

# PLAN FOR MIGRATION TO TABLE DRIVEN CODE FORMS

## Acknowledgements

*This document, written at the request of CBS, is based on ideas expressed by the WMO CBS Expert Team on Migration to Table Driven Code Forms. The chairman is Dr Fred Branski (USA). The members are Jean Clochard (France, Chairman Expert Team on Data Representation and Codes), Seid Amedie (Ethiopia), Heinrich Knottenberg (Germany), Keiichi Kashiwagi (Japan), Dick Blaauboer (Netherlands), Dr Vladimir Antsyrovich (Russia), Milan Dragosavac (ECMWF), Dr Simon Elliott (EUMETSAT), Etienne Charpentier (JCOMMOPS); Other participants: Pr Geerd Hoffmann (Germany), Jaap van der Plank (Netherlands), Jeffrey Ator (USA); WMO Secretariat: Joël Martellet.*

Geneva, August 2002

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# PLAN FOR MIGRATION TO TABLE DRIVEN CODE FORMS

## I. INTRODUCTION

1.1 Meteorological observation data are the lifeblood of all the meteorological activities of the 185 Member Countries of the World Meteorological Organisation (WMO). Efficient real time exchange of these data is crucial for operational meteorology, in particular for weather forecasting. Standardisation in the formatting of these data has been a fundamental requirement for more than 60 years. For the operation of the World Weather Watch (WWW), traditional meteorological and marine in-situ observations are still exchanged in Traditional Alphanumeric Codes (TAC) today. Although their total volume is only several megabytes per day (compared to 645 megabytes per day for BUFR satellite data), they are still, despite the constant increase in remote sensing systems, required input for all meteorological applications. The table driven code **BUFR** (**B**inary **U**niversal **F**orm for the **R**epresentation of meteorological data) has existed since 1985 and has been approved by the World Meteorological Organisation (WMO) for operational use since 1988. The character image of the binary code BUFR is **CREX** (**C**haracter form for the **R**epresentation and **E**Xchange of data). CREX has been approved as an operational data representation code form since 3 May 2000.

1.2 Regarding data representation, the WMO Executive Council noted in 2001 that CBS had recognized that the self-description, flexibility and expandability of Table Driven Codes like BUFR and CREX would be the solution to the frequent demands of the rapidly evolving science and technology for representation of new data types and metadata. Table driven codes would also substantially contribute to improving data quantity and quality received at meteorological centres. In 2002, the Council recalled that CBS had embarked on developing a well-coordinated phased approach for a WMO-wide progressive transition from the use of character-based WMO codes to the table-driven data representation forms BUFR and CREX. The ultimate goal of this strategy was to enable the NMCs of all Member countries to exchange observational data in Table Driven Code Forms (TDCFs). In order for WMO to achieve this goal, the strategy would need to include support projects for training and decoding/encoding software distribution mainly for developing countries. The Council urged CBS to study thoroughly all the implications, both operational and resource-related, that Members will have to face in this transition process, giving specific attention to the situation and needs of the developing countries in that regard, and to develop the appropriate proposals for support and training. The Council also invited the regional associations to consider the implementation aspects of the transition strategy and to determine the realistic timeframe for implementation from the perspective of their Members with a view to achieving a smooth transition without operational interruptions or disadvantages to Members.

1.3 CBS XII stated that all observations should ultimately be exchanged in BUFR, which offers more features than CREX. The use of BUFR requires data communication links supporting binary data, and the majority of GTS Centres have reached this stage or will reach it soon. However some countries will need more time before being able to receive binary observations and a far longer period to be able to encode observations in BUFR. For these countries the use of CREX might be an interim solution. The Commission agreed to milestones leading to a plan for the migration to Table Driven Codes and the gradual phasing out of traditional character codes. As from November 2002, in a voluntary and experimental manner, some data producers, may transmit observations in BUFR or CREX in real time (and also in traditional alphanumeric codes, i.e. double dissemination, if the voluntary experimental users request this). CBS-Ext. (2002) is to review the migration process and consider the detailed plan for elimination of all traditional WMO Code forms for observations and retaining only Table Driven Codes: FM 94 BUFR and FM 95 CREX.

1.4 The Commission recognized that provision of and support for encoding and decoding software for the Table Driven Code forms was an indispensable part of any migration plan. The Commission considered that a successful migration to Table Driven Codes would depend on several supporting projects, new measures and assistance to Member Countries. These would

have to include information dissemination, training, software distribution and possible assistance in implementation. The Commission considered that the migration to Table Driven Codes will have implications in all the elements of the World Weather Watch system. However, the Commission insisted it be a smooth transition without negative impacts on the World Weather Watch operations. The Commission therefore requested the OPAG on ISS to develop an implementation plan on the migration to Table Driven Codes.

### *Some principles for the Migration Plan*

1.5 It is not the term "change" to table driven code but instead the term "migration" which is used, because the conversion process must be progressive and well coordinated with a smooth evolution over several years. It is critical that the important ideas and philosophy of migration should be clearly expressed and passed to the WMO community to avoid misunderstanding. There is also a necessity of coordination with other Technical Commissions of WMO, Regional Associations and external Programmes related to the WWW, like ICAO. There is a need for a coordination mechanism to ensure the migration impact is positive and sustains smooth operation of the WWW data flow. WMO Members should have the freedom to switch to BUFR when they want and when they are ready to do so. It will therefore have to be a long-term process with considerable flexibility. The advantages and the reasons for the migration should be briefly recalled at the beginning of the plan. The benefits of the migration have to be clearly explained to Members. The plan should be helpful for managers and decision-makers. Manufacturers of observing systems as well as processing software should be made well aware of the purpose of the migration and of its benefits. The plan should consider all WMO Members with their various capabilities and allow for every WMO Member to migrate.

## **II. ADVANTAGES AND REASONS OF THE MIGRATION TO TDCFs**

### **Satisfying science requirements**

2.1 The WMO codes are fundamental to meteorology because they made possible the real-time exchange of data, which are the raw material for all meteorological applications. When the requirement for changing to a new type of codes for transmitting the main meteorological observations is recognised, great concern is expressed, because it touches on the core of WWW operations and has numerous other implications, such as program costs, staff training, etc. In today's times of fast evolution in science and technology, there are more frequent requests for representation of new data types, more metadata, higher resolution data in time or space dimensions and higher accuracy data. High-resolution models will require higher resolution data in time and in vertical dimension. More metadata are requested by the meteorological applications, especially the data assimilation systems. The TDCF will permit the satisfaction of needs not being met today or even not known today.

### **Benefits: better data representation, better products**

2.2 All WMO Members would be somehow affected by the migration and should be concerned by the migration plan. It is important to fully understand the positive benefits and implications of TDCF. These positive benefits will help to create an incentive to migrate. What will be the benefits to switch to the table driven codes instead of keeping the traditional alphanumeric codes? BUFR and CREX offer great advantages in comparison with the traditional alphanumeric codes. The main features of the table driven codes are self-description, flexibility and expandability, which are fundamental in times of fast scientific and technical evolution. In addition, BUFR offers condensation (packing). The alphanumeric code CREX provides simple readability but no packing. BUFR has been used mainly, so far, for satellite, aircraft and wind profiler observations, but also for tropical cyclone information and for archiving of all types of observational data. CREX is already used among centres for exchange of ozone data, radiological data, hydrological data, tide gauge data and soil temperature data. Ideally BUFR should always be used to exchange observations internationally. CREX should be used only if binary transmission is not possible.

These two codes can satisfy all WMO needs for observation coding and are recommended for all present and future WMO applications.

### *Self description*

2.2.1 In a table driven code, the presence of a datum is described in the message itself: it is the self-description feature. There will be a section at the beginning of the message, which defines what data are transmitted in this message. That section will in fact contain pointers towards elements in predefined and internationally agreed tables (stored in the official WMO Manual on Codes). Once this section (the Data Description Section) is read, the following part of the message containing the data (the Data Section) can be understood. Indeed, the characteristics of the parameters to be transmitted must already be defined in the tables of the WMO Manual.

### *Flexibility*

2.2.2 In CREX and BUFR the parameters are simply listed as required by the user of the codes (in fact the data producer). CREX and BUFR offer flexibility and self-description. An item (the data value of a parameter to be transmitted in a report) will be translated in a set of bits in BUFR. It will be translated in a set of characters (bytes) in CREX. Since the datum are laid out one after the other, it is very simple to read a CREX message. CREX is the image in characters of BUFR bit fields.

### *Expandability*

2.2.3 When there is a requirement for transmission of new parameters or new data types, new elements are simply added to the WMO BUFR and CREX Tables (to be agreed by WMO). Table driven codes can transmit almost an infinite variety of informations. There is total flexibility. Definition of new «codes» as such is no more necessary and new software need not to be written; expansion of tables is sufficient. BUFR and CREX can be easily expanded to satisfy all observational requirements without deviating from WMO recommendations, even to answer national needs for specific domestic data exchange, as it is presently the case in many Countries.

### *Specific Features*

2.2.4 BUFR offers condensation, therefore voluminous data (ex. satellites, wind profilers) will require less resources for transmission and stocking. Condensation (or packing) is performed by an algorithm defined within the code regulations. BUFR also permits the transmission of associated data (flags, substituted values) with the original observation data. However, the big disadvantage is that human cannot read BUFR data directly. BUFR processing does assume the availability of well designed computer programs (decoder and encoder for the reverse) that are capable of parsing the descriptors, matching them to the bit stream of data and extracting the numbers from the bit stream, and reformatting the numbers in a way suitable for subsequent calculations. The bit oriented nature of the message also requires the availability of bit transparent communications systems which modern means offer, like TCP/IP protocol (INTERNET) or the already old X.25 protocol. Such protocols have various error detecting schemes built in so there need be little concern about the corruption of information in the transmission process.

2.2.5 CREX provides human readability. It is easy to understand, to code manually and to read (to decode) with only several hours of explanation. It requires for the transmission of big or many reports a substantial amount of characters. CREX tables have the same parameters as BUFR tables and are ruled by similar regulations. CREX is in some way the image of BUFR in characters. CREX is simpler than BUFR, but CREX does not offer the packing, and no facility for coding associated data (quality control information, substituted values), that BUFR permits. The role of CREX should be an interim solution since all data currently using traditional code forms should eventually be exchanged in BUFR. However, for countries that cannot transmit binary data, conversion to CREX could be an option in the interim.

## *In summary*

### 2.2.6 Table driven codes, like BUFR and CREX offers:

- o self description
- o flexibility
- o expandability
- o *condensation (packing), quality flags, associated values for BUFR*
- o *simple readability for CREX*

These codes are universal. They are the ideal codes for coding observations and the most adapted to the fast scientific and technological evolution of the 21<sup>st</sup> Century.

### **More data and of better quality**

2.3 The reliability of binary data transmission leads to expectation for an increase in data quality and data quantity received in meteorological centres. In addition, the systematic passing of metadata including geographical coordinates (latitude, longitude, height) in every report, easily performed with the table driven codes, would alleviate the notorious WMO Volume A problems. The Volume A is updated with too much delay, the WMO secretariat receiving sometimes with considerable delay and other times not at all, the updates that the Countries should send. The use of BUFR or CREX would solve the majority of the cases where there is a problem of wrong coordinates for a station. Increase data quantity and quality will lead to the generation of better products by data processing centres.

### **Operational benefits**

2.4 The impacts of migration to TDCF on WMO Member resources will show many benefits that will not be realized at the beginning. There will be the price of progress to pay, however there will be offsetting positive benefits. It is important to focus WMO Member's attention to these positive benefits.

#### *Less development*

2.4.1 Migration to TDCF would reduce the diversity of data formats needed to be processed and consequently reducing software and operational requirements. A universal decoder for BUFR/CREX would simplify greatly the maintenance of decoding software in pre-processing system of GDPS Centres.

#### *Less maintenance*

2.4.2 The self-descriptive feature of BUFR and CREX leads to another advantage over traditional alphanumeric character codes: the relative ease of decoding a BUFR (or a CREX) message. Where a large number of specialized and complex programs are needed to decode the plethora of character codes in current use, only a single "universal BUFR (or CREX) decoder" program is capable of decoding any BUFR (or CREX) message. It is not a trivial task to write such a BUFR/CREX decoder, but once it is done, it is done for all time. The program does not need to be modified with changes in observational requirements; only the tables need to be augmented, a relatively trivial task. The program needs to keep in memory the BUFR/CREX Tables. For new parameters or new data types, no need to change software, just additional table entries.

