BUFR Tables

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Topics Covered

- WMO predefined BUFR tables
- NCEP DX BUFR table
- DX BUFR table application examples

WMO Predefined BUFR Tables

WMO BUFR Table Types

- WMO BUFR employs 3 types of tables:
  - Content definition tables
    - Contains information to describe, classify, and define the contents of a BUFR message
    - Include Tables A, B, C and D
  - Code tables
    - Define an element based on a code (e.g., Cloud Type)
  - Flag table
    - Define an element based on a set of conditions defined by flags (bits set to 0 or 1)

WMO BUFR Table A

- Subdivides data into a number of discrete categories
  - Surface data – land, Surface data – sea
  - Vertical soundings (other than satellite)
  - Vertical soundings (satellite)
  - …
- Not technically essential for BUFR encoding/ decoding
- Useful for telecommunications purposes, for storage and retrieval of data from a data base

WMO BUFR Table B

- Describes how individual elements are to be encoded and decoded in BUFR
- Fundamental to encode and decode BUFR

Class 12 - Temperature

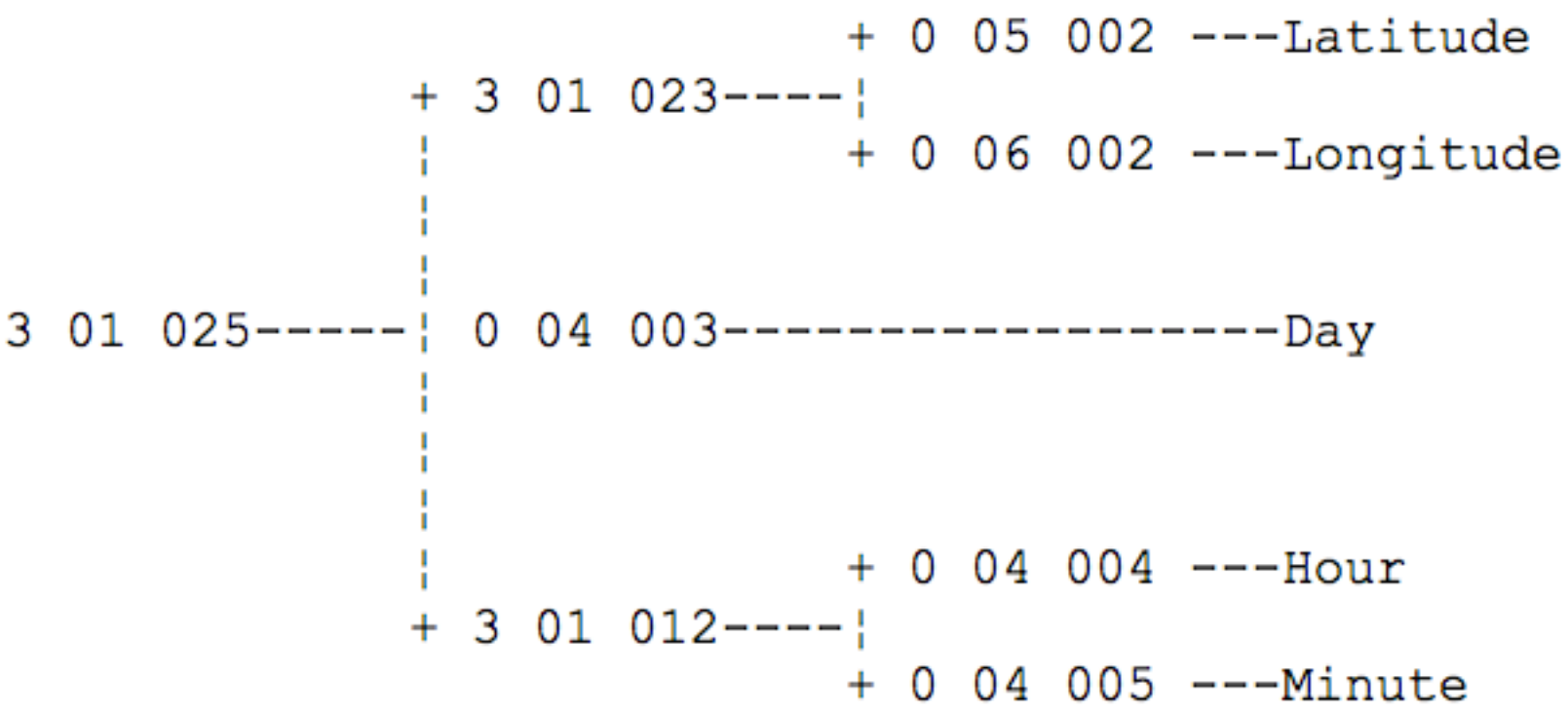
TABLE REFERENCE			TABLE ELEMENT NAME	BUFR			
				UNIT	SCALE	REFERENCE VALUE	DATA WIDTH (Bits)
F	X	Y					
0	12	001	Temperature/dry-bulb temperature	K	1	0	12
0	12	002	Wet-bulb temperature	K	1	0	12
0	12	003	Dew-point temperature	K	1	0	12
0	12	004	Dry-bulb temperature at 2 m	K	1	0	12
0	12	005	Wet-bulb temperature at 2 m	K	1	0	12
0	12	006	Dew-point temperature at 2 m	K	1	0	12
0	12	007	Virtual temperature	K	1	0	12

