2005)
- Final report of the fourth meeting of the CNS Committee of the GREPECAS ATM/CNS/SG.
- Final report of EANPG/47 (November 2005)
- Report of the EANPG task force on the assessment of the transition to BUFR (version 1.0, October 2004).
- Report of the ICAO Meteorology divisional meeting (MET) (2002)

1. Introduction

1.1 The WMO is currently in the process of converting all of its traditional alphanumeric codes to BUFR, in an ambitious programme that covers all the domains where there is an exchange of meteorological information, including aviation. Although the WMO Committee on Basic Systems (CBS) approved the introduction of BUFR at its meeting held in January/February 1988, the transition to the BUFR code in OPMET messages was agreed in principle by ICAO at the divisional meeting held in Montreal in September 2002.

1.2 Taking into account the importance of this matter for the aeronautical community in the CAR/SAM Regions, the GREPECAS/13 meeting (Santiago, Chile, Nov 2005) approved DECISION 13/29.- *PLAN FOR THE MIGRATION OF AERONAUTICAL METEOROLOGICAL MESSAGES TO THE BUFR CODE IN THE CAR/SAM REGIONS* requesting the AERMET Subgroup to develop, in coordination with the CNS Committee of GREPECAS ATM/CNS/SG, a detailed plan for the migration of aeronautical meteorological codes to BUFR. On the other hand, as a

follow up to Recommendation 2/5 c) of the Meteorology divisional meeting (MET), (Montreal, Canada, 2002), and to facilitate a smooth transition, there was a need to provide training to CAR/SAM States/Territories on the introduction of the BUFR code and the necessary means of communication and processing requirements. Accordingly, GREPECAS formulated CONCLUSION 13/30.- *TRAINING ON THE BUFR CODE*, requesting WMO, in collaboration with ICAO, to organise a seminar on the BUFR code and its transmission, in order to introduce the necessary communication and processing requirements for its implementation in the CAR/SAM Regions.

1.3 Issues related to the complexity derived from the transition from alphanumeric to binary codes within the aeronautical environment have resulted in a study and analysis of the implications that these changes could have on communication support systems, and of the reliability and availability of operational meteorological information as they affect safety. Many of the following aspects are still under discussion and analysis in other Regions (EANPG/47), and several meetings have included in their discussions the possible impact of BUFR on communication systems (ATNICG/1 of APANPIRG, SADISOPSG/11, etc.).

1.4 This working paper has been prepared by the COM/MET task force of the AERMET Subgroup as a follow-up to the planning for the migration of OPMET coded messages to BUFR in the CAR/SAM Regions, and it analyses several issues related to the migration from alphanumeric codes to BUFR in aviation, which are presented in detail in Appendix A.

1.5 These issues include an assessment of the benefits that the aeronautical community would derive from a complete transition to BUFR, an assessment of different transition approaches, and whether the timetable proposed for the transition is realistic. Furthermore, consideration should be given to whether this transition is justified in the aeronautical sphere for the CAR/SAM Regions/Territories, and what should be the requirements to ensure a safe and effective transition, also taking into account the various regional and global scenarios in which the proposed change would take place.

2. Analysis

2.1 Assessment of the benefits of introducing BUFR

2.1.1 The FM 94 BUFR (*Binary Universal Form for the Representation of meteorological data*) code is a form of code based on tables (TDCF: Table-Driven Code Form) developed by the World Meteorological Organization (OMM). This code can be used to code meteorological data, using a self-descriptive code presented in binary format, and is designed to represent any type of meteorological data, using a continuous binary flow.

2.1.2 Several of the main approaches with respect to the benefits to be derived from the migration from the traditional alphanumeric codes to the BUFR code are based on the advantages offered by the use of a self-descriptive code, which, being a table-driven code form, would permit the simple addition of new parameters or new types of data, and there would be uniformity in the data. It is assumed that the data filing process could be simplified, as compared to data based on alphanumeric messages.

