2014 GSI Community Tutorial
July 14-16, 2014, NCAR, Boulder

Data Processing – NCEP Data Process and PrepBUFR/BUFR

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Topics covered

- NCEP observation data
  - Observation data processing
  - Operation BUFR/PrepBUFR types and data servers
- Community BUFR/PrepBUFR basic tools
  - BUFR/PrepBUFR file structure
  - Encode, decode and append a simple BUFR file
- NCEP DX BUFR table
  - DX BUFR table structure and examples
  - DX BUFR table application examples

This talk is based on DTC BUFR/PrepBUFR User's Guide:
http://www.dtcenter.org/com-GSI/BUFR/docs/index.php
and Dennis Keyser's talk in 2013 GSI Community Tutorial

NCEP observation data

Community BUFR/PrepBUFR basic tools

NCEP DX BUFR table

- Observation data processing
- Operation BUFR/PrepBUFR types and data servers

Observation processing at NCEP

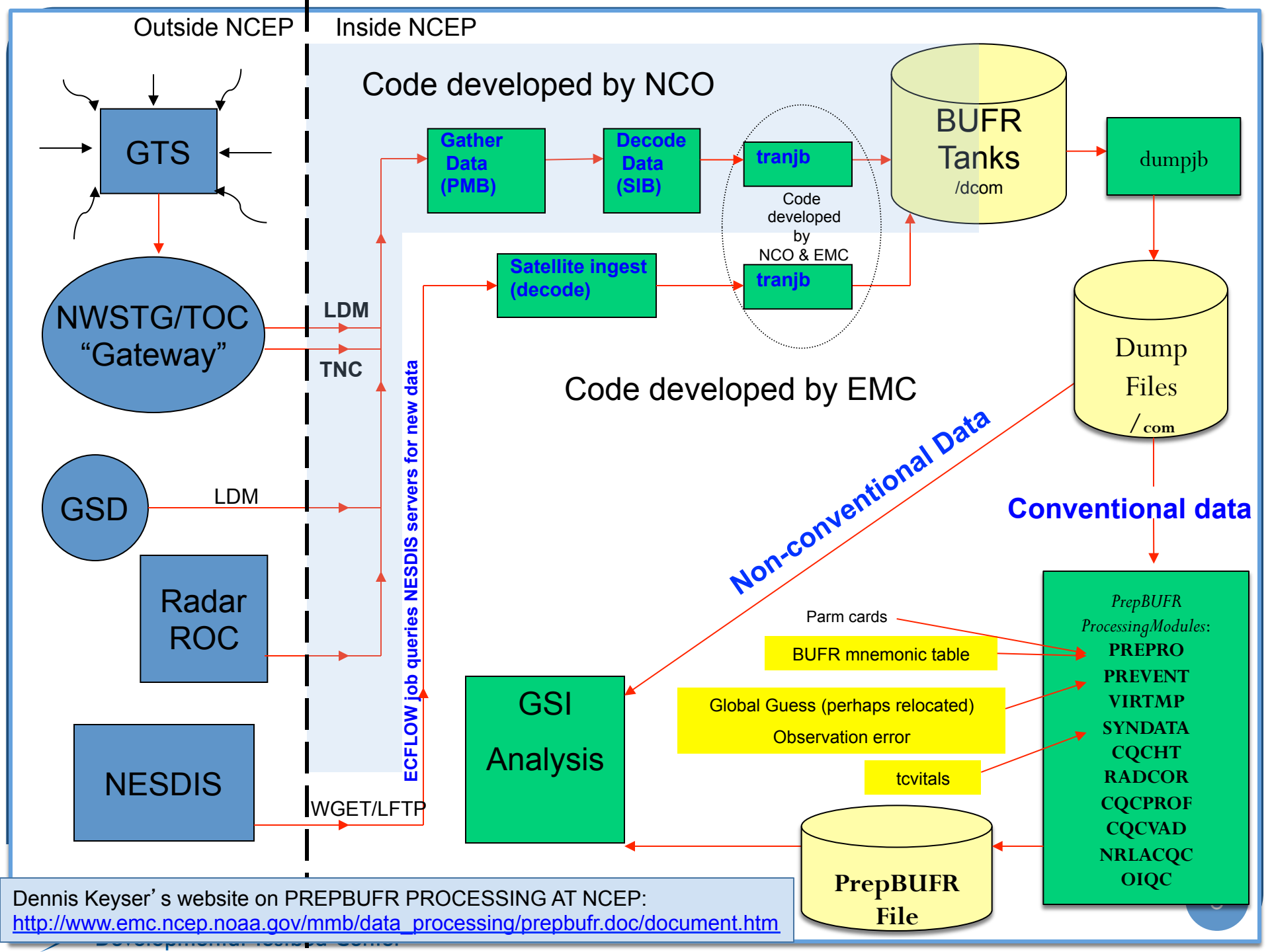
- Managed jointly by NCEP Central Operations (NCO) and EMC
- Relies on NCEP BUFRLIB software
- Four stages:

Data flow into NCEP

Tank files (Continuous decoding of data and accumulation into BUFR database, large BUFR files holding 24h of data)

Dump files (Network-specific generation, duplicate-checked data from tanks; contain 1, 3, 6h blocks of data)

PrepBUFR files (QC'd "conventional" obs from dump files)



Dennis Keyser's website on PREPBUFR PROCESSING AT NCEP:
http://www.emc.ncep.noaa.gov/mmb/data_processing/prepbufr.doc/document.htm

GTS = Global Telecommunications System

- World wide data gathers in GTS
- Sends data to NWSTG/TOC or the "Gateway"

NWSTG/TOC = NWS Telecommunication Gateway/Telecommunication Operations Center

- Intercepts GTS messages
- Sends data to **NCO** via TNC (TOC to NCEP Communications) line and via LDM (Local Data Manager)