WMO BUFR Table C and D

- **TABLE C** defines a number of operations that can be applied to the elements. Each such operation is assigned an operator descriptor.

- **TABLE D** defines groups of elements that are always transmitted together (common sequence)
  - Contains a list of sequence descriptors
  - Not essential for BUFR encoding and decoding
  - Useful in decreasing the space requirements for BUFR messages

WMO BUFR Table D Example



WMO BUFR Code Table

- An element based on a code (e.g., Cloud Type)

Class 20 - Observed phenomena

TABLE REFERENCE			TABLE ELEMENT NAME	BUFR			
				UNIT	SCALE	REFERENCE VALUE	DATA WIDTH (Bits)
F	X	Y					
0	20	024	Intensity of phenomena	Code table	0	0	3

Code table: **0 20 024** ***Intensity of phenomena***

Code figure	
0	No phenomena
1	Light
2	Moderate
3	Heavy
4	Violent
5-6	Reserved
7	Missing value

WMO BUFR Flag Table

- An element based on a set of conditions defined by flags (bits set to 0 or 1)

THE FOLLOWING ARE TABLE B ENTRIES FOR THE REPORT HEADER						
MNEMONIC	**NUMBER**	**DESCRIPTION**	**SCALE**	**REFERENCE**	**BITS**	**UNITS**
RSRD	035200	RESTRICTIONS ON REDISTRIBUTION	0	0	9	FLAG TABLE

0-35-200 - RSRD
Restrictions on redistribution

BIT NUMBER	DESCRIPTION
1	No redistribution allowed
2	Can redistribute to any U.S. government agency
3	Can redistribute to any U.S. research group
4	Can redistribute to any U.S. educational institution
5	Can redistribute to any U.S. government agency within NOAA
6-8	Reserved
All 9	Missing value

NCEP DX BUFR Table

NCEP DX BUFR table

- Define report structures in any kind of BUFR file ("PrepBUFR" files too!) when use the NCEP BUFRLIB software
- In NCEP BUFR files, the BUFR tables are embedded at the top of the file
- Excellent reference for NCEP BUFR Tables: http://www.nco.ncep.noaa.gov/sib/decoders/BUFRLIB/toc/dfbftab/

DX BUFR table structure

- Section 1
  - Table A mnemonic: Refer to report types
  - Table B mnemonic: Refer to basic data values
  - Table D mnemonic: Sequences composed of one or more Table B or D mnemonics; Constituents of a particular Table A mnemonic.
- Section 2
  - Table A and Table D mnemonics are defined as a sequence of one or more Table B or D mnemonics.
- Section3
  - Table B mnemonics are defined in terms of their scale, reference value, bit width, and unit.