#### *Facilitate archives processing*

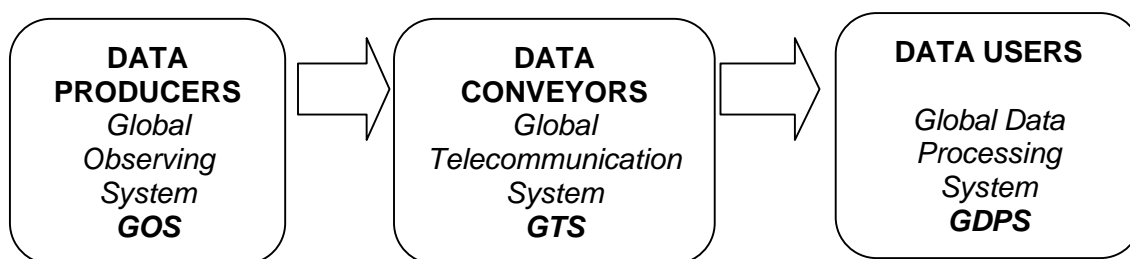
2.4.3 The fact that all time and geographical coordinates are passed in any single BUFR or CREX message makes easier the archiving of information. Since every BUFR and CREX messages includes tables edition and version numbers, the correct retrieval of parameters from archives for any historical post-processing applications is safer and simpler.

### III. ANALYSIS OF THE CURRENT OBSERVATION DATA FLOW IN THE WORLD WEATHER WATCH AND POTENTIAL IMPACTS OF THE MIGRATION TO TDCF<sub>s</sub>

#### The concepts of data producers, data conveyors and data users

3.1 The CBS considered that the migration to TDCF would have implications at every step of the World Weather Watch (WWW) data flow. The technical impacts of the migration (and possible solutions) must be identified in all aspects of the WWW and associated operations. The concepts of data producers, data conveyors and data users has to be introduced to understand well the WWW data flow (see diagram below). The Global Observing System (GOS) and similar systems are the data producers; the data conveyors are elements of the Global Telecommunication System (GTS), and the Global Data Processing System (GDPS) and others, who utilize the data, are the data users. Entities making up the GOS, GTS and GDPS are all Centres located within the National Meteorological or Hydrological Services (NMHSs) of the 185 WMO Member States.

#### THE WORLD WEATHER WATCH DATA FLOW



#### Impact on WMO observation data producers

3.2 One hundred eighty five National Meteorological Centres (NMCs) still encode traditional observations using alphanumeric codes like SYNOP, TEMP, PILOT. A number of specialised collecting Centres produce:

- Satellite data (the majority already in BUFR)
- Aircraft data (AMDAR (some already in BUFR), AIREP)
- SHIP data
- BUOY data
- XBT/CTD
- Sub-surface profiling floats data (soon in BUFR)

#### WMO Members observing stations and platforms

##### Observers

3.2.1 Most countries still take many observations manually. Migration to BUFR will require automation, either by an automatic weather station generating BUFR messages or by an observer entering the observations into a system (possibly a Web-based interface) that encodes them into BUFR. Migration to CREX would allow manual encoding by a human observer to continue. In any case however, when observer tasks will change preliminary training will definitely be required.

##### Automated stations

3.2.2 For most NMHSs already using fully automated observing systems, it will take several years to encode observations in BUFR at observation sites because most of the current automated systems were designed to encode data in TAC. Where human observers enter data into a

computer, the encoding is de-coupled from the measurement. In this case, encoding in BUFR or CREX could be done through appropriate modifications to the encoding procedures and to the software. At a functional level, double dissemination of current and new formats could be done. A country has estimated that the work associated with the implementation of new encoding software would be about six man/months per observing system. The Implementation costs would depend on each observing system, but in most cases would be reasonable if performed as part of normal life cycle maintenance.

3.2.3 The choice of BUFR or CREX would be made based on telecommunication issues. For instance, experience with Data Collection Platform (DCP) systems indicates CREX may be preferred for DCPs because of potentially lower error rates (better error detection through the use of CREX check digits) with possibly some recovery over the lines. CREX based messages could then be translated into BUFR at the concentration system level, either at a national centre, or at a DCP data collection centre.

#### National Collection

3.2.4 Data collected at observational sites are usually sent to a central site for transmission into the GTS. The compilation of bulletins made of new BUFR or CREX reports will require an adjustment of the related system and software. In some developing countries, like for most NMHSs in Africa, data exchange at the national level is still carried out through voice communication systems. The migration to BUFR cannot be envisaged in these cases before binary data connections are implemented nationally.

3.2.5 Climatological messages (CLIMAT) are usually generated at the central service (NMC) of NMHS. Implementing their production in BUFR would be relatively easy and one country estimated the development work to require few months. Double dissemination in BUFR and the CLIMAT format would not be too difficult to implement by central services of NMCs.

#### *Other data collected nationally*

3.2.6 It will be very difficult for voluntary ships to encode observations in BUFR or CREX and will require a lengthy transition period. A similar situation exists for data that are encoded in traditional codes by producers outside of NMHSs such as aircraft data.

### **Impact on WMO observation data conveyors**

3.3 The impacts of the migration on the 31 Regional Telecommunication Hubs (RTHs) which make the Global Telecommunication System (GTS) are now considered. There is significant variation of capability in different part of the GTS and among RTHs. There is also significant variability in the capabilities of processing Centres associated with each RTH. It may be that the limits of some processing Centres will affect how migration can be implemented on some parts of the GTS.

#### *Dual dissemination*

3.3.1 The question is whether the most effective way to migrate would be by providing dual dissemination of data by the data producer in both traditional and table driven formats or whether translation between formats should be done at RTHs for users who will not be able to receive BUFR for a long time. Format translation is not a role of an RTH and many RTHs would not have the processing power to be able to do this. Dual dissemination should not cause any serious problems with computer system hardware and bandwidth of telecommunication lines, because the rapid progress of information technology and services will greatly reduce the costs. There will be, however, an increase of demand on GTS switching systems with more bulletins during migration period while dual dissemination is occurring. The additional bandwidth required by dual dissemination of code formats is relatively small and partially offset by the compressibility of BUFR encoded data. Dual dissemination would only add a few megabytes per day to GTS traffic. The

additional data volume will not be significant in comparison with satellite, aircraft data and NWP products. Most importantly, dual dissemination provides the greatest flexibility to WMO members from both data production and use standpoints. Dual dissemination should be the primary mechanism utilized for migration.

3.3.2 However, some RTHs or concentration centres may have the capability to do format translation and may decide to do translation for the needs of connected NMCs. RTHs in the Main Telecommunication Network have the capabilities to transmit binary data, as well as Managed Data-communication Networks or most satellite dissemination systems. However in other parts of the GTS there are limitations. This will result in the pace of migration varying throughout different portions of the GTS. For example, RTHs in Region I are automated and can handle binary data, but many NMCs have not the facilities for BUFR processing. In order to be able to use BUFR data, NMCs in the region should be automated and have binary data connection facilities.

### **Impact on WMO observation data users**

3.4 The users of real time meteorological data in the Global Data Processing System (GDPS) are primarily the 185 National Meteorological Centres (NMCs), among them:

- 16 Centres run operationally global models
- 65 Centres run operationally regional or mesoscale models
- 185 (all NMCs) Centres performing regional nowcasting.

3.4.1 The 65 Centres running numerical models have decoders of WMO TAC. Those running global models usually have also BUFR decoders for satellite and aircraft data. Few Centres have a fully universal BUFR decoder. A great number of others might have some automated data switching systems, with a small computer decoding TAC and processing the data for input to automatic plotting, or to databases for real time access or archive. Some also have simple "turn-key" type workstations, which received as input GTS observation data in TAC. Finally there are still about 40 Centres which operates "manually", with plotting still performed manually.

3.4.2 The Global Data Processing System is fed by meteorological observations. The data processing program receiving meteorological data from the GTS interface centre is the first one to encounter the data formats, usually after having cracked the WMO Bulletins. The decoders of WMO TAC are not simple pieces of software. Two thirds of the program, if not more, are usually dedicated to detect and correct errors in the format due to manual coding errors or transmission failures. Clearly a switch to the reception of BUFR data instead of reception of WMO TAC, should improve the data quality. CREX would also improve the quality, but not as much as BUFR. A universal decoder for BUFR/CREX would simplify greatly the maintenance of decoding software in pre-processing system of GDPS Centres. The migration to TDCF would be an improvement for all meteorological applications, especially the data assimilation systems, which will be able to receive more and better quality data, new data types, additional parameters, metadata, higher resolution data in time or space and higher accuracy data.

3.4.3 Often, in advanced Countries, the decoding and encoding software used in the numerical analysis and prediction systems and other data processing systems are basically developed by the staff. One country estimated that work to develop software for conversion to BUFR will be roughly a few man-months per TAC if programmers' work can be dedicated solely to migration, but it may take more than six man-months under the normal working situation in some cases. Therefore, there will be no serious impact if the migration time schedule for each TAC is decided sufficiently before the operational implementation (preferably more than one year).

3.4.4 Data base storage of real time data will not be much of a problem since usually data are decoded before storage, and stored in an internal format, or BUFR itself in some advance Centres. If the data are stored in the original format, then if it could be replaced by BUFR or CREX, and if a process was operated on the data for displaying or plotting, a decoding programme for BUFR or CREX would have to be implemented.

3.4.5 The necessary software changes will be mainly in the pre-processing layer, except if the new available parameters will be needed by the applications. The Application Programme Interfaces (APIs) might not be impacted if decoders provide the same data in the same position. Applications layers may not be impacted, except if handling of new parameters is required. In the simplest approach (no extra parameter to be added or used), one country estimated the adaptation work at one man-month work per observation type. Impact on resources will vary depending on each application and on the number of applications concerned.

3.4.6 In some countries, only a few centres possess sufficient computing and financial resources to modify their data processing facilities to migrate to Table Driven Code Forms, and for those it will be a slow phased process depending on the capabilities and needs of each centre. Even the adaptation of a few centres will be difficult, because companies, who were or are the software providers, are either no longer in existence or require substantial funding to update the software. There are centres running out-of-date software and without enough funds to provide for their updating. During the transition period, these centres need to be provided with data in TAC. However, the list of these code forms processed by such centres is limited. In some cases, the telecommunication systems of these centres receive information in a format implemented in the present Data Base of the centre that is not in a standard WMO code form.

3.4.7 Provision of and support for encoding and decoding software for TDCF would be necessary but not sufficient for a successful migration. It would take quite a long time for many NMHSs to introduce computer systems to process binary data at their local offices and a national telecommunication network to transmit binary data to their local offices even if their NMCs and GTS Centres could deal with binary data. Furthermore, a number of advanced NMCs using automated data processing systems also used application software directly linked to TAC for data plotting, data display and database simply because most of conventional observations are coded in TAC. It should be noted that the introduction of new software (and additional hardware) for migration might have a small to significant financial impact on many NMHSs.

#### *Impacts on end-users*

3.4.8 The impact of the migration on end-users can only be beneficial since data assimilation programmes, forecasters, climate, and marine and aviation data bases will receive more and better data and additional useful parameters. Training of some users, in particular forecasters, who may have to deal with new parameters, will have to be organised.

#### **Impact of the migration to TDCF on other programmes or organisations**

3.5 The advantages of the migration to table driven codes start to be well known not only by the WWW community, but also outside the WWW circles. One could distinguish three types of other Programmes, which are somehow connected with the WWW:

- a) the Programmes depending on the operation of WWW, which provides input data to them (e.g. World Climate Programme, GCOS, Hydrology)
- b) the Programmes which contribute to some data collection as input to the WWW, but which, anyway, are depending fully of the data processing of WWW (e.g. CAeM-aviation meteorology -ICAO, JCOMM-Marine Meteorology)
- c) the Programmes, which contribute data to the WWW, but which do not need fully the WWW processing for operation (e.g. Satellites, Oceanography-IOC)

3.5.1 The impacts of the migration are considered for every type of Programmes.

3.5.2 Type (a) Programmes, usually receive already processed data by extraction from databases. The decoding of BUFR or CREX would have been performed previously by

meteorological data processing centres. If TAC were usually stored and delivered, then decoders of BUFR/CREX would have to be provided to these users for the migration. In many countries, the meteorological and hydrological services are run by different organizations. The hydrological services normally use other means of communications (independent of the GTS) to transmit data for global exchange. Some of them, such as SADC-HYCOS and MEDHYCOS, use CREX for meteorological/hydrological observations. Other hydrological services should be notified of the current progress of migration for planning to switch to table driven codes.