GSD = NOAA/ESRL/GSD

- Provide Mesonet data to **NCO** via LDM several times hourly
- SIB converts data from NetCDF to WMO BUFR

Radar/ROC = NOAA Radar Operations Center

- For more information on how Radar data is processed see http://www.emc.ncep.noaa.gov/mmb/data_processing/data_processing/

NESDIS = National Environmental Satellite, Data, and Information Service

- Servers:
  - DDS – serves up POES data
  - SATEPSDIST1E – serves up GOES data
- **EMC** runs ECFLOW jobs to query the NESDIS servers for new data

NCO = NCEP Central Operations

PMB = NCO/Production Management Branch, two groups with EMC interaction:

- Data Flow - pull data from the outside
  - Interacts w/ the "Gateway", LDM, ROC, etc. …
  - Data retrieval occurs continuously
  - Gather all the data then pass it off to SIB for decoding
- SPA group – make sure production is running 24x7 & implement change

SIB = NCO/Systems Integration Branch, one group with EMC interaction:

- Decoders - translate data from their native format to NCEP BUFR, includes:
  ACARS (MCDRS), Aircraft (AIREP, PIREP, AMDAR, TAMDAR, RECCO), Land Sfc (SYNOP, METAR), RADAR (VAD winds, WSR-88D, Canadian, P3 TDR), Oceanographic (Bathy, TESAC, TRAKOB), Marine Sfc (Ship, Buoy, Tide Gauge, Coast Guard, CMAN), RARS, Profiler/RASS (NPN, MAP, Europe, Japan, Hong Kong), Upper Air (RAOB, PIBAL, DROP), GPS-IPW, GPS-RO, USGS River/Stream, SHEF (precip, land & marine sfc), Satellite Wind (JMA, EUMETSAT, India), CREX (marine sfc), Satellite Altimetry/Wave, Mesonet (incl. COOP, CRN, HYDRO, SNOW), SEVIRI, Lightning, LaRC Cloud, AIRNOW (ozone)
- Decoding operates continuously on both WCOSS machines (prod & dev)
- NCEP BUFR files stored in the database "tanks" on the WCOSS machines
- "tranjb" is the process that takes a single BUFR file and appends it to the appropriate database tank

EMC = Environmental Modeling Center

- Runs ECFLOW jobs periodically to query NESDIS servers for new data files
  - Compares list of files on server against local history file
- Retrieves new data via WGET or LFTP file transfer protocol
- Converts native data to NCEP BUFR and stores them in the database tanks
- "tranjb" is the process that takes a single BUFR file and appends it to the appropriate database tank
- Processing runs on both NCEP WCOSS machines (prod and dev) at discrete wall-clock times defined for each data type
- Satellite data types decoded here include:
  - 1B radiances from GOES (sounder and imager), SSM/IS, ATOVS (AMSU-A, AMSU-B, MHS, HIRS-3, HIRS-4), AQUA/TERRA (AIRS, AMSU-A, IASI), AVHRR/GAC, NPP (ATMS & CrIS)
  - Cloud data from GOES (via NESDIS & LaRC), global cloud analyses from AFWA & CLAVR
  - Temperature soundings from ATOVS
  - Sat-derived winds from GOES (IR, WV-img, WV-snd, VIZ), MODIS (IR, WV-img), AVHRR (IR)
  - Scatterometer winds from ASCAT, WindSat
  - Rainfall from TRMM/TMI
  - SST from POES (via NAVO & NESDIS), GOES, global SST analyses
  - Ozone from SBUV-2, GOME-2, OMI, MLS
  - Aerosol, Green Vegetation Fraction and smoke from NESDIS (Global)
  - Daily snow and ice analyses from NESDIS & USAF
  - Imager data (11 μ channel) from GOES

What is BUFR/PrepBUFR

- **B**inary **U**niversal **F**orm for the **R**epresentation of meteorological data (BUFR)
- BUFR is a "self-descriptive" table driven code form
  - The form and content of the data contained within a BUFR message are described within the BUFR message itself
- Advantages of BUFR:
  - Flexibility
  - Compact Data Storage
  - WMO Standard
- Features of NCEP BUFR files:
  - Use BUFRLIB routines to interface with files
  - BUFR table encoded into "dictionary" messages at top of file
    - Files are self defined, no need for external BUFR table to decode
  - Uses a single sequence descriptor to define complete subset structure in descriptor section (3) of BUFR messages (more on this later)

- **PrepBUFR is the NCEP term for "prepared" or QC'd data in BUFR format (NCEP convention/standard)**
- **PrepBUFR file is still a BUFR file**

PrepBUFR processing Modules

- **PREPRO**:
  - Reads in dumps, parm cards and PrepBUFR mnemonic table. Preforms rudimentary QC. Generates initial (pre-QC) PrepBUFR file.
- **PREVENT**:
  - Encodes global guess interpolated to obs locations into PrepBUFR file (used by subsequent QC modules).
    - Tropical cyclones may be relocated in guess in upstream processing.
  - Encodes observation error into PrepBUFR file (used by GSI).
  - Performs some rough quality control checks on surface pressure (vs. the background). Updates are encoded into PrepBUFR file.
- **VIRTMP**
  - Converts dry bulb temperature to virtual temperature and dewpoint temperature to specific humidity. Updates are encoded into PrepBUFR file.
- **SYNDATA** [runs in GFS/GDAS (for weak storms with no relocation upstream) and NAM/NDAS (for all storms)]
  - Reads in QC'd tropical cyclone records ("tcvitals"). Generates bogused wind profile reports in the vicinity of tropical storms. Generates bogused surface pressure and vertical profile moisture reports at storm center (NAM/NDAS only). Updates are encoded into PrepBUFR file.
  - Flags (for non-assimilation) all mass observations in the vicinity of each storm in the tcvitals file list. Updates are encoded into PrepBUFR file.
  - Flags (for non-assimilation) all dropwinsonde wind observations in the vicinity of each storm in the tcvitals file list. Updates are encoded into PrepBUFR file.