2.1.3 Since a binary code cannot be entered manually in a simple manner, it requires a certain level of automation, which, in turn, ensures that there are no syntactic errors. The nature of BUFR coding can make it simpler for automated systems to extract particular fields from the messages, which may be considered as a possible advantage with respect to the provision of personalised information for briefing purposes, and for the direct link of meteorological data to the aircraft. On the other hand, this code format implies the use of bit-oriented communication protocols, such as TCP/IP or X.25.

2.2 Technical and safety matters to be considered for the introduction of BUFR

2.2.1 Despite the benefits attributed to the introduction of the BUFR code in the aeronautical field, there are certain issues derived from this transition that need to be resolved in order to have a smooth global transition.

2.2.2 One of the aspects under discussion is the possible impact that a change of code would have on data display systems, since information presented to end users, like flight crews, must be translated into a known format for interpretation.

2.2.3 The use of a table-driven code implies the need for standard templates, which will have to be specified by ICAO, WMO or both. It is also inferred that there will be a need for standard converters and decoders, which would probably come from different vendors. Consideration should be given to the responsibility issue in case a system incorrectly decodes a BUFR message and causes an incident. Another matter related to the conversion software has to do with the deep implications of trying to integrate external codes into other complex and sensitive systems such as the integrated ATC systems.

2.2.4 The concept of a centralised converter of alphanumeric codes to BUFR may be appealing to the States that are not in a position to invest in expensive and complex updates to the existing meteorological observation and forecasting systems. In those States where the National Meteorological Service conducts the observations and provides aeronautical forecasting services, an effective measure would be to convert systems to BUFR as part of the general WMO migration. However, that is not the case in all States. On the other hand, in many States, observations are provided by different staff, such as ATC controllers, trained as meteorological observers, be it on a manual basis or with the assistance of semi-automatic meteorological observation systems.

2.2.5 There is a deep concern about the additional safety risks involved in the use of BUFR-coded OPMET messages. The most relevant aspects to bear in mind are the following:

- a) Many States have discrepancies with respect to the standards and recommended practices contained in ICAO Annex 3 regarding the use of METAR, SPECI and TAF codes, which is not expected to change in the near future. These discrepancies may cause serious difficulties in the international exchange of data, in the case of the coding and decoding between BUFR and the traditional alphanumeric codes.
- b) METAR, SPECI and TAF templates contain recommended practices that the State may or may not apply. Nevertheless, these facilities can also cause serious problems in the case of the coding and decoding between BUFR and the traditional alphanumeric codes.
- c) BUFR-coded OPMET messages must adhere to rigid formats in terms of units of measurement. However, some States use several formats and units of measurement, as described in the templates contained in Annex 3, reason why the integrity of the original information could be lost in the coding and decoding process, thus adding to the safety risk, especially if it is assumed that changes to BUFR tables and their conversion to traditional alphanumeric codes would have to be simultaneously coordinated on a global scale.

2.2.6 The transition will have an impact on the end users of the ISCS and SADIS systems, which will have to support the conversion of BUFR data to alphanumeric codes for their interpretation. The systems of these end users will also have to be capable of integrating the data provided in BUFR format and in alphanumeric codes. Although no problems are expected in the conversion from BUFR to alphanumeric codes and *vice versa*, we must remember the difficulties

encountered in the generation of software programmes capable of producing SIGWX in BUFR format with an acceptable performance in end user systems.

2.2.7 Another important aspect to bear in mind is the fact that aviation deals with other data aside from OPMET, such as SIGMETs, AIRMETs, GAMETs, volcanic ash and tropical cyclone advisories. This may give rise to a fragmented dissemination of transmitted information, since METARs, SPECIs, TAFs, CODARs, AMDARs, WINTeMs, ARFORs and ROFORs would be broadcast in BUFR format (or alphanumeric codes), while the other data, such as advisories and GAMETs, would only be available in alphanumeric form.