3.5.3 Type (b) Programmes would seriously require to be convinced of the interest of switching to BUFR (or CREX, if BUFR cannot be implemented), which will enable the transmission of more parameters and metadata, to the benefit of their users. For example, Service ARGOS, DBCP and SOOP are planning and developing systems for the transmission in BUFR during 2003 of buoy, XBT, XCTD and sub-surface floats observations. Indeed the recipient of these data (WWW data processing centres also) will have to be equipped as soon as possible with BUFR decoders. Data producers who were often contractors for automatic observation platforms would have to work with the platform manufacturers to recommend BUFR or CREX as efficient codes. In some case, it was a centralised centre, which encodes in GTS format, rather than each platform coding GTS messages (e.g. Service ARGOS). In this last case, the migration would be easier since it would be easy to convert to BUFR in a centralised processing centre. Double dissemination (TAC and BUFR) could also be performed for a while. The civil aviation community will probably be slow to migrate. However, some ACARS data have been transmitted for a long time in BUFR, and ICAO knows well the advantages of BUFR. The WAFS centres are disseminating SIG weather data in BUFR. Their users (e.g. pilots) will certainly need a presentation in clear character formats, but the transmission could be done in BUFR, followed by an automatic decoding prior to the visualisation program.

3.5.4 Type (c) Programmes have less constraint imposed by a migration to BUFR or CREX, since they are probably limited users of raw observation data. The bulk of satellite data are transmitted already in BUFR. The oceanography will be a contributor of BUFR data via Service ARGOS. Scientific research Programmes will need to be informed of the benefit of TDCF. If they need to receive raw meteorological observations (perhaps satellite operators), BUFR/CREX decoders will have to be provided to these Programmes (on reciprocity for their services to the WWW).

#### **Impact for decision makers**

3.6 Indeed, there will be implications, due to the migration process, on WMO Members' resources for development and operation. One has to be aware of the financial impact of the various steps of the migration process on NMHSs' budgets. There will be costs for:

- a. Training of personnel who generate or use data
- b. Training of system and software personnel
- c. Project management for transition
- d. Documentation updates
- e. Infrastructure, hardware and system changes (e.g. for automation)
- f. Software development
- g. Operational procedure changes

3.7 It is legitimate that WMO Members express concern about the impact on financial resources that migration may have. There will be significant changes to systems that will require many man-hours of work. However, many Members feel this is manageable and outweighed by the advantages of migration as long as sufficient time and flexibility is allowed for in the plan, which should minimise the costs.

#### **IV. SOLUTIONS AND PLAN OF ACTIONS**

4. Training and availability of encoder/decoder software are the two main keys to success.

- Training on BUFR/CREX:

- o WMO seminars will be organized
- o To train the trainers (of WMO Regional Meteorological Training Centres, meteorological schools, colleges and universities in necessary)
- o WMO Seminars on TDCFs in all WMO Regions
- o National training programmes within countries.

- Software project:

- o Software house: a centre distributing free BUFR/CREX encoder/decoder software, providing documentation, providing assistance for implementation and answering queries.

### **Basic principles for the plan**

4.1 A big misconception is: "migration means that on a pre-defined agreed date all Member countries will switch to BUFR for a certain data type, like if it was a change of code for observing a new parameter or transmitting a new group in SYNOP". On the contrary, the freedom and flexibility of the migration will be the main principles of the plan.

4.1.1 The leading idea is: "it is the data producer, generating the meteorological coded data, who is the initiator of the migration process". Starting on a date pre-defined by the producer, reports from one or more observation stations or platforms will be, from now on, produced in BUFR or CREX. The migration of a national sub-set of data will be determined by each data producer. The decision of the data producer for the migration will be based on consideration of advantages, national benefits and interest of users.

4.1.2 The ultimate goal of the plan should be to achieve complete freedom for observational data producers to switching to BUFR (or CREX) when they want and to give them the means to be ready to do so. Data producers who want to produce BUFR or CREX data should not be constrained from doing so. At the same time, data users must be guaranteed access to the new data produced in BUFR or CREX. To achieve this, the data users should be able to receive the meteorological information, which is produced in BUFR or CREX. The data users should be given the means to receive and process the data coded in BUFR or CREX.

4.1.3 Therefore, the users should have first priority for training and have implemented BUFR and CREX decoders as soon as possible. If this cannot be achieved quickly enough, the user should be able, to receive at least the same data as before, from a producer who switches to a TDCF. WMO Members will not migrate at the same pace. To ensure access to data for all users, the constitution of the same observation in two types of format at some stage in the WWW data flow (concept of the double transmission or double dissemination), has to be considered.

4.1.4 Double dissemination means transmitting reports still in TAC at the same time as in BUFR. A double dissemination "BUFR and CREX" would be preferable to "BUFR and TAC" if users can process CREX, because it will enable users to receive almost all the benefits from the migration to TDCF. Double dissemination should be considered to provide for non-automated users or "non-binary-connected" users, who cannot receive BUFR. Conversion from BUFR back to traditional code forms should be avoided, if a conversion has to take place back to an alphanumeric code, it is better to be from BUFR to CREX, to keep the advantages of the TDCF. However, this is possible only if users are ready to process CREX or to read CREX.

4.1.5 The plan will consider data users who are automated and those who are not (about 40 out of 185 NMCs) and the data users who can receive binary data and those who cannot. Similarly, the plan will consider the data producers who can easily switch to binary transmission and those

who cannot. Then the plan will provide guidelines for what each category of data users and data producers should do, and what are priorities.

4.1.6 The plan will see CREX as an interim solution since all data currently encoded in traditional code forms should eventually be exchanged in BUFR. Countries that cannot produce BUFR data, but need to transmit more or different parameters than allowed by the TAC, could encode in CREX in the interim.

4.1.7 All WMO Members meteorological staff involved in observation, telecommunications and data processing must become aware of the advantages of using BUFR and CREX for data exchange. Training must be a first priority activity in the migration process.

4.1.8 The successful implementation of the migration to table driven codes in developing countries largely depends on capacity building. Assistance to developing countries in the form of pilot and specific projects will be necessary for implementation of new coding procedures, new software and even hardware for automation.

4.1.9 The migration process will be long in time, but with targets (several years ahead) foreseeing elimination of traditional alphanumeric codes, which should be indicated for motivating the Members. The plan will describe a long-term migration process with considerable flexibility.

4.1.10 The plan should consider the exchange needs of all the WMO Programmes and WMO Members. These needs will be reviewed by data type.

4.1.11 The plan will list the respective roles of data producers, data conveyors, data users, NMCs and RTHs, as well as those expected from manufacturers of observing stations or platforms, and of the private software producers for telecommunication and processing packages, as well as for meteorological work-stations.

## **TRAINING IN PARALLEL WITH ACTIONS**

4.2 The training programme will be defined at the international level and training actions will be suggested at the national level. The CBS recommended that such training be completed by October 2005.

4.2.1 The first priority is to train data users on how to include in their automated processing chain BUFR and CREX decoders, and to train forecasters on the meaning or usage of these data. It is important to consider the problem of countries that have some automation capability, but are not very advanced. These may have difficulty implementing a decoder or encoder in their existing processing software. Some training might be needed specifically for that purpose. This illustrates the need for good API documentation of the delivered decoding software. The tasks of data producers wishing to switch to TDCF in automatic observing platforms should be facilitated. Depending on their capacities (telecommunication lines, level of automation) they will encode in CREX or BUFR. For encoding in BUFR, automation at the encoding stage is necessary; therefore some training for programmers of automatic station software, or encoding programs will have to be provided. Automatic observing platform software programmers are often concerned for only one or a small set of data types.

### *Training levels*

4.2.2 Three levels of training have to be considered:

- Level 1 – Understanding of general philosophy of TDCF and migration overview
- Level 2 – Deeper understanding of the TDCF - Introduction and use of TDCF software including debugging and interfacing with data processing applications
- Level 3 – Total understanding of the TDCF, for programming of encoder and decoder (only needed if the software project is not implemented)

## *WMO Training courses*

4.2.3 To implement the three levels of training, it is proposed two different types of WMO training courses for two types of trainees:

- P1: Trainers, data managers and also people interfacing with general users (meteorologists) and decision-makers for technical matters.
- P2: Technical users involved in operational software development.

4.2.3.1 The course P1 should cover the general philosophy of TDCF, migration overview and targets (Level 1). It should also include examples of manually encoding and decoding CREX data. The encoding and decoding of a very simple report should be done, but examples of a parameter addition should be included to demonstrate the flexibility of a TDCF. Interfacing with an NMC pre-processing system should also be covered (part of Level 2). This training should be organized at least once per WMO Region, from 2003 to 2005. The duration of the training should be at least two-three days and could be combined with GRIB 2 training to cover a week. Trainers (RMTCs, National Code experts and focal points) should be trained first. If funds are significantly limited, well advanced Countries should be omitted from the training. Countries already automated or in the process of becoming automated should be given higher consideration.

4.2.3.2 The course level P2 should start with the same general philosophy and overview as P1 (Level 1). It should then move on to a different focus (Level 2 and if necessary part or all Level 3). A PC-based environment will be needed as well as an encoding and decoding package, and simple application(s). Participants should be trained to use the software, and to debug it and the application(s). Implementation in a processing chain should be covered, and people should be trained how to write the technical part of an invitation to tender (ITT) related to systems in automatic observing platforms. This training should be done shortly before or along with members' planning activities for migration, typically one year before any migration implementation. The end of a pilot project in a Region might be the start of technical training in the concerned Region, building on the experience, difficulties and benefits reported. The training course should last five days.

4.2.4 In addition to P1 and P2, the general philosophy of TDCF (Level 1) is now presented in all WMO GDPS training seminars (Niamey 2000, Seychelles 2000, Bahrain 2002, Peru 2002) and this will continue. The targets here are the forecasters. Emphasis is and should continue to be put on the additional data they can receive and the value of the TDCFs for providing new parameters as well as their impacts on resolving the long term problems of metadata and Volume A.

## *Proposed WMO events*

4.2.5 These training seminars should include handling of software packages showing decoding facilities and visualization software of decoded data.

- Training seminar for English speaking countries in RA I on Table Driven Code Forms, P1 type course, about 28 external participants (NMHSs' experts in Codes) including representatives of three RMTCs, one week, in Tanzania, Arusha (tentatively 3 February to 7 February 2003) following the Meeting of Expert Team on Data Representation and Codes (tentatively 27 to 31 January).
- **COST: about: 50,000 CHF (Per diem only for lecturers, travel and lump sum for participants)**
- Training seminar for French speaking countries in RA I on Table Driven Code Forms, P1 type course, one week, in Niamey, EAMAC, co-sponsored by ASECNA, with lecturers and external

participants (NMHSs' experts in Codes) from three RMTCs and non-ASECNA countries paid by WMO - tentatively end February/beginning of March 2003.