PrepBUFR processing Modules(cont.)

- **CQCHT** (does not run in RTMA network)
  - Performs complex quality control on rawinsonde heights and temperatures to identify and/or correct location, transcription and communications errors. Erroneous data that cannot be corrected are flagged for non-assimilation. Updates are encoded into PrepBUFR file.
  - Checks include hydrostatic, increment, horizontal statistical, vertical statistical, temporal, baseline and lapse rate.
- **RADCOR** (does not run in RTMA network)
  - Applies intersonde (radiation) corrections to CQCHT QC'd rawinsonde height and temperature data. The degree of correction is a function of the rawinsonde instrument type, sun angle and pressure level. Updates are encoded into PrepBUFR file.
- **CQCPROF** (does not run in RTMA network)
  - Performs complex quality control on wind profiler and SODAR data to identify erroneous data and remove it from consideration by the analyses. Updates are encoded into PrepBUFR file.
  - Checks include increment, vertical statistical, temporal statistical, and combined vertical-temporal.
- **CQCVAD** (does not run in RTMA network)
  - Performs complex quality control on Velocity Azimuth Display (VAD) winds from WSR-88D radars to identify erroneous data and remove it from consideration by the analyses. Updates are encoded into PrepBUFR file.
  - Checks include increment, vertical statistical, temporal statistical, and combined vertical-temporal. In addition, there is an algorithm to account for contamination due to the seasonal migration of birds.

PrepBUFR processing Modules(cont.)

- **NRLACQC** (does not run in RTMA network)
  - Performs quality control on all types of aircraft wind and temperature data. Reports failing QC are flagged if they cannot be rehabilitated. Duplicate reports are removed. Updates are encoded into PrepBUFR file.
  - Checks on tracks include duplicate report, spike, invalid data, stuck value, gross, inconsistent altitude or position, flight order, suspect data, reject list. The QC algorithm was developed by the NRL.
- **OIQC** (runs only in GFS & GDAS networks; output is not used by GSI because it performs its own internal QC)
  - Performs an OI-based QC on the full set of obs in the PrepBUFR file. A final quality decision is made based on the results from all prior platform-specific quality checks (see above) and from any manual quality marks attached to the data. . Updates are encoded into PrepBUFR file.
  - Checks include horizontal, vertical, geostrophic.

- The updated observation and quality mark information from the modules listed above is stored in replicated "event stacks". They are arranged such that the first replication (i.e., the top of the stack) represents the final module's observation/quality mark update. This is what is read by the analysis.
  - If information about previous module updates is needed, the full event stack can be unpacked. This allows one to view the record of every change to an observation throughout the course of the PrepBUFR processing.

Operation BUFR/PrepBUFR types

- File name convention
  - gdas1.t00z.prepbufr.nr
  - gfs.t00z.gpsro.tm00.bufr_d
  - ndas.t18z.lbamub.tm03.bufr_d
  - nam.t00z.aircar.tm00.bufr_d.nr
- Data coverage and cut off time
  - GDAS (Global Data Assimilation System):
    Covers global, latest 6 hours data
  - GFS (Global Forecast System):
    Covers global, 2:45 hours data
  - NDAS (NAM Data Assimilation System):
    Covers North America, longer cut off time than NAM
  - NAM (North American Model):
    Covers North America, shorter cut off time comparing to others

RUN.*yyyymmdd*/
MODEL.t*cyc*z.*TYPE*.tm*MM*.bufr_d

RUN/MODEL: operation system
cyc: cycling time
TYPE: data type
MM: 00 for all types except for *NDAS*, in which MM indicate the NDAS catch up cycle analysis time:

=0 analysis time = cyc
>0 analysis time = cyc - MM
For example:
ndas.t18z.lbamub.tm03.bufr_d
has analysis time=18z-03z=15z

nr: non-restricted data
bufr_d: bufr format

See BUFR User's Guide Chapter 5.2

Operation BUFR/PrepBUFR data servers

- Resources listed in BUFR User's Guide Chapter 5.3

  - NCEP NOMADS Site:
    BUFR/PrepBufr for GDAS (Global) - 1 month buffer:
    http://nomads.ncep.noaa.gov/pub/data/nccf/com/gfs/prod/
    BUFR/PrepBufr for NDAS (North America) - 1 month buffer:
    http://nomads.ncep.noaa.gov/pub/data/nccf/com/nam/prod/

  - NCDC NOMADS Site:
    BUFR/PrepBufr for GDAS (Global) - archive starting May 2007:
    http://nomads.ncdc.noaa.gov/data/gdas/

  - NCAR/CISL Research Data Archive (RDA) Site:
    DS337.0: NCEP ADP Global Upper Air and Surface Observations (PrepBUFR and NetCDF PB2NC Output) - archive starting May 1997:
    http://dss.ucar.edu/datasets/ds337.0/