2.3 **Matters related to communications**

2.3.1 Regarding international communications, in addition to inter-regional satellite services such as ISCS and SADIS, the only feasible AFS option is AMHS, which has been considered as an essential requirement for the introduction of BUFR. Although the main communication support systems in the CAR/SAM Regions/Territories, such as MEVA and REDDIG, are capable of transporting binary data, the proposed migration would involve the standardisation of communication media and infrastructure, not only among States and switching centres, but also within the States themselves, which may involve high costs in equipment substitution and communication support. In order to support the BUFR, the international OPMET data banks, including those of Washington and Brasilia, shall guarantee connectivity with the AMHS.

2.4 **Transition timetable, coordination, and quality assurance tasks**

2.4.1 It is extremely difficult to establish a timetable for transition due to the existence of so many variables associated to this process. These factors include the establishment of display standards, template conversion specifications, acceptance standards, conversion software, the determination of the life cycle of the equipment and systems that will need to be replaced.

2.4.2 Assuming that the transition to BUFR takes place, the complexity of the task is such that, initially, the existing communication scheme should be maintained, together with a dual transmission of alphanumeric and BUFR codes. Once a qualitative criterion is met, international transmission would only be done in BUFR. Changes will also be required in the Washington and Brasilia OPMET data banks, and these will need to be coordinated with the other international OPMET data banks. The transition process will need to be planned, managed and monitored by a specialised group from WMO and ICAO.

2.4.3 The development and use of converters (software) of traditional alphanumeric codes to BUFR and *vice versa* will have to comply with strict standards developed by WMO and ICAO to ensure a consistent, correct and reliable operation.

3. **Conclusions**

3.1 With the transition from traditional alphanumeric codes to BUFR, important safety-related aspects have been highlighted which should not be neglected. These aspects, related to the incorrect conversion of an OPMET message, can cause an incident and, therefore, must be given high priority and be effectively resolved before carrying out any transition.

3.2 It is important that the national communication infrastructure permits the smooth transmission of BUFR-coded messages. States are faced with the option of moving directly to BUFR by updating the data generating systems of end users, or isolating these systems from the BUFR by using converters, which would mean significant investments by the States.

3.3 It could be said that BUFR offers some useful benefits, particularly the assurance that data will have the correct format and the automation of several processes, such as final display, etc.

Other benefits are not so clear yet. There is still no consensus across the Regions as to whether aviation should transition to BUFR. There is also the opinion that the benefits of implementing BUFR in the aeronautical industry in general are not as substantial as they would initially seem, particularly regarding flexibility to change the codes and, besides, actual benefits are extremely difficult to quantify in the absence of concrete examples.

3.4 There is still the need to specify the requirements, acceptance procedures and guidance materials. These should also be established and drafted prior to the operational transition, in order to ensure that the process is soundly based. The transition also depends largely on the regional implementation of AMHS, whose operational requirements and implementation timetable have already been defined, as shown in Appendix A to this working paper.

3.5 The proposal of amendment 74 to Annex 3, which should become effective in November 2007, introduces clauses enabling the transition of observational and forecasting information from alphanumeric code to BUFR. These proposed recommendations would mean that work should start so that detailed standards and specifications for aviation can be ready for Amendment 75. However, the many other variables involved could cause additional delays in the process, reason why the target date for completing the transition (year 2015) could be insufficient.

3.6 In view of the foregoing, the Subgroup is invited to approve the following draft conclusion:

DRAFT

CONCLUSION 8/XX

REVISION OF THE TRANSITION TO BUFR

That ICAO:

- a) consider reviewing the decision of transitioning from traditional alphanumeric code to BUFR-coded OPMET messages, and the possibility of reducing the negative impact to the aeronautical community; and
- b) submit the issue of BUFR coding, particularly safety-related aspects, to the corresponding WMO committees;
- c) ensure, through close coordination with the WMO Secretariat, that future decisions of this institution will continue giving full consideration to all aspects relevant for aviation.