- **COST: about 30,000 CHF for WMO**
- Training seminar for countries in East RA II and West RA V on Table Driven Code Forms, P1 and P2 type course, in East Asia, tentatively September 2003, 7 working days, participants (technical users involved in operational software development) from East RA II (21 countries) and West RA V (5 countries) and 3 RMTCs representatives (first five days only), lecturers: from ECMWF, Japan, USA
- **COST: about 100,000 CHF**
- Training seminar for countries in RA III and IV on Table Driven Code Forms, P1 and P2 type course, 7 working days, tentatively in 2004, participants (technical users involved in operational software development) from 33 countries and 5 RMTCs representatives (first five days only) , lecturers: two from USA and one from Brazil
- **COST: about 100,000 CHF**
- Training seminar for countries in East RA V on Table Driven Code Forms, P1 and P2 type course, 7 working days, tentatively in 2004, participants (technical users involved in operational software development) from 13 countries, lecturers: two from USA and one from Australia
- **COST: about 70,000 CHF**
- Training seminar for countries in West RA II and East RA VI on Table Driven Code Forms, P1 and P2 type course, 7 working days, tentatively in 2005, participants (technical users involved in operational software development) from 19 countries and 3 RMTCs (first five days only), lecturers: two from ECMWF and one from UK
- **COST: about 80,000 CHF**
- Training seminar for selected countries from RA I on Table Driven Code Forms, P1 and P2 type course, 7 working days, tentatively in 2005, participants (technical users involved in operational software development), lecturers: one from ECMWF, one from France and one from UK
- **COST: about 70,000 CHF**

**Total WMO training COST over 2003, 2004 and 2005 period: about 500 000 CHF**

#### *National training*

4.2.6 Currently, there is no or little training on TDCFs within the NMHSs. Level 1 and Level 2 training should be given. Level 3 should be considered if the software distribution project is not implemented.

4.2.7 Information on the general philosophy of BUFR and CREX codes should be included in meteorological training institutions of all countries for all technical staff, at least during the initial course. However most staff does not need instruction on the "physical" structure of the code(s). To some extent, this is also the case for traditional code forms, as far as in many advanced countries where automation has been implemented, the code is hidden by both the observation systems (even for manned stations, the non-automated part of an observation is typed in through an interface), as well as on forecasters' systems that present data in graphical form or plotted charts. In this case students should be given Level 1 type course.

4.2.8 Training in national training institutions (e.g. for students) should be done by trainers having followed a P1 type course and/or by experts in the field of TDCFs. In advanced Countries, this training may have already started. For developing Countries, it should start reasonably soon after the P1 training for trainers. Level 1 training should be widely given in NMHS including high

management. Level 2 training should be given by experts, having followed P2 courses, to telecommunications managers, personnel involved in data exchange and data management.

4.2.9 Observers should be given training for their new operational activities, whether it would be to type in a computer interface or to encode in CREX. Manual encoding to CREX would require the training of staff, first the observers to be able to code observations in CREX and also the staff at NMCs to understand CREX code coming from their national stations or from the GTS or from other means.

4.2.10 Forecasters and development meteorologists should be given training of Level 1 with emphasis on the new parameters and metadata that the TDCF will permit to receive.

#### *Information for manufacturers*

4.2.11 Information should also be provided to manufacturers of automatic observing systems, processing systems and workstations. It could be delivered in a seminar where some documentation could also be given along with general principles and some examples. The WMO Secretariat may be able to arrange for such a seminar at no cost for WMO via registration fees paid by the manufacturers themselves.

### **SOFTWARE HOUSE PROJECT**

4.3 The CBS recognized that provision of and support for encoding and decoding software for the TDCF was an indispensable part of any migration plan. A software house project is a new paradigm for the WMO but it is required for a successful migration to TDCFs. A centralized unit developing and supporting application program interface software is a valuable and necessary step to ensure that modern standard data representation forms, developed and coordinated by the WMO, be used by the widest possible user community. This will be of particular use to those users with very limited computer programming resources. The implementation of a software house project in an advanced State or through an International Organisation will favour and help migration to TDCF. It should be noted that the first beneficiaries of such a project would be the technologically advanced States themselves, and all their meteorological applications, in particular their operational forecasting systems, with the prospect of receiving more data and better quality data, leading to better products.

#### *Operating system*

4.3.1 Resulting from a survey among WMO Members, it appeared that a large majority of operating systems used to process WMO data representation forms were of only two types: one of the most common dialects of UNIX (including LINUX) or WINDOWS. The users should have the choice of getting a "source" code or a compiled version of the encoder/decoder. The compiled version would be especially valuable for small workstations.

#### *Good documentation (API)*

4.3.2 Implementing a decoder in an automated processing chain of a program or system is not simple. Documentation on the program and how to implement it ought to be clear and comprehensive, with all interfaces with the external application well defined. BUFR and CREX define the standard format of the "physical" data layout, they are not Application Program Interfaces. Clearly, the Application Program Interface (API) has to be well described by the software provider. It is absolutely necessary that any encoding or decoding software delivered include clear documentation describing its API.

#### *Printing and display routines*

4.3.3 The question of the human readability of the BUFR encoded data is crucial, and would be a key to the success of the migration, the users having the habit of "seeing" the meteorological observations in a SYNOP, or TEMP, or SHIP, etc. . It will be necessary that the encoder/decoder software be accompanied with display tools like a "BUFR viewer". If the decoding were done in a workstation connected to INTERNET a "BUFR viewer" in a browser would be useful. Software for displaying BUFR data in some standard manner should be delivered with the BUFR decoder software. It could be a program in JAVA for a workstation or PC plugged into the INTERNET or it could be a browser interface set up to view output from a BUFR decoder. The display standard could use XML or the presentation could be a new standard. It could also be CREX based or use CREX as the display form, however CREX was better suited as an exchange format than a visualization tool.

*Good assistance*

4.3.4 A software house will have to provide some assistance to WMO Member countries. The software and related documentation will be distributed, free-of-charge, to WMO Members through the NMHSs. It will be maintained and upgraded when required. Upgrades, with appropriate documentation, will be distributed to WMO Members. Queries will be answered by correspondence, usually e-mail, mainly to provide limited assistance for the local installation of the software and concerning the running of the software.

#### **Expected Functions of a Software House**

4.3.5 The software house will develop software, first to decode, and then to encode any BUFR, and CREX messages. The software should compile and run on the most common dialects of UNIX (including LINUX), as well as if possible OSF/1, HP\_UX, AIX, etc., but also Windows NT/2000/95/98/ME/XP, DOS, VMS. It should be compatible with 32-bit and 64-bit hardware architectures. The software delivered should be callable from applications, written in the most commonly used programming languages, such as FORTRAN, C and if possible JAVA.

4.3.5.1 The BUFR decoder should be able to decode previous editions of BUFR (starting from edition 0).

4.3.5.2 Printing and display routines should be available to view the whole content of decoded data, and should be complemented by user-friendly interface(s) as appropriate.

4.3.5.3 The user should have access to the BUFR/CREX Code tables, for human reading and editing; to be able to include new international additions or necessary local table entries; or, to be able to express requirements for additional international entries.

4.3.5.4 Documentation on the program will be provided with the software and should be clear and comprehensive. All interfaces with the external applications should be well defined.

4.3.5.5 User-friendly interface(s) to encode most current data types that may be collected manually would be required.

4.3.5.6 The software and related documentation will be distributed, free-of-charge, to WMO Members through the NMHSs. It will be maintained and upgraded when required. Upgrades, with appropriate documentation, will be distributed to WMO Members. Queries will be answered by correspondence, usually e-mail, mainly to provide limited assistance for the local installation of the software and concerning the running of the software.

4.3.5.7 The software should also be made available to manufacturers of systems encoding or using meteorological data. Such types of delivery should be made on an "as is" basis, in the appropriate form (binary form when possible, source code otherwise).

## *Resources*

4.3.6 After the programming development is completed, the task of the software project is estimated for one person full time.

### **PILOT PROJECT(S)**

4.4 Assistance in the form of pilot projects is urgently required for the automation of NMCs, for the introduction of information and communication technology and for the training of their technical staff. Pilot migration projects should be identified, developed and implemented, as test and precursor of the migration, to show the benefits and to show any difficulties. This will also allow for better solutions to problems to be identified.

4.4.1 One of the main problems associated with migration was fully understanding both the various data delivery issues to NMHSs receiving data and the various processing issues of data received via the GTS (or INTERNET) in CREX or BUFR by all National Meteorological Centres. Therefore, the idea of pilot project(s), where National Centre(s) could be selected for implementation of BUFR and CREX decoders, could be very useful as an experiment to find what and where the real problems are. This should also better reveal the needs for training to be dispensed to all staff involved in telecommunications, data management, data processing and forecasting.

4.4.2 A country, already automated for data processing, but not so advanced, could be selected for this test. Consultants have already been sent to analyse the problems to be faced because of the migration in some RA I and RA II countries. The implications of the migration for developing Countries could also be examined and evaluated during a special workshop organised for that purpose. The organisation of such a workshop should be done as soon as possible; it could be then the opportunity to select countries for pilot project(s).

**Action:** Secretariat to organize a 4 days workshop on capacities building for the migration strategy (tentatively during first half of 2003): Where are the main problems? What is necessary? Make recommendations, in particular define pilot project(s).

About 4 experts from RA II and 4 experts from RA I, plus 2 additional experts from experienced countries.

**Cost: About 40,000 CHF**

### **ACTIONS RECOMMENDED**

#### **TASKS OF WMO MEMBERS FOR PRODUCING TDCF**

4.5 Producers will have the freedom to switch to BUFR when they need (interest of some of their users for new parameters, new data types, metadata), however, they have to ensure their other users have access to the data. In many cases dual dissemination in BUFR and CREX will be necessary to ensure that users who cannot receive binary data can receive in real-time the basic information. The dual dissemination in BUFR and Traditional Alphanumeric Codes will not be the best since the user will not be able to receive the new parameters and greater precision transmitted within the BUFR message, but users should have the capacity to understand CREX.

#### *Manufacturers of automated platforms*

4.5.1 Some NMHSs will need to plan for replacement of their automated systems and others may plan to introduce automation. Financial considerations may make it necessary for Members to do this over a long time. Members should begin planning for the introduction of systems with software to encode observations in BUFR (or CREX). Automatic platform manufacturers have to be aware of the BUFR and CREX formats for developing their new systems. Manufacturers of observing systems should be solicited for the development of systems that comply with the migration strategy. By experience, the time necessary for a manufacturer to develop an encoder in BUFR (for one type of observation) is estimated at six months.

4.5.2 Development and implementation of new software to generate BUFR messages (BUFR encoding software) is needed at all places where messages are currently generated in TAC. The Software Project could take care of the software development itself. However, the specific site implementation would require special attention and work. The task is considerable because it will affect all NMHSs. They should be encouraged to start special migration projects to implement the new encoding software in all operational observation systems, which currently produce TAC.

#### *Need for double dissemination or not*

4.5.3 As some countries begin to migrate to TDCF, double encoding, dual dissemination or translation back to TAC will need to be done to cater for countries not equipped to receive or process BUFR. However, data flows and user requirements have to be analysed. So far, satellite data transmitted in BUFR have been used by a limited number of Centres running global numerical models; other users did not need these data. To decide on dual dissemination or not, producers will have to consider their users and analyse requirements for dual dissemination perhaps based on a geographical selection.

#### *National concentration*

4.5.4 It would not be practical and cost-effective to encode observations in both TAC and TDCF at observation sites and to send them to a collecting Centre. Observation sites will transmit the observation reports to a concentration site or to their NMC in a format, which could be national or non-standard, TAC, CREX or BUFR (see Table 1). The NMC or concentration site could convert in BUFR or CREX the national/non-standard format and transmit on the Global Telecommunication System (GTS) the observations in BUFR and/or CREX. Observations in TAC will be transmitted in TAC. The NMC or concentration site could convert observations reported in BUFR in TAC and transmit both formats (double-dissemination) if there is a need for non-binary compatible users. Eventually, when all NMCs can understand CREX, a double dissemination BUFR and CREX would be preferable. All NMCs should have BUFR decoder and CREX encoder software to perform this conversion.

#### *Testing*

4.5.5 Testing of encoded BUFR or CREX observations with an independent decoder, if possible from another WMO Members is a pre-requisite before starting to disseminate operationally these observations in TDCF.

#### *International constraints*

4.5.6 A WMO Member producing a new bulletin containing observations in BUFR or CREX will have to notify the Secretariat in advance of its transmission, in order to pass the information to all other Members for organising dispatching or reception.

4.5.7 Producers will have to give warning (through WMO Secretariat) at least one or two years in advance that they will stop the dissemination of observations in TAC, or later in CREX.