DX BUFR table example (GSI util/bufr_tools/prepobs_prep.bufrtable)

- Section 1: all Table A, B and D mnemonics are declared, assigned a unique FXY number, and given a short free-form text description.

Table A mnemonic

```
|-----------------------------------------------------------------------|
| MNEMONIC | NUMBER | DESCRIPTION                                       |
|----------|--------|---------------------------------------------------|
| ADPUPA   | A48102 | UPPER-AIR (RAOB, PIBAL, RECCO, DROPS) REPORTS     |
```

Table B mnemonic

```
|-----------------------------------------------------------------------|
| MNEMONIC | NUMBER | DESCRIPTION                                       |
|----------|--------|---------------------------------------------------|
| SID      | 001194 | STATION IDENTIFICATI                              |
| XOB      | 006240 | LONGITUDE                                         |
| YOB      | 005002 | LATITUDE                                          |
| DHR      | 004215 | OBSERVATION TIME MINUS CYCLE TI                   |
```

Table D mnemonic

```
|-----------------------------------------------------------------------|
| MNEMONIC | NUMBER | DESCRIPTION                                       |
|----------|--------|---------------------------------------------------|
| HEADR    | 348001 | REPORT HEADER SEQUENCE |
| PRSLEVEL | 348002 | PRESSURE LEVEL SEQUENCE (ALL TYPES EXCEPT "GOESND",
                       "AIRCFT" and "AIRCAR")
```

DX BUFR table example (GSI util/bufr_tools/prepobs_prep.bufrtable)

- Section 2

Table A, D mnemonic making up sequence

```
|----------|-----------------------------------------------------------------|
| MNEMONIC | SEQUENCE                                                        |
|----------|-----------------------------------------------------------------|
| ADPUPA   | HEADR  SIRC  {PRSLEVEL}  <SST_INFO>  <PREWXSEQ>  {CLOUDSEQ}     |
| ADPUPA   | <CLOU2SEQ>  <SWINDSEQ>  <AFIC_SEQ>  <TURB3SEQ>                  |

| HEADR    | SID  XOB  YOB  DHR  ELV  TYP  T29  TSB  ITP  SQN  PROCN  RPT   |
| HEADR    | TCOR  <RSRD_SEQ>
| PRSLEVEL | CAT <P___INFO> <Q___INFO> <T___INFO> <Z___INFO> <W___INFO>
| PRSLEVEL | <DRFTINFO>
```

Replication:

a way to efficiently store data in BUFR format

< >	Indicates that the enclosed mnemonic is replicated using 1-bit delayed replication (either 0 or 1 replications). e.g. **<SST_INFO>**
{}/[]	Indicates that the enclosed mnemonic is replicated using 8-bit delayed replication (between 0 and 255 replications) e.g. **{PRSLEVEL}**
( )	Indicates that the enclosed mnemonic is replicated using 16-bit delayed replication (between 0 and 65535 replications)
" "n	Indicates that the enclosed mnemonic is replicated using regular (non-delayed) replication, with a fixed replication factor of *n*. e.g. **"GQCPRMS"3**

DX BUFR table example (GSI util/bufr_tools/prepobs_prep.bufrtable)

- Section 3

Table B mnemonic scale, reference, bit, unit

MNEMONIC	SCAL	REFERENCE	BIT	UNITS
SID	0	0	64	CCITT IA5
XOB	2	-18000	16	DEG E
YOB	2	-9000	15	DEG N
DHR	3	-24000	16	HOURS
ELV	0	-1000	17	METER
TYP	0	0	9	CODE TABL

UNITS:

CCITT IA5: character

CODE TABL: go to http://www.emc.ncep.noaa.gov/mmb/data_processing/prepbufr.doc/table_1.htm, search that Table B mnemonic, click CODE TABL link and see the code.