NCEP observation data

Community BUFR/PrepBUFR basic tools

NCEP DX BUFR table

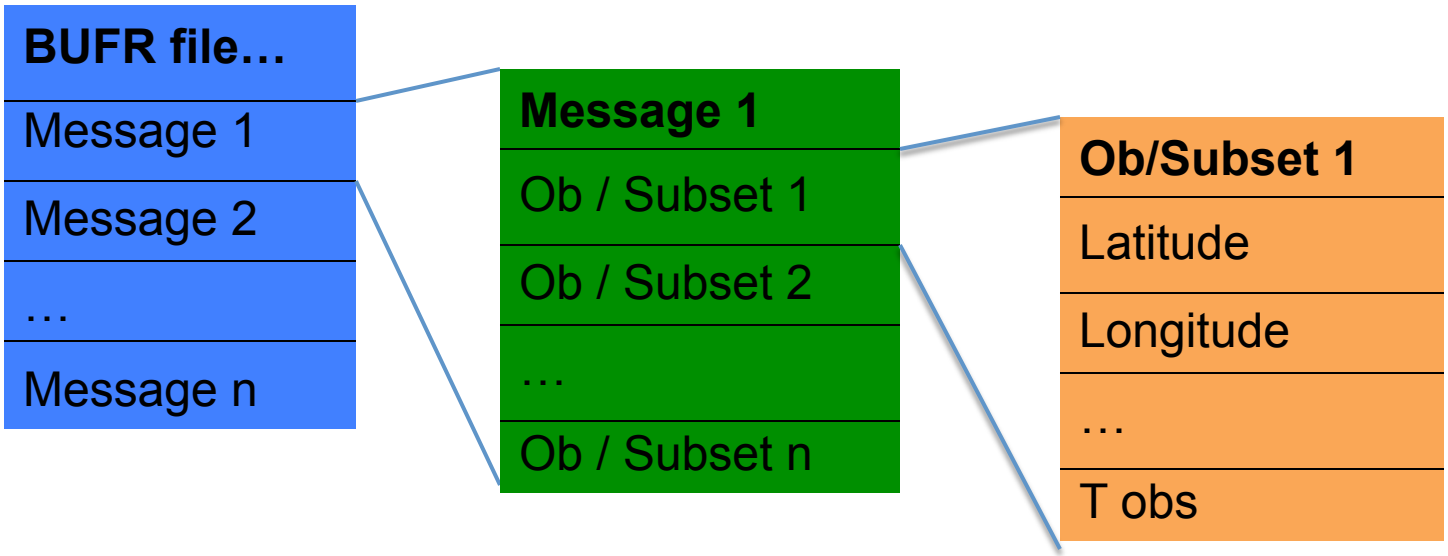
- BUFR/PrepBUFR file structure
- Encode, decode and append a simple BUFR file

All tools are in GSI util/bufr_tools; Detailed information is in BUFR User's Guide.

BUFR/PrepBUFR file structure

A bit of terminology:

BUFR files (including "PrepBUFR" files) contain "**messages**". Each message contains "**subsets**." Each subset contains meteorological "**observations**".



BUFR/PrepBUFR file structure

BUFR file example: *gdas1.t12z.prepbufr.nr*

Message 1: ADPSFC: Surface land (synoptic, metar) reports
Message 2: ADPUPA: Upper air (raob, pibal, recco, drops) reports
.
.
Message n:

Message 1	Lat	Lon	P	T	Q	U	V	Type	
Ob / Subset 1	52.1	12.5	984.4	10e10	10e10	1.7	4.7	281	**wind report**
Ob / Subset 2	52.1	12.5	984.4	23.1	12979.0	10e10	10e10	181	**mass report**
.									
.									
Ob / Subset n									

All tools based on NCEP BUFRLIB

- BUFRLIB contains close to 250 Fortran and C subprograms and functions, no more than 10-20 of them are directly called by a user, the rest are used to accomplish various underlying tasks.

  The detailed BUFRLIB documentation:

  http://www.nco.ncep.noaa.gov/sib/decoders/BUFRLIB/

- Previous versions of the BUFRLIB requires BUFR/PrepBUFR files to be FORTRAN-blocked before they are used by BUFRLIB.
  - Almost always, any BUFR file is already blocked
  - If your BUFR file is not blocked, Use NCEP cwordsh utility to block it http://www.nco.ncep.noaa.gov/sib/decoders/BUFRLIB/toc/cwordsh/

- The newest version (comGSI_v3.2 and after) will work with EITHER blocked or unblocked BUFR files
  - all new BUFR files are now unblocked (the default)

BUFR Processing Actions

- **Encode**:
  - **Write** the observations into a new BUFR file.
- **Decode**:
  - **Read** the observations from a BUFR file.
- **Append**:
  - **Add** the observations to the end of an existing BUFR file.

Encode BUFR file

- Write the observation into a BUFR file

```
program bufr_encode_sample   (34 Lines)
!
!  example of writing one value into a bufr file
!
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
 integer :: idate,iret

! set data values
 hdr(1)=75.;hdr(2)=30.;hdr(3)=-0.1
 obs(1,1)=17.15
 idate=2008120100  ! YYYYMMDDHH
 msgtype='ADPUPA'   ! upper-air reports

! encode
 open(unit_table,file='prepobs_prep.bufrtable')
 open(unit_out,file='sample.bufr',action='write',form='unformatted')
 call datelen(10)
 call openbf(unit_out,'OUT',unit_table)
   call openmb(unit_out,msgtype,idate)
      call ufbint(unit_out,hdr,3,1,iret,hdstr)
      call ufbint(unit_out,obs,1,1,iret,obstr)
      call writsb(unit_out)
   call closmg(unit_out)
 call closbf(unit_out)

end program
```

"A BUFR file contains one or more BUFR messages, each containing one or more BUFR data subsets, each containing one or more BUFR data values

Define variables and assign obs values

Open BUFR tables file

Open BUFR file

subsets

messages

BUFR file

BUFRLIB subroutines

```
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!  example of writing one value into a bufr file
 implicit none
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 obs(1,1)=17.15
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 msgtype='ADPUPA'   ! upper-air reports

! encode
 open(unit_table,file='prepobs_prep.bufrtable')
 open(unit_out,file='sample.bufr',action='write' ,form='unformatted')

 call datelen(10)
  call openbf(unit_out,'OUT',unit_table)
    call openmb(unit_out,msgtype,idate)
       call ufbint(unit_out,hdr,3,1,iret,hdstr)
       call ufbint(unit_out,obs,1,1,iret,obstr)
       call writsb(unit_out)
    call closmg(unit_out)
  call closbf(unit_out)

end program
```