4.5.8 For surface observations one message often contains observational information of a set of different stations at the same observation time. A compilation process in which the observation data from multiple stations is collected in the message usually creates this set. Mostly, there are a number of messages for different dissemination strategies (i.e. national, regional or worldwide dissemination). The place of this compilation process in the Information and Communication Technology-architecture of an NHMS can be different from case to case, but (when available) often this will be the meteorological message switching system. Now, the encoding of the observational information of the stations will take place on a per station basis, in principle, independent of the compilation process. When the encoding will take place in BUFR or CREX code, compilation of the information of various stations will only be feasible when all the reports will be in the same code, which will make the bulletins confection more complex.

**TABLE 1**

Observation site encodes observation report in:	Concentration site or National Meteorological Centre converts to:	Concentration site or National Meteorological Centre transmits (depending on their potential users requirements) in:
National or other non-WMO standard format	TAC	TAC
	BUFR	BUFR
	BUFR and TAC ( <i>not recommended when all automated (but non-binary) users are equipped with CREX decoder</i> )	BUFR and TAC
	BUFR and CREX	BUFR and CREX
	CREX ( <i>terminated when all users can process BUFR</i> )	CREX
TAC	No conversion	TAC
	BUFR	BUFR
		BUFR and TAC ( <i>not recommended when all automated (but non-binary) users are equipped with CREX decoder</i> )
	BUFR and CREX	BUFR and CREX
CREX	No conversion	CREX
BUFR	No conversion	BUFR
	TAC ( <i>not recommended when all automated (but non-binary) users are equipped with CREX decoder</i> )	BUFR and TAC
	CREX ( <i>terminated when all users can process BUFR</i> )	BUFR and CREX

4.5.9 There are some special cases where existing practices for collecting and disseminating TAC data have an operational basis that needs to be preserved when migrating to BUFR or CREX. The TDCF will permit the transmission of any number of levels of upper air data, however the timing for operational delivery of data imposes constraints. For instance, since balloon flights can last more than one hour, there is a need to transmit parts A and B of TEMP and PILOT data as soon as it becomes available to support operational forecasting. For TAC data this is done separately and before the parts C and D become available. There are thirteen WMO bulletin header definitions for TAC TEMP and PILOT data and there is no need to continue this practice. When BUFR or CREX would replace TEMP and PILOT data for international exchange, only three categories will be needed: one WMO heading  $T_1T_2$  definition for part 1 (equivalent to both

combined old parts A and B data), one for part 2 (equivalent to both combined old parts C and D data) and one for a combination of the two parts 1 and 2 (equivalent to all combined old parts A, B, C and D data).

#### *Non-automated stations*

4.5.10 For the long term, automation should be considered. When contracting with manufacturers of automatic platforms, encoding in BUFR or CREX, not TAC, should be specified. Level 1 training for observers (if still used for entering data) will be required for explaining the new technology and TDCF.

4.5.11 An intermediate step would be the migration to CREX, which can be handled manually. This should be done if new parameters or new data types have to be transmitted despite manual encoding. This migration would require the training of staff: first the observers to be able to code observations in CREX and also the staff at NMCs to understand CREX code coming from their national stations or from the GTS or from other means.

4.5.12 Is there interest to translate TAC into BUFR or CREX at national concentration site? Only if at that stage the site can add useful coordinates or metadata to the original TAC observation into the BUFR or CREX format.

### **Tasks of producers from associated Programmes**

#### *Satellite data producers*

4.5.13 The satellite observations which are not yet coded in BUFR (SATEM; SARAD; SATOB), should be converted to BUFR rapidly. However, users of SATOB in particular will have to be ready to receive the equivalent in BUFR. Warning of switch to BUFR should be given at least a year in advance. All new observation types are indeed coded in BUFR by the satellite Agencies. A note has been added in the Manual on Codes to remind satellite data producers that all new satellite observations should be coded in BUFR.

#### *Other producers*

4.5.14 For producers outside the WMO Members, tasks related to observing platforms and concentration centres should be the same as listed above for NMHS. It is expected that more time will be required for the conversion to TDCF of remote in situ platforms like ships, which will require training of staff and/or automation. Warning should also be given one or two years in advance (through the WMO Secretariat) of ending of dissemination in TAC or CREX.

### **TASKS OF WMO MEMBERS FOR CONVEYING TDCF**

4.6 With significant variation of capability in different part of the GTS and among RTHs, the pace of migration will vary throughout different portions of the GTS. New bulletins will have to be defined and added to message switching directories. The migration will require substantial updating of the Message Switching System Directories in NMC-GTS interfaces and in RTHs but it will be a slow process, since the migration will be very progressive. For GRIB 2 products and satellite data exchange, more than for traditional observations exchanged in BUFR, it is recommended that GTS Centres increase the size limit for all binary messages to 500,000 octets as soon as possible.

4.6.1 Format translation is not a role of an RTH and many RTHs would not have the processing power to be able to do this. Dual dissemination should be the primary mechanism utilised for migration. However some RTHs or Centres may have the capability to do format translation and may decide to do translation for their own needs. When NMHSs will convert BUFR messages received from the GTS into character code for their national use, there may be more sense in

encoding the information in CREX instead of TAC. In any case every effort should be made to avoid converting BUFR data back into the TAC.

4.6.2 There will be no mixed bulletins. The bulletins will contain only BUFR, or only CREX or only TAC reports.

4.6.3 There is a problem with bulletin identification caused by the historical assignment of available characters in the WMO heading to TAC bulletins and other existing bulletin types. There are not enough open combinations available to define the remaining bulletin type needed for BUFR and CREX bulletins message switching. The existing definition scheme needs to be revised and done so in a way that has minimal impact to existing bulletins.

4.6.3.1 Data designators (TTAAii) in abbreviated headings for TAC are defined in accordance with code forms, observation times, geographical areas and data flow but those of BUFR/CREX were based on broad data types. This can result in less routing flexibility for BUFR/CREX messages containing migrated data than messages in TAC. Additional capability to define migrated data types in the WMO heading should be developed. The idea is to use a currently unassigned letter for the T<sub>1</sub> of WMO headings for BUFR/CREX encoded migrated data. The rest of the WMO heading (T<sub>2</sub>AAii) could then be used to provide one to one mapping with the WMO headings of traditional data types. This is an issue that needs work coordinated within the OPAG on ISS dealing with the GTS.

4.6.3.2 The problem with bulletin identification is caused by the historical assignment of available characters in the WMO heading to TAC bulletins and other existing bulletin types. Of 26 possible T<sub>1</sub> characters, one is assigned for everything encoded in CREX, two are assigned for everything encoded in BUFR and 19 are already assigned to existing data types including text and GRIB. There are four characters that are unassigned, however these are being widely used nationally. To represent all assigned definitions for TAC bulletins taking into account the assignments of T<sub>1</sub>T<sub>2</sub> already made for BUFR and CREX, there are 41 definitions that are not assigned for BUFR and CREX. There are not enough open combinations available to define the remaining bulletin type needs. The existing definition scheme needs to be revised and done so in a way that has minimal impact to existing bulletins. Once the proposal for new bulletin definitions is accepted it should be implemented as soon as possible.

#### *National and regional Testing*

4.6.4 There has been considerable testing done regionally and nationally in support of programs to collect and disseminate data in table driven formats. In many cases this has centered on automated observation systems. There is also work being done to provide code translation either to or from a table driven code form depending on need. This regional and national testing has the potential to considerably ease migration especially, if the knowledge and capability is shared with other Members. Ideally, this will reduce the need for some Members to duplicate these activities.

## **TASKS OF WMO MEMBERS USING TDCF**

### **Automated NMCs**

4.7 To achieve a successful migration, the data users will need decoding software and support for this software early in the process. The Software House can assist centres with this. The NMCs will also have to analyse the possible impacts on data processing resulting from the availability of new BUFR or CREX reports, new parameters and new metadata. Some immediate fixes may be required to maintain operation. Further adjustments to their database management systems and application programs may also be necessary.

4.7.1 The programs receiving meteorological data are the first one to encounter the data formats, usually after having cracked the WMO Bulletins. Rapid provision of and support for decoding

software for TDCF would be necessary for a successful migration. The implementation and integration of decoder “plugged in” an operational chain of programs is not a trivial issue. The software house should deliver comprehensive documentation with the decoder program, in particular on the API. It should answer queries by correspondence, usually by e-mail, mainly to provide limited assistance for the local installation of the software and concerning the running of the software.

4.7.2 Required preparatory corrective actions at GDPS Centres to avoid missing data input can be divided in three categories:

4.7.2.1 Some Centres will have to add in their processing chain full universal BUFR and CREX decoders, to avoid missing observations.

4.7.2.2 Other Centres will have to implement a universal BUFR and CREX decoders, to be able to receive observations in BUFR or CREX. Manufacturers of "turn key" work-stations inputting GTS data would be approached so that they include in their software universal BUFR and CREX decoders, either in the existing systems, or for the new systems currently in development or to be developed.

4.7.2.3 Manually operated NMCs should seriously consider automation or envisage training to receive CREX as interim solution.

#### *Data processing*

4.7.3 The NMCs will have to analyse the possible impacts on data processing resulting from the availability of new BUFR or CREX reports, new parameters and new metadata. Some immediate fixes might be required to maintain operation, but further adjustments of data base management systems and application programmes might be necessary to fully benefit from the migration to TDCF, these may be accomplished in a longer time frame.

#### *National and other users*

4.7.4 When NMHSs will convert BUFR messages received from the GTS into character code for their national use, there may be more sense in encoding the information in CREX instead of TAC. In any case every effort should be made to avoid converting BUFR data back into the TAC. However this will imply training of users for CREX and fixing applications interfaces.

#### *Decoding for display*

4.7.5 There are two primary purposes for decoding data. One is for input into a processing or archival system and the other for display. Decoding data for processing has up to now been the primary use for table driven codes and most all of the existing exchanges has been developed to support this function. Although this has helped major Centers move forward with migration, it is not sufficient to support global scale migration. The "decoding for display" functionality however is a growing need. Some systems used in national hydrometeorological offices now have some capability to decode and display table driven code forms. Some commercial systems providers now manufacture systems with a decode-and-display capability. For migration on a global scale, decode-and-display capability must be widely available and affordable. Decode-and-display is especially critical to ICAO's migration plans.

#### **Manually operated NMCs**

4.7.6 Finally, the 40 Centres, which are currently operating manually, will have to seriously consider automation with software including a universal BUFR and CREX decoder. Almost all (but not all) RTHs can receive and transmit binary data, but many NMCs at the end of the lines cannot receive binary data. There are interim solutions to be envisaged for reception of data:

- Double dissemination by the producer (preferred solution): BUFR + CREX,

or

- Double dissemination by the producer: BUFR+ TAC (not the best solution),

or

- In the last RTH (if this has the capacity) before the NMC, reconversion to alphanumeric code: BUFR to CREX (not TAC, to keep the benefit of BUFR) and transmission of CREX, or BUFR+ TAC (but not the best solution).

4.7.7 An NMC considering automation should ensure that the data processing software developed in-house or delivered by a manufacturer would include universal BUFR and CREX decoders (and equally GRIB 1 and GRIB 2 decoders). Manufacturers of meteorological processing systems or workstations should offer these pieces of software in their tenders.

4.7.8 CREX should be seen as an interim solution; all NMCs should work at their capacity to receive binary data coded in BUFR. Before automation is implemented, they will be able to receive and understand CREX messages with a relatively simple training.

### **Use of Internet**

4.7.9 The use of the Internet may help to solve some migration problems. For some NMCs the Internet could allow earlier access to data in binary formats if they did not have a GTS link or if these data are not available over their GTS link. This assumes that these meteorological observations are made available on the Internet by some GDPS centres in their Web or FTP server.

### **ACTIONS BY WMO MEMBERS - DECISION MAKERS**

4.8 The WMO project for migration to Table Driven Code Forms will be successful if the benefits of using TDCFs are well perceived by the WMO Member Countries, who then will be motivated to implement national programmes for their migration. Some key elements to be considered by WMO Members are already available. Guides to explain codes and migration issues are accessible on the WMO web pages. Training is already provided in WMO seminars. Encoder/decoder software with data viewing capability is available. Templates in BUFR/CREX for all common traditional observation types have been prepared. The WMO Expert Team on Data Representation and Codes provides continuous development and maintenance of TDCFs. Central planning and coordination of the migration will be performed by the OPAG on ISS. Parallel transmission of TAC along with migrated data will allow flexibility of transition. CREX can be used where infrastructure cannot support BUFR. Easy translation can be done between BUFR and CREX. Progress of migration will be monitored to expedite reduction of un-needed dual transmissions. Coordination with manufacturers for encoding/decoding will be done.