4. Proposed action

4.1 The Subgroup is invited to:

- a) take into account the information presented in this working paper and its attachment, and
- b) based on its discussions, approve the draft conclusion shown above.

APPENDIX A

ANALYSIS OF THE MIGRATION FROM ALPHANUMERIC CODES TO BUFR IN AVIATION

1 General aspects of BUFR¹

1.1 The code based on **BUFR** (binary universal form of representation of meteorological data) tables offers two big advantages with respect to traditional alphanumeric codes: it is flexible and expandable. These features are possible because it is self-descriptive. The term “self-descriptive” means that the form and content of the data included in a BUFR message are described in the message itself. Furthermore, BUFR offers the possibility of condensing and packaging.

1.2 BUFR was first approved for practical use in 1988. Since then, it has been used for observations obtained from satellites, aircraft, and wind profilers, and for tropical cyclone observations. In all cases, BUFR should be the preferred code for the international exchange of observational data.

1.3 In principle, BUFR and CREX are the only codes that the WMO needs for the representation and exchange of observational data.

2 Benefits of the BUFR

2.1 Several possible effects associated with the introduction of BUFR have been identified, and these are described in the following paragraphs.

2.1.1 *Self-descriptive code.* BUFR is a table-driven code form (TDCF), and in a TDCF, the presence of a piece of data described in the message itself is a self-descriptive feature. At the beginning of the message, there shall be a section to define what data are being transmitted in the message. That section will contain indicators to elements in pre-defined and internationally accepted tables (officially contained in the WMO code manual). Once this section (data description section) is read, the next part of the message that contains the data (data section) can be understood. The characteristics of the parameters to be transmitted must be already defined in the tables of the WMO Manual.

2.1.2 *Simple addition of new parameters.* When there is a requirement for the transmission of new parameters or new types of data, these new elements are simply added to the WMO BUFR Tables (according to the WMO). Therefore, table-driven codes can transmit a wide variety of data in a flexible manner. According to the WMO, it would not be necessary to define new codes, or to develop new software; it would only be necessary to expand the tables. The BUFR code may be extended to meet all observational requirements without diverting from WMO recommendations, even to respond to national requirements for the exchange of specific domestic data.

2.1.3 *Data uniformity.* The adoption of BUFR may imply that messages must be more uniform. At present, different measurement units are used in METARs and TAFs for the same parameters. For example, according to WMO definition, visibility is expressed in meters; however, in the United States, Canada and Mexico, visibility is often expressed in statute miles. The adoption of a single standard for BUFR would be a significant step.

2.1.4 *Automation issues.* Since BUFR is expressed in binary code form, it cannot be manually entered, and thus requires a certain level of automation. This automation must be capable of ensuring that there are no syntactic errors. It is even possible to automatically verify the quality of input data. This should significantly reduce the number of incorrectly drafted messages.

¹ From “Guide of WMO table-driven codes”

2.1.5 *Communications.* The binary format of the BUFR code requires that the communication used for data dissemination must be a bit-oriented protocol, such as TCP/IP or X.25. These protocols use verification based on cyclic redundancy, thus significantly reducing the possibility of undetected data corruption during transmission. Although these protocols are extensively used for traditional alphanumeric codes, they can still be transmitted through asynchronous circuits that are much less safe in terms of undetected message corruption.

2.1.6 *Filing.* Due to its self-descriptive code, the historical analysis of BUFR-based data would be simpler than for those based in alphanumeric codes. The parameters used in the alphanumeric codes would be described within the message, reason why there is no need to adjust the analysis to code changes that may have occurred during the period being analysed.

2.1.7 *Personalised interpretation of meteorological data.* The systematic nature of BUFR coding, compared to alphanumeric coding, can make it simpler for automated systems to extract particular fields of the messages. This can be considered as a possible advantage with respect to the provision of personalised information for briefing purposes, and for direct meteorological data link with the aircraft.