DX BUFR table: structure example

```
 ------------   USER DEFINITIONS FOR TABLE-A TABLE-B TABLE D   --------------
| MNEMONIC | NUMBER | DESCRIPTION                                             |
|----------|--------|---------------------------------------------------------|
| ADPUPA   | A48102 | UPPER-AIR (RAOB, PIBAL, RECCO, DROPS) REPORTS           |
| ADPSFC   | A48109 | SURFACE LAND (SYNOPTIC, METAR) REPORTS                  |
|          |        |                                                         |
| HEADR    | 348001 | REPORT HEADER SEQUENCE                                  |
| PRSLEVEL | 348002 | PRESSURE LEVEL SEQUENCE (ALL TYPES EXCEPT GOESND)       |
| T___INFO | 348143 | TEMPERATURE INFORMATION                                 |
|          |        |                                                         |
| SID      | 001194 | STATION IDENTIFICATION                                  |
| DHR      | 004215 | OBSERVATION TIME MINUS CYCLE TIME                       |
| YOB      | 005002 | LATITUDE                                                |
| XOB      | 006240 | LONGITUDE                                               |
|-----------------------------------------------------------------------------|
| MNEMONIC | SEQUENCE                                                             |
|----------|----------------------------------------------------------------------|
|          |                                                                      |
| ADPUPA   | HEADR  SIRC  {PRSLEVEL}  <SST_INFO>  <PREWXSEQ>  {CLOUDSEQ}          |
| ADPUPA   | <CLOU2SEQ>  <SWINDSEQ>  <AFIC_SEQ>  <TURB3SEQ>                       |
|          |                                                                      |
| HEADR    | SID  XOB  YOB  DHR  ELV  TYP  T29  TSB  ITP  SQN  PROCN  RPT        |
| HEADR    | TCOR  <RSRD_SEQ>                                                     |
|-----------------------------------------------------------------------------|
| MNEMONIC | SCAL | REFERENCE   | BIT | UNITS                    |-------------|
|----------|------|-------------|-----|--------------------------|-------------|
|          |      |             |     |                          |
| SID      |    0 |           0 |  64 | CCITT IA5                |
| DHR      |    5 |    -2400000 |  23 | HOURS                    |
| YOB      |    2 |       -9000 |  15 | DEG N                    |
| XOB      |    2 |      -18000 |  16 | DEG E                    |
| ELV      |    0 |       -1000 |  17 | METER                    |-------------|
| TYP      |    0 |           0 |  10 | CODE TABLE               |-------------|
 -----------------------------------------------------------------------------
```

Table A mnemonic

Table D mnemonic

Table B mnemonic

Table A and Table D

Table B mnemonics

WMO BUFR table and DX BUFR Table

- DX BUFR table follows the FXY descriptors, description, unit, bit, scale, reference value of elements in WMO table.
- The difference are:
  - In WMO table, table A, B, C, D are separate tables; DX table contains table A, B, C, D information in one table.
  - DX table give a descriptive name (mnemonic) for elements in WMO table.
  - Other changes ….

BUFR Table B: WMO and DX

WMO Table B

Class 12 - Temperature

TABLE REFERENCE			TABLE ELEMENT NAME	BUFR			
				UNIT	SCALE	REFERENCE VALUE	DATA WIDTH (Bits)
F	X	Y					
0	12	001	Temperature/dry-bulb temperature	K	1	0	12
0	12	245	Temperature	C	1	-2732	14