4.8.1 Every WMO Member must:

- Define a Migration Contact Point (about 100 Members have nominated one already);
- Establish a National Migration to TDCF Steering Group (MTSG);
- Identify impacts of migration on national operation;
- Produce a national migration plan;
- Plan their requests for equipment and software (resources commitment);
- Start a national training programme on TDCF;
- As needed, modify or replace software used for observation, encoding, data concentration, dissemination systems, input data processing, message switching, decoding, visualisation and archiving;
- Evaluate the implications, due to the migration process, on WMO Members' resources for development and operation;
- Reserve the budget resources necessary to implement the migration.

4.8.2 Members should be convinced to consider reserving budget resources to implement the migration. Decision-makers need also to receive training of Level 1. Every country should make his own national migration plan, derived from the international plan, with analysis of impacts, cost,

solutions including how to raise financial resources if necessary, national training, technical planning and schedule. One of the main task is to evaluate the implications, due to the migration process, on WMO Members' resources for development and operation. The financial impact of the various steps of the migration process on NMHSs' budgets has to be listed. Budgets should be planned taking into account the migration cost, although this will be offset by the benefits. Plans must be drawn to formulate request for equipment and software (resources commitment). International coordination will be necessary bi-laterally or through the WMO to plan the migration process, in particular to organise the transmission of TDCF and encoding/decoding tests.

## SCHEDULE

4.9 The following first priority actions should occur in parallel:

- Training (2003 to 2005): organized by WMO and Nationally
- Installation of universal BUFR/CREX decoders as soon as possible, if necessary provided by the Software House, starting second half of 2003
- **Every country should formulate their own national migration plan, derived from the international plan, with analysis of impacts, cost, solutions, sources of funding (if necessary), national training, technical planning and schedule**

4.9.1 Staff implementing software should have followed P2 type course. Staff involved in operational implementation through the data flow should have followed a P1 type course. Reception of BUFR or CREX data should be preceded by a Level 1 course for the forecasters or other users.

4.9.2 Ideally, programmers of encoding software should have followed a Level 3 type course before starting development. Bi-lateral testing by an independent decoder should be performed before the operational implementation of new encoding software. Observers should be trained by Level 1 course and on their new operational encoding before introducing encoding of a new observation code.

### *Code migration schedule*

4.9.3 Even if the majority of the GTS Centres could support binary data early on, it would still take a long time for many NMHSs to introduce automated observing systems with the software to encode data in BUFR at the source sites, as well as implement their national telecommunication network capable of handling binary data. Based on a survey of code usage and considering constraints and factors linked to each type of TAC, the TACs have been grouped into six categories that share common characteristics that would allow migration to proceed in parallel. Considering established traditions and various factors (internal or external to the WWW) affecting each of these categories, three target dates have been set. They are: the start of experimental exchange, the start of operational exchange and the end of operational exchange (see Annex I).

4.9.4 It is certain that aviation and maritime TAC codes will be used longer than purely meteorological codes. One category of codes hardly used by WMO Members (Category 6) is not considered for migration. In several categories, exchanges of data in BUFR already take place. The target dates are not intended to limit when exchange may begin. In fact it is strongly encouraged that migration on a test, experimental or bi-lateral basis begin as soon as possible. These targets are the dates it is important to have exchange of migrated data occurring no later than. This migration schedule will be made more detailed, adjusted and updated by CBS, as the actions described in the plan are completed.

### *Migration matrix*

4.9.5 In Annex II, impacts and summary of actions to be taken on various operational units of the World Weather Watch are listed. There is a considerable amount of information that need to be gathered and collated in a fashion that would allow good analysis of the status and progress of

migration. The matrix will also be very useful as a tool for tracking the implementation of migration. It was felt the best way to organize this information was in a matrix keyed by the categories of TAC and type of Centre which would be the columns of the matrix. The cells of the matrix would include all the factors that are impacted by the migration. The matrix in Annex II will be regularly updated thereafter.

4.9.6 The actions already taken for the Migration are described in Annex III.

## **ACTIONS FOR THE CBS/ET DR&C**

4.10 It is not absolutely essential to have templates to encode traditional coded data in a table driven format but they greatly facilitate this function and they also provide a standard method of representation. It is nevertheless essential to have descriptors for all parameters that can be encoded in a traditional code form including regional and national practices. To this end the ET/DRC had already created many of the templates needed and most of the descriptors also exist, however several common sequences are still to be defined. Templates (can be found in the WMO web server) have been defined for:

- Automatic Weather Station data (n-minute period)
- Automatic Weather Station data (one-hour period)
- SYNOP and SYNOP MOBIL data
- SHIP data
- PILOT/PILOT SHIP/PILOT MOBIL with pressure as the vertical coordinate
- PILOT/PILOT SHIP/PILOT MOBIL with height as the vertical coordinate
- TEMP; TEMP DROP; TEMP SHIP; TEMP MOBIL
- XBT/XCTD
- Sub-surface profiling floats
- BUOY
- Simple AMDAR
- AIREP
- METAR/SPECI
- CLIMAT
- CLIMAT SHIP
- CLIMAT TEMP; CLIMAT TEMP SHIP
- Tropical cyclone tracks information derived from EPS
- New AMDAR
- AMDAR vertical profile

4.10.1 Not all reports will contain all the parameters that are proposed in the BUFR template for surface observations. Using the proposed templates for the BUFR code, all the fields of the non-observed parameters should be filled with a “missing value” code. This could generate a lot of “missing value” information, for instance a station that only registers a few parameters, or parameters from sea stations which will never be registered on land-surface stations (which are a majority). With these constraints, there is a need for a generic solution: i. e. several different common sequences, to cope with stations registering different numbers of parameters. The ET/DR&C should work more on these definitions.

4.10.2 The problem of the identification of type of data to be transmitted in BUFR or CREX should be addressed for message switching purpose. And the identification as sub-types within the TDCF message for the application processing, should also be addressed, perhaps within the frame of a new edition for BUFR/CREX.

4.10.3 Guidance and assistance should be provided to NMCs and RTHs that are using national and regional coding practices that differ from international coding procedures. There is a need to develop BUFR and CREX descriptors to address the optional sections of existing code structures within the current alphanumeric code forms as a replacement for these structures in BUFR.

4.10.4 The ET/DR&C should regularly review code descriptor and template requirements for representation of all data, coordinate needs with ICT/CM (see below in chapter V the reasons for ICT/CM) and provide central coordination of testing:

- This is critical to enabling successful migration of all traditional codes.
- Coordination of this activity will be done with the ET/DR&C but to insure better integration with overall migration the requirements review process will be integrated with the overall migration coordination process involving national and regional focal points along with the ICT/CM.
- This should be done at an organized meeting at least every year and as needed in between meetings via correspondence.

## **ACTIONS FOR OPAG ON ISS**

4.11 It will be useful to compile into a document migration guidance that could be provided to anyone interested. This new guide will specifically address migration issues whereas the guides to Codes are dedicated to the code forms themselves and their usage. This information could also provide benefit to those organisations and communities associated with WMO such as ICAO and IOC. The production of this guide will a useful enterprise and this action would be coordinated with the ET/DR&C and the Secretariat.

4.11.1 Many practices and procedures defined in the Manual on the GTS are directly linked to traditional codes. These issues needed to be looked at in more detail and coordinated with other Teams of the OPAG on ISS dealing with the GTS. Some examples are listed below:

- Attachment I-1: "Arrangement for the collection of ship's weather reports and oceanographic reports (BATHY/TESAC)",
- Attachment I-3 paragraph 2: "Principles for the establishment of the exchange programme for observational data on the MTN"
- Part II paragraph 2.3.3.2: "Text of meteorological bulletins in alphanumeric representation"
- Part II paragraph 2.8: "Procedure applicable to the transmission of reports from ships and other marine stations"

4.11.2 Migration will have significant impact on the Annual Global Monitoring and Annual Antarctic Monitoring programs. Procedures for both will need significant modification. This will need to be coordinated with other Teams of the OPAG on ISS dealing with the GTS and with the Secretariat.

## **ACTIONS BY THE SECRETARIAT**

4.12 The Software house requirement have driven the actions of the WMO Secretariat who approached ECMWF for support to WMO members for a software house (with first priority for universal BUFR, CREX and GRIB decoder). WMO has also approached EUMETNET. Since the EUMETNET OPERA software works on Windows operating system and on several more other operating systems than ECMWF software, the OPERA software could complement ECMWF software for the non-UNIX and Windows environments.

4.12.1 A CD-ROM containing all guides, Manuals, documentation and the migration plan itself should be produced by the Secretariat with translation in French, Spanish and Russian languages. The Guide on BUFR and CREX written in 2001 should be also translated; and put on a CD-ROM for worldwide distribution. **COST: about several thousands CHF**

4.12.2 The Secretariat should perform the following actions:

- Send information for Members through PR and Focal points

- Send questionnaire every two years to Focal Points - Inform Regional Rapporteurs - Results on Web
- Send METNO for migration warning (new bulletins) and Newsletter (advance warning and TAC stop warning)
- Maintain WMO Web site on migration
- Organise WMO training programme on MTDCF for trainers and software users
- Organise pilot projects and corresponding capacity building workshop
- Organise workshop with manufacturers
- Provide Level 1 training in WMO seminar (already started)

## V. RECOMMENDATIONS FOR CO-ORDINATION AND REVIEW MECHANISMS

5. To ensure minimum impact to Members from the migration to TDCF, an effective mechanism must be put in place to provide implementation monitoring and coordination. It is critical to the process that information on the timing of changes, the availability of data and the identification of both requirements and problems be made available to Members' managers and decision makers as well as to appropriate groups within WMO and other relevant organizations.

5.1 Members should provide national focal points for migration issues, preferably the *National Focal Point for Code Matters*. The national focal point should have direct knowledge of national migration implementation plans. The national focal point would provide coordination with the regional association and other relevant WMO groups as needed regarding national plans for migration, impacts of migration on national operations and status of implementation. The national focal point would define requirements to the Expert Team on Data Representation and Codes for code changes. They would provide notification of planned implementation dates. The national focal point would also provide a channel to make Members aware of activities and critical information from other Members or organizations, such as implementation dates or changes in availability data planned by other Members.

5.3 The regional associations will need to play an active role in the coordination of the migration in their Regions, including the identification of the most effective mechanisms for management and monitoring.

5.4 Central planning and coordination of the migration will be performed by the Open Programme Area Group on Information Systems and Services and its teams. There should be a mechanism for collecting, recording and reporting implementation dates, changes in data availability and any other migration issues which have an extranational impact including information on past and future changes. Technical guidance should be developed in the form of a *WMO Code Migration Guide*.

### *Information coordination and reporting of Migration Activities*

5.5. It is recommended the ET/MTDCF be disbanded and an ICT for Code Migration (ICT/CM) be established. The ICT/CM would provide the central coordination and reporting essential to the success of code migration. The ICT/CM should compile a Code Migration Guide which would be provided to those affected by migration. This could be web based and should be updated annually or as needed. This new guide will specifically address migration issues whereas the guides to Codes are dedicated to the code forms themselves and their usage. This Guide would also provide benefit to those organisations and communities associated with WMO such as ICAO and IOC.

5.5.1 Mechanisms must be put in place to ensure all activities are integrated, impacts are minimized, problems are identified and progress monitored.

- Information coordination will be done via a tree structure with national and organizational focal points at the bottom. The next level would be regional focal points (e.g. rapporteur on Data Management (on Codes and Migration to TDCF)) and possibly focal points in some other teams or groups. The high level will be the ICT/CM.
- Each level would have responsibility for collecting information on migration activities and progress, consolidating it and making it available to levels above and below them.
- Regional and other appropriate focal points should have migration responsibilities outlined in their terms of reference.
- These persons would provide central coordination of activities including experimental exchange and testing.
- ICT/CM would provide reports to OPAG/ISS, CBS or other bodies as needed and coordinate with them.
- It is recommended that the chairman of ICT/CM would sit as a member on ET/DRC and other groups as needed.