3. Assessment of problems derived from BUFR implementation

3.1 *Presentation to end users.* BUFR is a binary code, and therefore, not suited for permitting the interpretation of information by the end user, and must be translated into a format that can be interpreted by the end users of the information, such as flight crews. In essence, it is assumed that the current alphanumeric code formats for observations and forecasts, that is, FM15 (METAR), FM16 (SPECI) and FM51 (TAF), will be maintained. This assumption is based on the serious difficulty implied in retraining the whole aeronautical community in a new standard interpretation. On the other hand, it has the advantage of being compatible with current systems that use observations and forecasts. It could also be assumed that, in the future, the WMO will discontinue the use of all alphanumeric codes and that ICAO will take on the responsibility of maintaining the standards for the use of these codes. However, the need for these interpretation formats defeats the apparent benefit described in 2.1.1, since any subsequent change of codes would require modification of the software responsible for translating BUFR into standard alphanumeric codes and its subsequent display.

3.2 *Impact of code changes on display systems.* This has been already demonstrated in the application of BUFR data for SIGWX in ISCS and SADIS. The initial problems involved in obtaining a consistent display of the code from different software providers were mainly due to the graphical nature of SIGWX products; therefore, there should be no problem with observations and forecasts. Another limiting factor of the BUFR code could be the fact that if the coding sequence changes, the display software of the end user would have to change. This could become a risk for users who are not in a position to update the software, since not being up to date with changes in the BUFR standards could have safety implications.

3.3 Adding to the complexity of the problem, in to ensure a consistent BUFR implementation, it will be necessary to specify a detailed mapping between BUFR templates and the interpretation, through alphanumeric code standards. It is assumed that this specification must be developed and maintained by ICAO, the WMO, or both. This specification will need to cover, in addition to the code conversion, the assignment of bulletin headers and the traceability of messages when converted to the BUFR format.

3.4 Since the development of decoders from BUFR to alphanumeric codes and *vice versa* probably will not be limited to a single provider, but rather other software will be developed specifically for this application, there may be problems with some decoders that are unable to decipher BUFR codes developed in other coders. To ensure that meteorological information is properly coded and deciphered, every translator must undergo an acceptance test to see if it meets the specifications mentioned in the previous paragraph. Some decisions have to be made concerning the use of non-standard units in the conversion process; for instance, the expression of visibility in the

conversions to statute miles. The development of an acceptance test will require certain resources, as well as the conduction of the tests and the acceptance of the translators tested.

3.5 *Responsibility for, and safety of, coding/decoding software.* The sole possibility that a system may incorrectly decode a BUFR message and that this message might cause an incident means that this aspect must be carefully analysed. If the software passes the acceptance test, the responsibilities for test development and software validation need to be established. On the other hand, safety regulations vary from State to State; therefore, this aspect needs to be taken into account, and software security standards considered as part of BUFR implementation.

3.6 *Fragmentation.* The WMO Transition Plan states that the types of data that will be affected in aviation are METAR, SPECI, TAF, CODAR, AMDAR, WINTEM, ARFOR and ROFOR. WMO has only taken into account messages in code form contained in the WMO code manual, reason why several meteorological messages of operational significance are not included in the transition programme. These messages include SIGMETs, AIRMETs, GAMETs, and volcanic ash and tropical cyclone advisories. This situation may create confusion with respect to the exact scope of the proposed transition. Accordingly, there is the possibility of fragmenting messages according to their type, that is, that some data will be available in BUFR format or alphanumeric codes, while others, like all types of GAMET forecasts and advisories, will only be available in the form of alphanumeric codes.

3.7 *Communication infrastructure:* In addition to inter-regional services by satellites like ISCS and SADIS, the only feasible AFS option is AMHS, which has been considered as a basic requirement for the introduction of BUFR. In Regions like EUR, the introduction of AMHS is considered to be a long-term objective due to the complexity and broad variety of existing communication systems. Consequently, global implementation should face even more difficulties. However, the main communication supports in the CAR/SAM Regions/Territories, namely MEVA and REDDIG, can carry binary data. Despite this, the completion of the proposed migration would involve the standardisation of communication media and infrastructure not only between States and communication gateways, but also within the States themselves, which might involve high costs for replacing the equipment and for communication support. In order to support the BUFR, the international OPMET data banks, including the ones in Washington and Brasilia, must ensure the connectivity with the AMHS if the latter is implemented on a global scale.