DX BUFR Table

```
------------   USER DEFINITIONS FOR TABLE-A TABLE-B TABLE D   ---------
-----------------------------------------------------------------------
| MNEMONIC | NUMBER | DESCRIPTION
|----------|--------|--------------------------------------------------
| ADPUPA   | A48102 | UPPER-AIR (RAOB, PIBAL, RECCO, DROPS) REPORTS
|          |        |
| T__EVENT | 348173 | TEMPERATURE EVENT SEQUENCE
|          |        |
| TOB      | 012245 | TEMPERATURE OBSERVATION
-----------------------------------------------------------------------
| MNEMONIC | SEQUENCE
|----------|------------------------------------------------------------
| ADPUPA   | HEADR  SIRC  {PRSLEVEL}  <SST_INFO>  <PREWXSEQ>  {CLOUDSEQ}
| ADPUPA   | <CLOU2SEQ>  <SWINDSEQ>  <AFIC_SEQ>  <TURB3SEQ>
|          |
| T__EVENT | TOB  TQM  TPC  TRC
-----------------------------------------------------------------------
| MNEMONIC | SCAL | REFERENCE    | BIT | UNITS                    |------
|----------|------|--------------|-----|--------------------------|------
| TOB      |    1 |        -2732 |  14 | DEG C                    |------
-----------------------------------------------------------------------
```

DX BUFR Table Application Examples

- Understand certain element
- Inventory content in a BUFR message

DX BUFR table : understand SID

```
character(80):: hdstr='SID XOB YOB DHR TYP ELV SAID T29'
```

```
.-------------------------------------------------------------------------------.
| ------------   USER DEFINITIONS FOR TABLE-A TABLE-B TABLE D   -------------- |
|-------------------------------------------------------------------------------|
| MNEMONIC | NUMBER | DESCRIPTION                                               |
|----------|--------|-----------------------------------------------------------|
| ADPUPA   | A48102 | UPPER-AIR (RAOB, PIBAL, RECCO, DROPS) REPORTS             |
|          |        |                                                           |
| HEADR    | 348001 | REPORT HEADER SEQUENCE                                    |
| PRSLEVEL | 348002 | PRESSURE LEVEL SEQUENCE (ALL TYPES EXCEPT GOESND)         |
| T__EVENT | 348173 | TEMPERATURE EVENT SEQUENCE                                |
|          |        |                                                           |
| SID      | 001194 | STATION IDENTIFICATION                                    |
| TOB      | 012245 | TEMPERATURE OBSERVATION                                   |
| TQM      | 012246 | TEMPERATURE (QUALITY) MARKER                              |
|-------------------------------------------------------------------------------|
| MNEMONIC | SEQUENCE                                                           |
|----------|--------------------------------------------------------------------|
| ADPUPA   | HEADR  SIRC  {PRSLEVEL}  <SST_INFO>  <PREWXSEQ>  {CLOUDSEQ}        |
|          |                                                                    |
| HEADR    | SID  XOB  YOB  DHR  ELV  TYP  T29  TSB  ITP  SQN  PROCN  RPT       |
| HEADR    | TCOR  <RSRD_SEQ>                                                   |
|          |                                                                    |
| PRSLEVEL | CAT  <P___INFO>  <Q___INFO>  <T___INFO>  <Z___INFO>  <W___INFO>     |
| PRSLEVEL | <DRFTINFO>                                                         |
|          |                                                                    |
| T__EVENT | TOB  TQM  TPC  TRC                                                 |
|-------------------------------------------------------------------------------|
| MNEMONIC | SCAL | REFERENCE   | BIT | UNITS                    |-------------|
|----------|------|-------------|-----|--------------------------|-------------|
| SID      |    0 |           0 |  64 | CCITT IA5                |-------------|
| TOB      |    1 |       -2732 |  14 | DEG C                    |-------------|
| TQM      |    0 |           0 |   5 | CODE TABLE               |-------------|
`-------------------------------------------------------------------------------'
```

BUFR table: understand PQM

```
character(80):: qcstr='PQM QQM TQM ZQM WQM NUL PWQ     '
```