#### *Catalogue of data available in a table driven format*

5.6 A catalogue of all data available (Bulletins) in table driven format (either BUFR or CREX) should be built and made available on the web:

- It will help to spread the capability to handle table driven code forms.
- There is already a mechanism in WMO for cataloguing this information. It is Pub. 9, Vol. C. It can be amended to include information on the migration.
- The purpose of the cataloguing is to help increase data exchange by making Members aware of what is available, to assist in tracking migration and as a tool to help coordinate migration and data exchange.
- This activity would be started with information from national focal points that WMO has already requested from each member, regional Rapporteur who would be given migration responsibilities. It is also would be coordinated with each respective RTH focal point.
- The cataloguing would include a complete review of existing bulletin definition to ensure the current catalogue is correct. It is important that obsolete bulletins are removed and that the de-cataloguing of bulletins is continued through the migration process.
- Information for all the Members would then be possible by the Secretariat with this information.

#### **At WMO level**

##### *Inter-Commissions*

5.7 Other WMO Commissions should be informed of development and progress of the migration, by correspondence or participation with representative in the ICT/CM meetings.

##### *With other Organisations, Agencies*

5.7.1 Coordination at the international level in the marine and oceanographic communities of WMO and IOC will primarily be done through the JCOMM Data Management Programme Area (data distribution and archive, data users) and through the JCOMM Observations Programme Area where panels such as the DBCP, SOOP, ASAPP, and VOS actively participate and make observations (data producers). A representative of IOC should always participate in the meetings of the ICT/CM and DR&C.

5.7.2 Coordination with ICAO is done through the representative of ICAO who should always participate in the meetings of the ICT/CM and DR&C.

#### **At Regional and National Levels**

### *Role of regional rapporteurs*

5.8 The successful implementation of the migration to table driven codes in developing countries largely depends on capacity building. Therefore an analysis of needs for further development of the WWW including GTS should be carried out at national and regional levels, and then regional strategic plans should be formulated to enhance basic facilities in the NMCs of developing countries. The regional rapporteurs should follow and coordinate the migration in their region and contribute to the establishment of the regional plan if necessary. They should provide guidance and assistance to NMCs and RTHs that are using national and regional coding practices that differ from international coding procedures. There is a need of coordination with the ET/DR&C to develop BUFR and CREX descriptors to address the optional sections of existing code structures within the current alphanumeric code forms as a replacement for these structures in BUFR.

### *Role of national focal-points*

5.8.1 The national focal points should follow and coordinate the migration in their country and contribute to the establishment of the national plan. The focal point should ensure that the country notify the WMO Secretariat when planning to transmit data in BUFR or CREX, and send warning when TAC transmission are planned to be interrupted. National Focal points on Code matters should be reminded of these recommendations and should have access to documentation (WMO server, CD-ROM).

### *Establishment of a National Migration to TDCF Steering Group (NMTSG)*

5.8.2 A national Migration to TDCF Steering Group (MTSG) composed of national experts and including the national focal point should be established in every country to plan and optimize the transfer to Table Driven Code Forms. Russia and USA have already taken this initiative.

## ANNEX I: Code Migration Schedule

Category →	Cat.1: common	Cat.2: satellite observations	Cat.3: aviation <sup>(1)</sup>	Cat. 4: maritime	Cat. 5 <sup>(2)</sup> : miscellaneous	Cat. 6 <sup>(2)</sup> : almost obsolete
<b>Lists of → Traditional code forms</b>	SYNOP SYNOP MOBIL PILOT PILOT MOBIL TEMP TEMP MOBIL TEMP DROP CLIMAT CLIMAT TEMP	SAREP SATEM SARAD SATOB	METAR SPECI TAF AMDAR ROFOR	BUOY TRACKOB BATHY TESAC WAVEOB SHIP CLIMAT SHIP PILOT SHIP TEMP SHIP CLIMAT TEMP SHIP	RADOB IAC IAC FLEET GRID( <i>to GRIB</i> ) MAFOR HYDRA HYFOR RADOF	CODAR ICEAN GRAF NACLI etc. SFAZI SFLOC SFAZU RADREP ROCOB ROCOB SHIP ARFOR WITEM
<b>Schedule ↓</b>						
<b>Start experimental Exchange<sup>(3)</sup></b>	Nov. 2002 for some data (AWS SYNOP, TEMP USA)	Current at some Centres	2006  2002 at some Centres for AMDAR	2005  2003 for Argos data (BUOY, sub-surface floats, XBT/XCTD)	2004	Not applicable
<b>Start operational exchange<sup>(3)</sup></b>	Nov. 2005	Current at some Centres	2008  2003 for AMDAR	2007  2003 for Argos data (BUOY, sub-surface floats, XBT/XCTD)	2006	Not applicable
<b>Migration complete</b>	Nov. 2010	Nov. 2006	2015  2005 for AMDAR	2012  2008 for Argos data (BUOY, sub-surface floats, XBT/XCTD)	2008	Not applicable

Notes:

- (1) Aviation Codes require ICAO coordination and approval, [except for AMDAR](#)
- (2) For category 5 consider that codes need to be reviewed in order to decide whether or not they should be migrated to BUFR/CREX. Codes in category 6 are not to be migrated.
- (3) All dates above are meant as "not later than". However, Members and Organizations are encouraged to start experimental exchange, and, if all relevant conditions (see below) are satisfied, to start operational exchange as soon as possible.

- Start of experimental exchange: data will be made available in BUFR (CREX) but not operationally, i.e. in addition to the current alphanumeric codes, which are still operational.
- Start of operational exchange: data will be made available in BUFR (CREX) whereby some (but not all) Members rely on them operationally. Still the current alphanumeric codes will be distributed (parallel distribution).
- Migration complete: at this date the BUFR (CREX) exchange becomes the standard WMO practice. Parallel distribution is terminated. For archiving purposes and at places where BUFR (CREX) exchange still causes problems the alphanumeric codes may be used on a local basis only.

*Relevant conditions to be satisfied before experimental exchange may start:*

- Corresponding BUFR/CREX-tables and templates are available;
- Training of concerned testing parties has been completed;
- Required software of testing parties (encoding, decoding, viewing) is implemented;

*Relevant conditions to be satisfied before operational exchange may start:*

- Corresponding BUFR/CREX-tables and templates are fully validated;
- Training of all concerned parties has been completed;
- All required software (encoding, decoding, viewing) is operational.

## ANNEX II: Centre/Facility Migration Matrix

(see notes at bottom)

TAC Category ↓	Type of Centre and Role →  TAC ↓	Observing Site Data Producer			National Observation Data Collection Centre Data Producer	Observation Data Generation Centre Data Producer	RTH Data Conveyor	Data Processing Centre (NMC) Data User and Data Producer (products)?	Local Forecast Office Data User and Data Producer (products)?	National Met. Service Administration Data Producer, Conveyor?, User
		Observer	Micro-chip Embedded System	Software Programmer						
<b>CAT1 common:</b> (Exp Exch Nov. 2002, Oper Exch Nov 2005, Migr Cmpl Nov 2010)	SYNOP SYNOP MOBIL PILOT PILOT MOBIL TEMP TEMP MOBIL TEMP DROP CLIMAT CLIMAT TEMP	Typing in parameters (BUFR) or Encoding (CREX) Training: L1(BUFR) or L3(CREX) for one data type only	Encoding, Reprogramming EPROM, Double encoding?	Encoding, Double encoding? Volume + Training: L3	Conversion? Encoding? Double encoding? Double Transmission? Volume + Training: P2 or L3	<i>Not Applicable</i>	Double Transmission? Volume + Bulletins +	Decoding Display? Volume + Bulletins + Conversion? Training: P2	Decoding? Display? Parameters: + Volume + Training: L1 or P1 or P2	Plan and formulate request for equipment and software (resources commitment). Need to receive Training: L1
<b>Cat.2 Satellite: obs:</b> (Exp Exch Current, Oper Exch Current, Migr Cmpl Nov 2006)	SAREP SATEM SARAD SATOB	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	Encoding? Double encoding? Double Transmission? Volume + Training: P2 or L3	Volume + Double Transmission? Bulletins +	Decoding Display? Volume + Bulletins + Training: P2	Decoding? Display? Parameters: + Volume + Training: L1 or P1 or P2	Training: L1
<b>CAT3 aviation:</b> (Exp Exch Current, Oper Exch Nov 2008, Migr Cmpl Nov 2015)	Observations: METAR SPECI CODAR AMDAR	Typing in parameters (BUFR) or Encoding (CREX) Training: L1(BUFR) or L3(CREX) for one data type only	Encoding, Reprogramming EPROM, Double encoding?	Encoding, Double encoding? Volume + Training: L3	Conversion? Encoding? Double encoding? Double Transmission? Volume + Training: P2 or L3	Conversion? Encoding? Double encoding? Double Transmission? Volume + Training: P2 or L3	Double Transmission? Volume + Bulletins +	Decoding Display? Volume + Bulletins + Conversion? Training: P2	Decoding? Display? Parameters: + Volume + Training: L1 or P1 or P2	Plan and formulate request for equipment and software (resources commitment). Need to receive Training: L1

TAC Category ↓	Type of Centre and Role →  TAC ↓	Observing Site Data Producer			National Observation Data Collection Centre Data Producer	Observation Data Generation Centre Data Producer	RTH Data Conveyor	Data Processing Centre (NMC) Data User and Data Producer (products)?	Local Forecast Office Data User and Data Producer (products)?	National Met. Service Administration Data Producer, Conveyor?, User
		Observer	Micro-chip Embedded System	Software Programmer						
<b>CAT3 aviation:</b> (Exp Exch Current, Oper Exch Nov 2008, Migr Cmpl Nov 2015)	Products: TAF WITEM ARFOR ROFOR	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	Double Transmission? Volume + Bulletins +	Decoding Display? Volume + Bulletins + Encoding? Double encoding? Double Transmission? Training: P2 or L3	Parameters: + Volume + Decoding? Display? Encoding? Double encoding? Training: L1 or P1 or P2	Plan and formulate request for equipment and software (resources commitment). Need to receive Training: L1
<b>CAT4 maritime:</b> (Exp Exch Nov. 2003, Oper Exch Nov 2007 Migr Cmpl Nov 2012)	BUOY TRACKOB BATHY TESAC WAVEOB SHIP CLIMAT SHIP PILOT SHIP TEMP SHIP CLIMAT-TEMP SHIP	Typing in parameters (BUFR) or Encoding (CREX) Training: L1(BUFR) or L3(CREX) for one data type only	Encoding, Reprogramming EPROM, Double encoding?	Encoding, Double encoding? Volume + Training: L3	Conversion?, Encoding? Double encoding? Volume + Training: P2 or L3	Conversion, Encoding? Double encoding? Volume + Training: P2 or L3	Double Transmission? Volume + Bulletins +	Decoding Display? Volume + Bulletins + Conversion? Training: P2	Parameters: + Volume + Decoding? Display? Training: L1 or P1 or P2	Plan and formulate request for equipment and software (resources commitment). International coordination Need to receive Training: L1
<b>CAT5 m\sc:</b> (Exp Exch Nov. 2004, Oper Exch Nov 2006 Migr Cmpl Nov 2008)	Observations: HYDRA RADREP RADOB	Encoding Typing in parameters (BUFR) or Encoding (CREX) Training: L1(BUFR) or L3(CREX) for one data type only	Encoding, Reprogramming EPROM, Double encoding?	Encoding, Double encoding? Volume + Training: L3	Conversion?, Encoding? Double encoding? Volume + Training: P2 or L3	Conversion, Encoding? Double encoding? Volume + Training: P2 or L3	Double Transmission? Volume + Bulletins +	Decoding Display? Volume + Bulletins + Conversion? Training: P2	Parameters: + Volume + Decoding? Display? Training: L1 or P1 or P2	Plan and formulate request for equipment and software (resources commitment). International coordination Need to receive Training: L1