The BUFRLIB subroutines and functions used here:

openbf, closbf,
openmb, closmg,
ufbint, writsb,
datelen

They are very often used to read/write BUFR file. Understanding usage of them will be very helpful in users own application.

```
program bufr_encode_sample   (34 Lines)
!
!  example of writing one value into a bufr file
!
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
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! set data values
 hdr(1)=75.;hdr(2)=30.;hdr(3)=-0.1
 obs(1,1)=17.15
 idate=2008120100  ! YYYYMMDDHH
 msgtype='ADPUPA'   ! upper-air reports

! encode
 open(unit_table,file='prepobs_prep.bufrtable')
 open(unit_out,file='sample.bufr',action='write' ,form='unform
 call datelen(10)
 call openbf(unit_out,'OUT',unit_table)
   call openmb(unit_out, msgtype,idate)
      call ufbint(unit_out,hdr,3,1,iret,hdstr)
      call ufbint(unit_out,obs,1,1,iret,obstr)
      call writsb(unit_out)
   call closmg(unit_out)
 call closbf(unit_out)

end program
```

DX BUFR table

BUFR table is in released GSI version ./util/bufr_tools directory.

BUFR table defines the content and form for each of message types. It is embedded within the first few BUFR messages of the file itself.

Understanding BUFR table will be very helpful in users own application.

```
program bufr_encode_sample   (34 Lines)
!
!  example of writing one value into a bufr file
!
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
 integer :: idate,iret

 ! set data values
 hdr(1)=75.;hdr(2)=30.;hdr(3)=-0.1
 obs(1,1)=17.15
 idate=2008120100 ! YYYYMMDDHH
 msgtype='ADPUPA'  ! upper-air reports
! encode
 open(unit_table,file='prepobs_prep.bufrtable')
 open(unit_out,file='sample.bufr',action='write',form='unformatted')
 call datelen(10)
 call openbf(unit_out,'OUT',unit_table)
   call openmb(unit_out, msgtype,idate)
      call ufbint(unit_out,hdr,3,1,iret,hdstr)
      call ufbint(unit_out,obs,1,1,iret,obstr)
      call writsb(unit_out)
   call closmg(unit_out)
 call closbf(unit_out)

end program
```

Define BUFR table mnemonics
Assign data values

A mnemonic is a descriptive, alphanumeric name for an data value.

XOB: Longtitude (006240)
YOB: Latitude
DHR: obs time – cycle time
TOB: temperature
ADPUPA: UPPER-AIR (RAOB, PIBAL, RECCO, DROPS) REPORTS

Setup data

Data written to subset.

Match mnemonics and data

hdstr= XOB	YOB	DHR	obstr= TOB
hdr = (1)75.	(2)30.	(3)-0.1	obs(1)= 17.51

BUFR file

```
program bufr_encode_sample   (34 Lines)
!
!  example of writing one value into a bufr file
!
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
 integer :: idate,iret

! set data values
 hdr(1)=75.;hdr(2)=30.;hdr(3)=-0.1
 obs(1,1)=17.15
 idate=2008120100  ! YYYYMMDDHH
 msgtype='ADPUPA'   ! upper-air reports
! encode
 open(unit_table,file='prepobs_prep.bufrtable')
 open(unit_out,file='sample.bufr',action='write' ,form='unformatted')
 call datelen(10)
 call openbf(unit_out,'OUT',unit_table)
   call openmb(unit_out, msgtype,idate)
     call ufbint(unit_out,hdr,3,1,iret,hdstr)
     call ufbint(unit_out,obs,1,1,iret,obstr)
     call writsb(unit_out)
   call closmg(unit_out)
 call closbf(unit_out)

end program
```

Fortran 'open' command to open an unformatted binary file for write.

***OPENBF* (LUBFR, CIO, LUNDX)**

Purpose: Identifies to the BUFRLIB a BUFR file of logical unit *LUBFR.*

***CLOSBF* (LUBFR)**

Purpose: close the connection between logical unit *LUBFR* and the BUFRLIB.

```
program bufr_encode_sample   (34 Lines)
!
!  example of writing one value into a bufr file
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
 integer :: idate,iret

! set data values
 hdr(1)=75.;hdr(2)=30.;hdr(3)=-0.1
 obs(1,1)=17.15
 idate=2008120100  ! YYYYMMDDHH
 msgtype='ADPUPA'   ! upper-air reports

! encode
 open(unit_table,file='prepobs_prep.bufrtable')
 open(unit_out,file='sample.bufr',action='write',form='unformatted')

 call datelen(10)
 call openbf(unit_out,'OUT',unit_table)
   call openmb(unit_out, msgtype,idate)
      call ufbint(unit_out,hdr,3,1,iret,hdstr)
      call ufbint(unit_out,obs,1,1,iret,obstr)
      call writsb(unit_out)
   call closmg(unit_out)
 call closbf(unit_out)

end program
```

Set cycle date

***DATELEN* (LEN)**

Purpose: specify the format *IDATE.*

Input arguments:
LEN INTEGER
Length of Section 1 date-time values
 8 = YYMMDDHH (2-digit year)
10 = YYYYMMDDHH (4-digit year)

```
program bufr_encode_sample   (34 Lines)
!
!  example of writing one value into a bufr file
!
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
 integer :: idate,iret

! set data values
 hdr(1)=75.;hdr(2)=30.;hdr(3)=-0.1
 obs(1,1)=17.15
 idate=2008120100  ! YYYYMMDDHH
 msgtype='ADPUPA'   ! upper-air reports

! encode
 open(unit_table,file='prepobs_prep.bufrtable')
 open(unit_out,file='sample.bufr',action='write',form='unformatted')
 call datelen(10)
 call openbf(unit_out,'OUT',unit_table)
   call openmb(unit_out, msgtype,idate)
     call ufbint(unit_out,hdr,3,1,iret,hdstr)
     call ufbint(unit_out,obs,1,1,iret,obstr)
     call writsb(unit_out)
   call closmg(unit_out)
 call closbf(unit_out)

end program
```

Message

OPENMB **(LUBFR, CSUBSET, IDATE)**
Purpose: Open and initialize, within internal arrays, a new BUFR message for eventual output to *LUBFR*, using *CSUBSET* as message type, *IDATE* as date.