---------- USER DEFINITIONS FOR TABLE-A TABLE-B TABLE D ----------		
MNEMONIC	NUMBER	DESCRIPTION
ADPUPA	A48102	UPPER-AIR (RAOB, PIBAL, RECCO, DROPS) REPORTS
HEADR	348001	REPORT HEADER SEQUENCE
PRSLEVEL	348002	PRESSURE LEVEL SEQUENCE (ALL TYPES EXCEPT GOESND)
T__EVENT	348173	TEMPERATURE EVENT SEQUENCE
SID	001194	STATION IDENTIFICATION
POB	007245	PRESSURE OBSERVATION
PQM	**007246**	**PRESSURE (QUALITY) MARKER**

MNEMONIC	SEQUENCE
ADPUPA	HEADR SIRC {PRSLEVEL} <SST_INFO> <PREWXSEQ> {CLOUDSEQ}
HEADR	SID XOB YOB DHR ELV TYP T29 TSB ITP SQN PROCN RPT
HEADR	TCOR <RSRD_SEQ>
PRSLEVEL	CAT <P___INFO> <Q___INFO> <T___INFO> <Z___INFO> <W___INFO>
PRSLEVEL	<DRFTINFO>
P__EVENT	POB **PQM** PPC PRC

MNEMONIC	SCAL	REFERENCE	BIT	UNITS
SID	0	0	64	CCITT IA5
POB	1	0	14	MB
PQM	**0**	**0**	**5**	**CODE TABLE**

DX BUFR table: flag and code table

http://www.emc.ncep.noaa.gov/mmb/data_processing/prepbufr.doc/table_1.htm

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CURRENT PREPBUFR MNEMONIC T...

PRESSURE

MNEMONIC	NUMBER	DESCRIPTION	SCALE	REFERENCE	BITS	UNITS
POB	007245	PRESSURE OBSERVATION	1	0	14	MB
PQM	007246	PRESSURE (QUALITY) MARKER	0	0	5	CODE TABLE

Find: PQM | Next | Previous | Highlight all | Match case | Reached end of page, continued from t

Table 7. Code table for observation quality markers (last revised 1/22/2008).

Quality Marker	Definition
0	All steps: Keep (always assimilate). Applies to pressure, height, wind, temperature, specific humidity, rainfall rate, precipitable water and cloud top pressure.
1	All steps: Good. Applies to pressure, height, wind, temperature, specific humidity, rainfall rate, precipitable water and cloud top pressure.
2	All steps: Neural or not checked (default). Applies to pressure, height, wind, temperature, specific humidity, rainfall rate, precipitable water and cloud top pressure.
3	All steps: Suspect. Applies to pressure, height, wind, temperature, specific humidity, rainfall rate, precipitable water and cloud top pressure.
4-15	All steps: Rejected (don't assimilate), as defined below (see % below table):
4	Step **OIQC**: An observation with pre-existing quality marker 0 (keep) is flagged. Applies to pressure, height, wind, temperature, specific humidity and precipitable water.

Find: TQM | Next | Previous | Highlight all | Match case | Reached end of page, continued from