TAC Category ↓	Type of Centre and Role →  TAC ↓	Observing Site Data Producer			National Observation Data Collection Centre Data Producer	Observation Data Generation Centre Data Producer	RTH Data Conveyor	Data Processing Centre (NMC) Data User and Data Producer (products)?	Local Forecast Office Data User and Data Producer (products)?	National Met. Service Administration Data Producer, Conveyor?, User
		Observer	Micro-chip Embedded System	Software Programmer						
<b>CAT5 m\sc:</b> (Exp Exch Nov. 2004, Oper Exch Nov 2006 Migr Cmpl Nov 2008)	Products: IAC IAC FLEET GRID (->GRIB) MAFOR HYFOR RADOF	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	Double Transmission? Volume + Bulletins +	Decoding Display? Volume + Bulletins + Conversion? Encoding? Double encoding? Double Transmission? Training: P2 or L3	Parameters: + Volume + Decoding Display? Encoding? Double encoding? Training: P2 or L3	Plan and formulate request for equipment and software (resources commitment). International coordination Need to receive Training: L1
<b>CAT6 almost obsolete:</b> (Exp Exch NA, Oper Exch NA Migr Cmpl Nov 2012)	ICEAN GRAF NACLI etc. SFAZI SFLOC SFAZU ROCOB ROCOB SHIP	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>	<i>Not applicable</i>

NOTES:

- Question marks mean a possibility or a choice to be decided by the country depending on its interest and need. The sign "+" means increase, for example in volume of information to transmit or in number of parameters or bulletins to process.
- National Observation Data Collection Centres collect observations and produce observation reports and generate GTS bulletins. It can be also part of the functions of a National Telecommunication Centre interfacing with the GTS.
- Observation Data Generation Centres produces observations or observations products (e.g., Service ARGOS, EUMETSAT). They may produce GTS bulletins.
- NMCs and Local Forecast Offices can generate products.
- The Data Processing Centre (NMC) may produce bulletins of products. . It can be also part of the functions of a National Telecommunication Centre interfacing with the GTS.
- Levels of Training:
  - L1 – General philosophy of TDCF and migration overview
  - L2 – Meteorological users, Telecommunications Managers, Data Managers, and those involved with Application Interfaces
    - P1) Trainers, data managers and also people interfacing with general users (meteorologists) and decision-makers for technical matters.
    - P2) Technical users involved in operational software development.
  - L3 – For encoder and decoder programmers (only needed if the software project is not fully implemented)

## **ANNEX III: Actions already undertaken for the Migration (15/08/02)**

1. The WMO experts on codes have defined standard examples (called templates) for the format in BUFR of all the traditional observations. Manufacturers of automatic weather stations and other observing platforms have already been invited to take into account the coming shift to table driven codes for their software development. The WMO secretariat distributes guidance information describing in a simple manner the table driven codes and explaining their advantages. A new guide on BUFR/CREX with 3 layers of understanding and difficulties has been written in 2001 and is in the WMO web ([www.wmo.ch](http://www.wmo.ch) search top right to Codes). A new attachment to the Manual on Codes defining for TDCF reporting practices which were previously associated to TAC code forms (e.g. synoptic observations and FM 12 SYNOP ) is currently being written.

2- BUFR had been used for a long time to exchange, satellite data, wind profiler data, ACARS data, radar data and tropical cyclone information. BUFR is also used to transmit SIG Weather data and SIGMET. CREX is used operationally for exchange of ozone data (Global), soil temperature data (Europe), hydrological data (Africa and Europe), tropical cyclone data (Pacific), Radiological data (Europe) and tide-gauge data (USA).

3. The ET/MTDCF had reviewed the current exchange of observations in BUFR or CREX at the time of May 2002. The Team considered that the actions taken so far by some WMO Member Countries were very encouraging, showing clearly that the advantages of TDCF had been well understood. Advanced Countries in North America, Europe, Asia and Pacific are progressively migrating. Many are already or planning soon using BUFR nationally for their Automatic Weather Station data transmission. Some are planning to code in BUFR Rawindsonde data. Several producers will be able to start to transmit traditional observation data in BUFR at end of 2002 or in 2003 (reports from: automatic weather stations, radiosonde stations).

3.1 USA indicated that BUFR encoded rawindsonde data could be made available on the GTS. Double dissemination will be performed and the list of stations will be available. The U.S.A. currently maintains a software registry where it makes available decoding, encoding, translation and other software for download to anyone. These programs are provided with existing documentation. Limited help can be provided for these programs but only as resources allow.

3.2 The Japanese Meteorological Agency is transmitting wind profiler data (25 stations), typhoon analysis information and cloud motion vectors derived from GMS images around typhoon in BUFR.

3.3 Within the EUMETNET pilot project, the hourly exchange of observations from both automated and manned stations in BUFR, using the EUMETNET OPERA software, was planned to start in December 2002. Five countries were involved: Czech Republic, Germany, France, Netherlands and Slovakia. The OPERA software had been used to encode/decode BUFR for exchanging radar data within Europe for several years.

3.4 The Russian expert indicated that to maintain international commitment of transfer to Table Driven Code Forms, the procedure of conversion from traditional code forms to Table Driven Code Forms at WMC Moscow, RSMC Novosibirsk and RSMC Khabarovsk will be implemented. WMC Moscow will be able to encode and decode Table Driven Code Forms by 2004. RSMC Novosibirsk and RSMC Khabarovsk will be fully able to encode and decode Table Driven Code Forms by 2005. The situation regarding information transfer from observing stations is more complicated. Given the large number of observing stations in Russia, it will not be possible to perform information transfer in Table Driven Code Forms within the period recommended by the migration plan due to technological, economic and social reasons. The migration to BUFR encoding for observing stations, in particular, will be performed within the normal course of upgrade or replacement of their technology. Presumably, this situation is typical for many National Meteorological Services maintaining a significant quantity of observing stations, for which automated data transfer is not implemented.

3.5 AMDAR data will be distributed within Europe in BUFR before end of 2002, with AMDAR vertical profiles also in CREX for readability by all countries.

3.6 Service ARGOS plans to transmit Sub-surface float data and XBT/XCTD in BUFR before end of 2003.

#### *Surface buoy data*

3.6.1 At its 16<sup>th</sup> session, the WMO-IOC Data Buoy Cooperation Panel (DBCP) took steps to insure GTS distribution of buoy data in BUFR as of year 2003. Buoy data would continue to be distributed in BUOY format in parallel for some years after BUFR distribution starts.

#### *ARGO sub-surface profiling float data*

3.6.2 A few float providing countries would eventually implement national solutions to GTS distribution of ARGO float data in BUFR. Other countries would rely on ARGOS system capabilities to produce BUFR reports that would be developed primarily for surface buoys (such capability should be compatible to some extent with requirements for GTS distribution of sub-surface floats in BUFR).

#### *XBTs from Ship Of Opportunity*

3.6.3 There were no firm plans at this point to develop capability to distribute XBT data in BUFR except by Service ARGOS. This is discussed in the context of JCOMM, its Ship Observations Team, and SOOPIP.

#### *Voluntary observing ships (VOS Programme)*

3.6.4 There were no firm plans at this point to develop capability to distribute VOS meteorological data in BUFR or even CREX. The difficulty is the equipment of all the ships and the training of all concerned sailors and port officers. This is discussed in the context of JCOMM and its Ship Observations Team. National initiatives to distribute ship data in BUFR or CREX would be welcome although it was recommended that character codes such as SHIP (if BUFR is used) continue to be used in parallel for a long period.

## ANNEX IV: LIST OF ACRONYMS

ACARS	AirCRAFT Addressing and Reporting System
AFWA	Air Force Weather Agency
AMSU	Advanced Microwave Sounding Unit
ANSI	American National Standards Institute
API	Application Program Interface
ARGO	Array for Geostrophic Oceanography
ASAPP	Automated Shipboard Aerological Programme Panel
AWS	Automatic Weather Station
ATSR	Along Track Scanning Radiometer
BUFR	Binary Universal Form for the Representation of (meteorological) data
CBS	Commission for Basic Systems
CBS-Ext.(98)	Extraordinary session of CBS held in 1998
CIMO	Commission for Instruments and Methods of Observations
COST	European Co-Operation in the field of Scientific and Technical research
CREX	Character Representation form for data EXchange
DBCP	Data Buoy Cooperation Panel
DBMS	Data Base Management System
DCP	Data Collection Platform
DIF	Directory Interchange Format
DPFS	Data Processing and Forecasting Systems
DRT	Data Representation Template
DT	Data Template
DWD	Deutscher Wetter Dienst
EC	Executive Council of the WMO
ECMWF	European Centre for Medium-range Weather Forecast
EPS	Ensemble Prediction System
ERS	European Research Satellite
ESA	European Space Agency
ET	Expert Team
ET/EDF	Expert Team on Evolution of Data Formats
ET/DR&C	Expert Team on Data Representation and Codes
EUMETNET	European Meteorological Networks
EUMETSAT	EUropean organisation for the exploitation of METeorological SATellites
FNMOCC	Fleet Numerical Meteorology and Oceanography Centre
FORTTRAN	FORmula TRANslation
FTP	File Transfer Protocol
GCOS	Global Climate Observing System
GDPS	Global Data Processing System
GDT	Grid Definition Template
GIF	Graphic Interchange Format
GIS	Geographic Information System
GOS	Global Observing System
GRIB 1	Processed data in the form of GRId-point values expressed in Binary form - GRIB Edition 1
GRIB 2	General Regularly distributed Information in Binary form - GRIB Edition 2
GTS	Global Telecommunications System
HTML	Hyper Text Markup Language
ICAO	International Civil Aviation Organisation
ICT	Implementation/Coordination Team (of CBS)
ICT/DRC	Implementation/Coordination Team on Data Representation and Codes
ICT	Information and Communication Technology
ID	Identifier
IEC	International Electrotechnical Commission
IEEE	Institution of Electrical and Electronics Engineers
IOC	Intergovernmental Oceanographic Commission

ISO	International Standards Organization
ISS	Information Systems and Services
JCOMM	Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology
JMA	Japan Meteorological Agency
JPEG	Joint Photographic Experts Group format
LINUX	<i>Not an acronym – name of an operating system</i>
MS/DOS	/Disk Operating System
MSS	Message Switching System
MTDCF	Migration to Table Driven Code Forms
MTN	Main Telecommunications Network (of the GTS)
NASA	National Aeronautics and Space Administration
NCEP	National Centre for Environment Prediction
NESDIS	National Environmental Satellite Data and Information Service
NMC	National Meteorological Centre
NMHS	National Meteorological or Hydrological Service
NMS	National Meteorological Service
NWP	Numerical Weather Prediction
NWS	National Weather Service
OMF	weather Observation Markup Format
OPAG	Open Programme Area Group (of CBS)
OPAG-ISS	Open Programme Area Group on Information Systems and Services
PDT	Product Definition Template
PNG	Portable Network Graphic
RA	Regional Association (WMO)
RASS	Radio Acoustic Sounding System
RDBC	Regional Data Bank Centre
RMTN	Regional Meteorological Telecommunication Network
RSMC	Regional Specialised Meteorological Centre
RTH	Regional Telecommunication Hub
SGDR&C	Sub-Group on Data Representation and Codes (CBS)
SGML	Standard Generalized Markup Language
SI	System International
SOOP	Ship Of Opportunity Programme
SOOPIP	Ship Of Opportunity Programme Implementation Programme
SST	Sea Surface Temperature
TAC	Traditional Alphanumeric Codes
TCP	Tropical Cyclone Programme
TCP/IP	Transport Control Protocol/Internet Protocol
TDCF	Table Driven Code Forms
TDL	Techniques Development Laboratory
TIFF	Tagged Image File Format
TOVS	TIROS Operational Vertical Sounder
UKMO	United Kingdom Meteorological Office
UNIX	<i>Not an acronym – name of an operating system</i>
UTC	Universal Time Coordinate
VOS	Voluntary Observing Ship
WAFS	World Area Forecasting System
WGDM	Working Group on Data Management (CBS)
WGS	Working Group on Standards
WMO	World Meteorological Organization
WWW	World Weather Watch
W3C	World Wide Web Consortium
XBT	eXpendable Bathy Thermograph
XCTD	eXpendable Conductivity Temperature Depth sensor
XML	eXtensible Markup Language