CLOSMG **(LUBFR)**
Purpose: Close existing internal BUFR message (if any) and write it to output.

```
program bufr_encode_sample   (34 Lines)
!
!  example of writing one value into a bufr file
!
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
 integer :: idate,iret

! set data values
 hdr(1)=75.;hdr(2)=30.;hdr(3)=-0.1
 obs(1,1)=17.15
 idate=2008120100  ! YYYYMMDDHH
 msgtype='ADPUPA'   ! upper-air reports

! encode
 open(unit_table,file='prepobs_prep.bufrtable')
 open(unit_out,file='sample.bufr',action='write',form='unformatted')
 call datelen(10)
 call openbf(unit_out,'OUT',unit_table)
   call openmb(unit_out, msgtype,idate)
   call ufbint(unit_out,hdr,3,1,iret,hdstr)
   call ufbint(unit_out,obs,1,1,iret,obstr)
   call writsb(unit_out)
   call closmg(unit_out)
 call closbf(unit_out)

end program
```

Data subsets

hdstr= XOB YOB DHR

hdr = (1)75. (2)30. (3)-0.1

***UFBINT* (LUBFR, R8ARR, MXMN, MXLV, iret, CMNSTR)**

Purpose: writes or reads specified values to or from the current BUFR data subset within the internal arrays.

obstr= TOB

obs(1)= 17.51

```
program bufr_encode_sample   (34 Lines)
!  example of writing one value into a bufr file
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
 integer :: idate,iret

! set data values
 hdr(1)=75.;hdr(2)=30.;hdr(3)=-0.1
 obs(1,1)=17.15
 idate=2008120100  ! YYYYMMDDHH
 msgtype='ADPUPA'   ! upper-air reports

! encode
 open(unit_table,file='prepobs_prep.bufrtable')
 open(unit_out,file='sample.bufr',action='write',form='unformatted')
 call datelen(10)
 call openbf(unit_out,'OUT',unit_table)
   call openmb(unit_out, msgtype,idate)
     call ufbint(unit_out,hdr,3,1,iret,hdstr)
     call ufbint(unit_out,obs,1,1,iret,obstr)
    call writsb(unit_out)
   call closmg(unit_out)
 call closbf(unit_out)

end program
```

Data subsets

***WRITSB* (LUBFR)**

Purpose: Indicates to BUFRLIB that the subset is ready to be encoded into the current message for the BUFR file.

```
program bufr_encode_sample   (34 Lines)
!
!  example of writing one value into a bufr file
!
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
 integer :: idate,iret

! set data values
 hdr(1)=75.;hdr(2)=30.;hdr(3)=-0.1
 obs(1,1)=17.15
 idate=2008120100  ! YYYYMMDDHH
 msgtype='ADPUPA'   ! upper-air reports

! encode
 open(unit_table,file='prepobs_prep.bufrtable')
 open(unit_out,file='sample.bufr',action='write',form='unformatted')
 call datelen(10)
 call openbf(unit_out,'OUT',unit_table)
   call openmb(unit_out, msgtype,idate)

    call ufbint(unit_out,hdr,3,1,iret,hdstr)
    call ufbint(unit_out,obs,1,1,iret,obstr)
     call writsb(unit_out)
   call closmg(unit_out)
 call closbf(unit_out)

end program
```

Mnemonics and data array

hdstr= XOB YOB DHR obstr= TOB

hdr = (1)75. (2)30. (3)-0.1 obs(1)= 17.51

Write to bufr file sample.bufr

Message type: ADPUPA

Section 3	Section 4
XOB YOB DHR TOB	75. 30. -0.1 17.51

Decode BUFR file

- Read the observation out from BUFR file

```
program bufr_decode_sample
!
! example of reading observations from bufr
!
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,10)

 integer :: ireadmg,ireadsb
 character(8) msgtype
 integer :: unit_in=10
 integer :: idate,iret,num_message,num_subset

! decode
 open(unit_in,file='sample.bufr',action='read',form='unformatted')
 call openbf(unit_in,'IN',unit_in)
 call datelen(10)
   num_message=0
   msg_report: do while (ireadmg(unit_in,msgtype,idate) == 0)
    num_message=num_message+1
    num_subset = 0
    write(*,'(I10,I4,a10)') idate,num_message,msgtype
     sb_report: do while (ireadsb(unit_in) == 0)
      num_subset = num_subset+1
       call ufbint(unit_in,hdr,3,1 ,iret,hdstr)
       call ufbint(unit_in,obs,1,10,iret,obstr)
      write(*,'(2I5,4f8.1)') num_subset,iret,hdr,obs(1,1)
     enddo sb_report
   enddo msg_report
 call closbf(unit_in)

end program
```

"A BUFR file contains one or more BUFR messages, each containing one or more BUFR data subsets, each containing one or more BUFR data values