4. Transition assessment

4.1 Converters

4.1.1 For the transition to take place, it is essential to have conversion programmes available to convert BUFR to alphanumeric codes and *vice versa*. An important requirement would be for ICAO to investigate the requirements of a converter to be used by aviation users, basically taking into account those States with budgetary difficulties. The development of this software could be commissioned and made available to aviation users, and then maintained and verified by ICAO and WMO.

4.1.2 An important aspect to bear in mind is the incorporation of conversion software into the integrated ATC systems, which is very complicated and probably expensive, due to the profound implications that the intended integration of external codes into other complex and sensitive systems may have.

4.1.3 It is essential that the specifications for the conversion from BUFR to alphanumeric codes ensure that the conversion process will not be affected by the inclusion of supplementary information in the BUFR data by a State. Otherwise, there is the risk that data will be undecipherable by a significant proportion of users if the supplementary information affects the conversion process. Somehow, ICAO and WMO should, at least:

- specify the minimum standard BUFR templates for several types of data;
- define a process to test template changes before operational implementation, to ensure that they do not disrupt or interrupt the conversion process.

4.1.4 Assuming it is impossible to ensure that all States adopt uniform units of measurement for observations and forecasts (see 2.1.3), then the technical specifications for the conversion from alphanumeric codes to BUFR and *vice versa* should consider how to address situations in which the unit used for the original data is presented in a different way for data output in the conversion from BUFR to alphanumeric codes. An example of this is the expression of horizontal visibility in meters or statute miles. Special care should be taken to ensure that any rounding error would not have a significant impact on operational minima.

4.2 National aspects

4.2.1 It can be estimated that most States will continue broadcasting only data in alphanumeric codes from their original sources for a significant period of time. However, it is known that, in relation to the introduction of CNS/ATM systems, many States have made significant progress, mainly in domestic communication systems capable of supporting the exchange of binary data, and some have plans to implement such systems in the next few years.

4.2.2 A State may issue duly standardised BUFR data even if its domestic communication infrastructure is not suited to transmit binary data or if it wants to continue issuing alphanumeric codes in the original data sources. This would be done by installing a converter of alphanumeric codes to BUFR between the domestic communication infrastructure and the international AMHS interface. There are at least two major issues that need to be considered in this respect:

- The interface between the converter of alphanumeric codes to BUFR and the future AMHS system must support binary messages and operate properly. This is an aspect of the interface between the AMHS and the alphanumeric code-BUFR conversion that must be included in the specifications for the conversion of alphanumeric codes to BUFR.
- Messages that cannot be converted from alphanumeric code to BUFR due to a syntactic error in the original message must be immediately returned to the message originator for correction. This can be done automatically or manually, but message originators must clearly understand that syntactic errors will prevent data transmission, reason why corrections should be given due priority.

4.2.3 During the transition, a State could be receiving data in alphanumeric codes (assuming that data will be available in both alphanumeric code and BUFR formats during the transition period), or could be implementing a BUFR-alphanumeric code converter for incoming BUFR data. It is expected that the BUFR-alphanumeric code conversion will be less problematic, since the automatic processing required for the generation of BUFR data must ensure the production of syntactically correct data that should cause no problems in the conversion. This will depend on a sufficiently detailed specification of the BUFR-alphanumeric code mapping.

4.2.4 Another problem that should be considered at national level is the consistency between military meteorological observations and forecasts in the existing codes and the new BUFR codes. It could happen that meteorological data are required at a military aerodrome, such as an emergency aerodrome. Military messages are not always issued in alphanumeric code formats, for instance, using colour codes. It is therefore important to take into account these problems when specifying the alphanumeric codes for BUFR conversion. It is also essential that, if the army must migrate its codes to BUFR, that they use templates compatible with those specified by WMO and ICAO since, otherwise, data could be useless.