BUFR table application: message content

```
msg_report: do while (ireadmg(unit_in,subset,idate) == 0)
subset = ADPUPA, ADPSFC, …
```

```
.-------------------------------------------------------------------------------.
| ------------   USER DEFINITIONS FOR TABLE-A TABLE-B TABLE D   -------------- |
|-------------------------------------------------------------------------------|
| MNEMONIC | NUMBER | DESCRIPTION                                               |
|----------|--------|-----------------------------------------------------------|
| ADPUPA   | A48102 | UPPER-AIR (RAOB, PIBAL, RECCO, DROPS) REPORTS             |
|          |        |                                                           |
| HEADR    | 348001 | REPORT HEADER SEQUENCE                                    |
| PRSLEVEL | 348002 | PRESSURE LEVEL SEQUENCE (ALL TYPES EXCEPT GOESND)         |
| T__EVENT | 348173 | TEMPERATURE EVENT SEQUENCE                                |
|          |        |                                                           |
| SID      | 001194 | STATION IDENTIFICATION                                    |
| TOB      | 012245 | TEMPERATURE OBSERVATION                                   |
| TQM      | 012246 | TEMPERATURE (QUALITY) MARKER                              |
|-------------------------------------------------------------------------------|
| MNEMONIC | SEQUENCE                                                               |
|----------|------------------------------------------------------------------------|
| ADPUPA   | HEADR  SIRC  {PRSLEVEL}  <SST_INFO>  <PREWXSEQ>  {CLOUDSEQ}            |
|          |                                                                        |
| HEADR    | SID  XOB  YOB  DHR  ELV  TYP  T29  TSB  ITP  SQN  PROCN  RPT           |
| HEADR    | TCOR  <RSRD_SEQ>                                                       |
|          |                                                                        |
| PRSLEVEL | CAT  <P___INFO>  <Q___INFO>  <T___INFO>  <Z___INFO>  <W___INFO>         |
| PRSLEVEL | <DRFTINFO>                                                             |
|          |                                                                        |
| |
|-------------------------------------------------------------------------------|
| MNEMONIC | SCAL | REFERENCE   | BIT | UNITS                    |-------------|
|----------|------|-------------|-----|--------------------------|-------------|
| SID      |    0 |           0 |  64 | CCITT IA5                |-------------|
| TOB      |    1 |       -2732 |  14 | DEG C                    |-------------|
| TQM      |    0 |           0 |   5 | CODE TABLE               |-------------|
`-------------------------------------------------------------------------------'
```

BUFR table example: expand ADPUPA

```
| MNEMONIC | SEQUENCE                                                                |
|----------|-------------------------------------------------------------------------|
| ADPUPA   | HEADR  SIRC  {PRSLEVEL}  <SST_INFO>  <PREWXSEQ>  {CLOUDSEQ}             |
| ADPUPA   | <CLOU2SEQ>  <SWINDSEQ>  <AFIC_SEQ>  <TURB3SEQ>                          |

| HEADR    | SID     XOB   YOB   DHR   ELV   TYP   T29   TSB   ITP   SQN       |
| HEADR    | PROCN   RPT   TCOR <RSRD_SEQ>                                      |

| PRSLEVEL | CAT    <P___INFO>  <Q___INFO>  <T___INFO>  <Z___INFO>  <W___INFO> |
| PRSLEVEL |        <DRFTINFO>

      | P___INFO | [P__EVENT]              <P__BACKG>  <P__POSTP>
      | Q___INFO | [Q__EVENT]    TDO       <Q__BACKG>  <Q__POSTP>
      | T___INFO | [T__EVENT]    TVO       <T__BACKG>  <T__POSTP>
      | Z___INFO | [Z__EVENT]              <Z__BACKG>  <Z__POSTP>

            | P__EVENT |              POB                PQM    PPC    PRC
            | Q__EVENT |              QOB                QQM    QPC    QRC
            | T__EVENT |              TOB                TQM    TPC    TRC
            | Z__EVENT |              ZOB                ZQM    ZPC    ZRC

            | P__BACKG | POE       PFC       <PFC__MSQ>
            | Q__BACKG | QOE       QFC       <QFC__MSQ>
            | T__BACKG | TOE       TFC       <TFC__MSQ>
            | Z__BACKG |           ZFC       <ZFC__MSQ>

            | P__POSTP | PAN       <PCLIMATO>   POETU   PVWTG   PVWTA
            | Q__POSTP | QAN       <QCLIMATO>   QOETU   QVWTG   QVWTA   ESBAK
            | T__POSTP | TAN       <TCLIMATO>   TOETU   TVWTG   TVWTA
            | Z__POSTP | ZAN       <ZCLIMATO>
```

It is always a good idea to fully expand all the sequences for Table A mnemonic, which help you easily understand exactly what is contained within the report.

(GSI util/bufr_tools/prepobs_prep.bufrtable)

Questions?

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