Message and subsets loop though all file to read all observations

BUFR file

messages

subsets

Encode

```
program bufr_encode_sample
!
!  example of writing one value into a bufr
!
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
 integer :: idate,iret

! set data values
 hdr(1)=75.;hdr(2)=30.;hdr(3)=-0.1
 obs(1,1)=17.15
 idate=2008120100  ! YYYYMMDDHH
 msgtype='ADPUPA'   ! upper-air reports

! encode
 open(unit_table,file='prepobs_prep.bufrtable')
 open(unit_out,file='sample.bufr',action='write' &
             ,form='unformatted')
 call datelen(10)
 call openbf(unit_out,'OUT',unit_table)
  call openmb(unit_out,msgtype,idate)
     call ufbint(unit_out,hdr,3,1,iret,hdstr)
     call ufbint(unit_out,obs,1,1,iret,obstr)
       call writsb(unit_out)
   call closmg(unit_out)
 call closbf(unit_out)

end program
```

Decode

```
rogram bufr_decode_sample
!
! example of reading observations from bufr
!
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,10)

 integer :: ireadmg,ireadsb
 character(8) msgtype
 integer :: unit_in=10
 integer :: idate,iret,num_message,num_subset




! decode
 open(unit_in,file='sample.bufr',action='read',form='unformatted')
 call openbf(unit_in,'IN',unit_in)
 call datelen(10)
   num_message=0
 msg_report: do while (ireadmg(unit_in,msgtype,idate) == 0)
     num_message=num_message+1
     num_subset = 0
     write(*,'(I10,I4,a10)') idate,num_message,msgtype
   sb_report: do while (ireadsb(unit_in) == 0)
      num_subset = num_subset+1
      call ufbint(unit_in,hdr,3,1 ,iret,hdstr)
      call ufbint(unit_in,obs,1,10,iret,obstr)
      write(*,'(2I5,4f8.1)') num_subset,iret,hdr,obs(1,1)
    enddo sb_report
  enddo msg_report
 call closbf(unit_in)

end program
```

Read message, data subset, and data values

```
program bufr_decode_sample
!
! example of reading observations from bufr
!
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,10)

 integer :: ireadmg,ireadsb
 character(8) msgtype
 integer :: unit_in=10
 integer :: idate,iret,num_message,num_subset

! decode
 open(unit_in,file='sample.bufr',action='read',form='unformatted')
 call openbf(unit_in,'IN',unit_in)
 call datelen(10)
   num_message=0
msg_report: do while (ireadmg(unit_in,msgtype,idate) == 0)
    num_message=num_message+1
    num_subset = 0
    write(*,'(I10,I4,a10)') idate,num_message,msgtype
   sb_report: do while (ireadsb(unit_in) == 0)
     num_subset = num_subset+1
     call ufbint(unit_in,hdr,3,1 ,iret,hdstr)
      call ufbint(unit_in,obs,1,10,iret,obstr)
     write(*,'(2I5,4f8.1)') num_subset,iret,hdr,obs(1,1)
   enddo sb_report
  enddo msg_report
 call closbf(unit_in)

end program
```

IRET = *IREADMG* (LUBFR, CSUBSET, IDATE)
Purpose: reads the next BUFR message from the given BUFR file pointed to by *LUBFR*.

IRET = *IREADSB* (LUBFR)
Purpose: reads a subset from that internal message.

***UFBINT* (LUBFR, R8ARR, MXMN, MXLV, iret, CMNSTR)**
Purpose: writes or reads specified values to or from the current BUFR data subset within the internal arrays.

```
program bufr_decode_sample
!
! example of reading observations from bufr
!
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,10)

 integer :: ireadmg,ireadsb
 character(8) msgtype
 integer :: unit_in=10
 integer :: idate,iret,num_message,num_subset

! decode
 open(unit_in,file='sample.bufr',action='read',form='unformatted')
 call openbf(unit_in,'IN',unit_in)
 call datelen(10)
   num_message=0
   msg_report: do while (ireadmg(unit_in,msgtype,idate) == 0)
     num_message=num_message+1
     num_subset = 0
     write(*,'(I10,I4,a10)') idate,num_message,msgtype
     sb_report: do while (ireadsb(unit_in) == 0)
       num_subset = num_subset+1
       call ufbint(unit_in,hdr,3,1 ,iret,hdstr)
       call ufbint(unit_in,obs,1,10,iret,obstr)
       write(*,'(2I5,4f8.1)') num_subset,iret,hdr,obs(1,1)
     enddo sb_report
   enddo msg_report
 call closbf(unit_in)

end program
```

Mnemonics and data array

hdstr= XOB YOB DHR obstr= TOB

Message type: ADPUPA

Section 3	Section 4
XOB YOB DHR TOB	75. 30. -0.1 17.51

read from sample.bufr

hdr = (1)75. (2)30. (3)-0.1 obs(1)= 17.51

Append to BUFR file

- Append the observation to existing BUFR

Encode

```
program bufr_encode_sample
!
!  example of writing one value into a bufr file
!
 implicit none

 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
 integer :: idate,iret

! set data values
 hdr(1)=75.;hdr(2)=30.;hdr(3)=-0.1
 obs(1,1)=17.15
 idate=2008120100  ! YYYYMMDDHH
 msgtype='ADPUPA'   ! upper-air reports




! encode
 open(unit_table,file='prepobs_prep.bufrtable')
 open(unit_out,file='sample.bufr',action='write' &
             ,form='unformatted')
 call datelen(10)
 call openbf(unit_out,'OUT',unit_table)
   call openmb(unit_out, msgtype,idate)
      call ufbint(unit_out,hdr,3,1,iret,hdstr)
      call ufbint(unit_out,obs,1,1,iret,obstr)
      call writsb(unit_out)
   call closmg(unit_out)
 call closbf(unit_out)
end program
```