4.2.5 It should be noted that the “centralised” converter approach developed by WMO and ICAO restricts the possibility of adding supplementary domestic data to the BUFR format, just as these data cannot be added to alphanumeric code formats. On the other hand, national approaches to transition can be also influenced by state regulations concerning the scope of application of safety standards related to meteorological data systems.

4.3 Regional aspects

4.3.1 In view of the diversity of plans for data dissemination and communication systems in the States, it would be desirable to document and analyse the degree of documentation in all CAR/SAM States, so that a feasible transition process can be planned. This process may be technically demanding, difficult to implement and may take time.

4.3.2 The transition should be an evolutionary process and, probably, at the beginning, only a small amount of data will be available in BUFR code format. During this stage, it would be advisable to track the gradual availability of data in BUFR code, and for a regional task force to document it, so as to have at all times a clear listing of the data available in BUFR format and what bulletins are being disseminated.

4.3.3 It is assumed that, when the transition begins, all States will be able to internationally issue data at least in alphanumeric and BUFR formats from the beginning. This dual transmission will require additional bandwidth in communication infrastructures, but it is the only way to ensure a more flexible scenario in terms of data availability for the States that are at different transition phases. In order to establish a point at which the transition would be considered as completed, that is, a scenario in which only BUFR data are transmitted, the following conditions must be met:

- A high level of confidence has been achieved in the conversion from BUFR to alphanumeric codes, through clear specifications, verification procedures, and test results.
- Formal arrangements have been made for the provision of alphanumeric data to States that are not in a position to implement BUFR data conversion.
- Message routings have been revised to ensure that alphanumeric codes issued by external BUFR-alphanumeric code converters are not routed to the originating State.

4.3.4 The data banks currently available in the CAR/SAM Regions are those of Washington and Brasilia. An important issue within the context of regional data provision will be the use of converters in these data banks, which should also provide connectivity with the AMHS. In order to support the introduction of BUFR, specific forms of query must be defined for the BUFR code, while keeping the form of query for alphanumeric codes unchanged. This also implies that procedures must be established for requesting and filing BUFR data, and for writing over data previously filed in BUFR.

4.3.5 The fact that the BUFR SIGWX is already broadcast by the ISCS and SADIS service means that, at least for communications, the ISCS and SADIS should suffer no significant impact from the BUFR transition. It could be possible for observational and forecast data in BUFR format to be jointly transmitted with the existing BUFR SIGWX data, or to use another PVC socket exclusively for observations and forecasts in BUFR format. Although the communication infrastructure should not be significantly affected by this transition, the following issues should be addressed:

- The transition will have an impact on the end users of the ISCS and SADIS systems, which will need to support the conversion of BUFR data to alphanumeric codes for their interpretation. End user systems will also need to be capable of integrating the data provided in BUFR and alphanumeric code formats. It is unlikely that global BUFR coverage will be available for some time during the transition.
- The transition will also affect the operation of ISCS and SADIS gateways. The gateway must continue addressing data to the satellite uplink, but validation and

supervision responsibilities could become more complicated due to the need to decipher BUFR messages in order to retrieve the information required.

4.3.6 As the transition progresses, the feasibility of implementing regional BUFR to alphanumeric code converters should be analysed. The implementation of these regional converters would allow those regions where all meteorological data are internationally transmitted in BUFR format to cease inter-regional transmission of alphanumeric codes.

4.3.7 Assuming that the criterion for considering the transition as completed is that all data exchange is done exclusively in BUFR, it may be inferred that an inter-regional link has completed the transition when data exchange between the two Regions is done in BUFR format, regardless of how data exchange is done within each Region.

5. Variables associated to the transition

5.1 Transition timetable

5.1.1 In this phase, it is not possible to establish an objective timetable for the transition, due to the existence of so many variables associated to this process. Some of the factors that might have significant impact on this timetable are the following:

- a) *Display standards.* It has already been suggested that the transition requires specifications for display standards. Since these are expected to be based on the existing METAR and TAF codes, it is assumed that they are defined with certain level of detail in Annex 3.
- b) *Conversion specifications.* The drafting of conversion specifications will be a significant and complex task. BUFR templates for observations and forecasts need to be completed before starting the conversion process. The specifications must include a detailed definition of data conversion between alphanumeric codes and BUFR. Consideration should also be given to conversion units and the use of non-standard alphanumeric codes, like those used in some States and by the military. The specifications may also include bulletin heading assignment rules, including the modification of group CCCC and possibly the data quality check. If these specifications are going to be published as part of Annex 3, then they must be developed now for inclusion in Amendment 75 to Annex 3. A publication separate from Annex 3 could be a flexible solution, although it will still need to make reference to this Annex.
- c) *Acceptance standards.* As in the case of conversion specifications, acceptance standards will need to be established in order to ensure that converters are considered ready to operate. This would also represent a significant amount of work, which, if not ready for Amendment 75 to Annex 3, could cause delays in the transition.
- d) *Conversion programmes.* It is assumed that it will not be possible to operationally use programmes to convert alphanumeric codes to BUFR and *vice versa* until the specifications and acceptance standards have been completely developed, which might represent another delay. Safety regulations could also extend the time for the development of conversion systems.
- e) *Availability of AMHS.* In order to provide BUFR data on an operational basis, the AMHS must be implemented with the appropriate profile, and some Regions may have a much slower transition to the AMHS. Within the development of CNS/ATM systems, the CAR/SAM Regions are already taking the necessary steps within the first phase of their ATN implementation timetable (2005-2011), in which the update, interconnection and interoperability of digital networks will be completed, and ATN routes deployed in order to implement ground-ground (AMHS and AIDC) and air-ground data exchange applications through the implementation of ICAO SARPS and PANS and GREPECAS guidelines.

- f) *Equipment life cycle.* Equipment will need to be replaced at the end of their life cycle, and since the transition period to BUFR is relatively long, several systems will probably need to be replaced during this period. As soon as the standards and operational concepts are defined for the implementation of BUFR, it is expected that BUFR-compatible products will appear in the market or be developed at national level. Until such definition has been completed, there will be the risk that products developed are not recommendable for operations. Consequently, it is extremely important to complete all of the aforementioned detailed information as soon as possible; otherwise, the opportunity to replace obsolete systems with BUFR-compatible ones in the next few years will be lost, and thus the transition period will be extended.

6. Main aspects to be assessed

6.1 The issues that must be carefully assessed in order to do the transition from alphanumeric codes to BUFR are as follows:

- Impact of BUFR on the information provided by the sensors of the equipment involved in the production of METARs.
- Impact of BUFR on the drafting and issuance of TAFs.
- Impact of BUFR on internal domestic communications.
- Impact of BUFR on AFS international communications. This assessment shall include the AMHS and the ISCS/SADIS.
- Impact of BUFR on airline information systems and other briefing systems.
- Impact of BUFR on ATC information systems.
- Impact of BUFR on OPMET data banks.

A separate assessment should be done of the effectiveness of BUFR to reduce costs associated to code changes. This would be based on the number of problems identified during the other three assessments of the impact of BUFR introduction. Although no detailed data on costs are provided, work done in the EUR Region in relation to the transition has identified cost advantages and disadvantages.

6.2 Assessment of the benefits of a complete transition

- The cost of modifying or replacing the existing BUFR support equipment.
- The expected life cycle and replacement schedule of the equipment currently in operation.
- The investment cost of changing the life cycle of the equipment as a result of BUFR; for example, maintenance, changes in management, and training.
- Safety implications of the use of BUFR.

These assessments must be based on the equipment and should be conducted in several States. Wherever possible, consideration should be given to the situation in Regions other than CAR/SAM.