Append

```
program bufr_append_sample

!sample of appending one observation into bufr file
 implicit none
 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
 integer :: idate,iret

! set data values
 hdr(1)=85.0;hdr(2)=50.0;hdr(3)=0.2
 obs(1,1)=15.0
 idate=2008120101  ! YYYYMMDDHH
 msgtype='ADPSFC'   ! surface land reports

! get bufr table from existing bufr file
 open(unit_table,file='prepobs_prep_app.bufrtable')
 open(unit_out,file='sample.bufr',status='old',form='unformatted')
 call openbf(unit_out,'IN',unit_out)
 call dxdump(unit_out,unit_table)
 call closbf(unit_out)

! append
 open(unit_out,file='sample.bufr',status='old',form='unformatted')
 call datelen(10)
 call openbf(unit_out,'APN',unit_table)
   call openmb(unit_out, msgtype,idate)
      call ufbint(unit_out,hdr,3,1,iret,hdstr)
      call ufbint(unit_out,obs,1,1,iret,obstr)
      call writsb(unit_out)
   call closmg(unit_out)
 call closbf(unit_out)
end program
```

Extract BUFR table from existing BUFR file

```
program bufr_append_sample
!
! sample of appending one observation into bufr file
 implicit none
 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
 integer :: idate,iret

! set data values
 hdr(1)=85.0;hdr(2)=50.0;hdr(3)=0.2
 obs(1,1)=15.0
 idate=2008120101  ! YYYYMMDDHH
 msgtype='ADPSFC'   ! surface land reports

! get bufr table from existing bufr file
 open(unit_table,file='prepobs_prep_app.bufrtable')
 open(unit_out,file='sample.bufr',status='old',form='unformatted')
 call openbf(unit_out,'IN',unit_out)
 call dxdump(unit_out,unit_table)
 call closbf(unit_out)

! append
 open(unit_out,file='sample.bufr',status='old',form='unformatted')
 call datelen(10)
 call openbf(unit_out,'APN',unit_table)
   call openmb(unit_out, msgtype,idate)
      call ufbint(unit_out,hdr,3,1,iret,hdstr)
      call ufbint(unit_out,obs,1,1,iret,obstr)
      call writsb(unit_out)
   call closmg(unit_out)
 call closbf(unit_out)
end program
```

Appending requires the report structure (BUFR table) of the new data subset fits the report structure in the existing file. So we use the following subroutine to retrieve BUFR table from the existing BUFR file:

***DXDUMP* (LUBFR, LDXOT)**

Purpose: reads the embedded tables information in the BUFR file and write it out to the ASCII format file.

Append

```
program bufr_append_sample
! sample of appending one observation into bufr file
 implicit none
 character(80):: hdstr='XOB YOB DHR'
 character(80):: obstr='TOB'
 real(8) :: hdr(3),obs(1,1)

 character(8) msgtype
 integer :: unit_out=10,unit_table=20
 integer :: idate,iret

! set data values
 hdr(1)=85.0;hdr(2)=50.0;hdr(3)=0.2
 obs(1,1)=15.0
 idate=2008120101  ! YYYYMMDDHH
 msgtype='ADPSFC'   ! surface land reports

! get bufr table from existing bufr file
 open(unit_table,file='prepobs_prep_app.bufrtable')
 open(unit_out,file='sample.bufr',status='old',form='unformatted')
 call openbf(unit_out,'IN',unit_out)
 call dxdump(unit_out,unit_table)
 call closbf(unit_out)

! append
 open(unit_out,file='sample.bufr',status='old',form='unformatted')
 call datelen(10)
 call openbf(unit_out,'APN',unit_table)
 call openmb(unit_out, msgtype,idate)
    call ufbint(unit_out,hdr,3,1,iret,hdstr)
    call ufbint(unit_out,obs,1,1,iret,obstr)
    call writsb(unit_out)
 call closmg(unit_out)
 call closbf(unit_out)
end program
```

Write the new message type and data subset to the existing BUFR file.

Test results (Basic Practice case 0):

./bufr_encode_sample.exe
This generates a new bufr file *sample.bufr*

./bufr_decode_sample.exe
This reads one observation from *sample.bufr*, and write result on screen:

```
2008120100    1   ADPUPA
     1     1     75.0     30.0     -0.1    17.1
```

./bufr_append_sample.exe
Now, append a new observation to *sample.bufr*.

./decode_sample.exe
Read *sample.bufr* and show two observations in it:

```
2008120100    1   ADPUPA
     1     1     75.0     30.0     -0.1    17.1
2008120101    2   ADPSFC
     1     1     85.0     50.0      0.2    15.0
```

Examples for GSI BUFR/PrepBUFR files

Code name	Illustrated process function
prepbufr_decode_all.f90	• read BUFR table from an existing prepbufr file • read all observation information used by GSI analysis from an existing prepbufr file.
prepbufr_encode_surface.f90	• write a surface observation into a new prepbufr file
prepbufr_encode_upperair.f90	• write a upper air observation into a new prepbufr file
prepbufr_append_upperair.f90	• read BUFR table from an existing prepbufr file • append a upper air observation into an existing prepbufr file
prepbufr_append_surface.f90	• read BUFR table from an existing prepbufr file • append a surface observation into an existing prepbufr file.
prepbufr_append_retrieve.f90	• read BUFR table from an existing prepbufr file • append retrieved data into an existing prepbufr file.
bufr_decode_radiance.f90	• read BUFR table from an existing radiance bufr file • real radiance data from an existing radiance bufr file.

- These examples have the same structure and call the same BUFRLIB subroutines/functions as those three simple examples
- The only difference is the mnemonic lists used in these examples are much longer

MNEMONIC in prepbufr_decode_all.f90

In GSI, *read_prepbufr.f90* reads PrepBUFR file. The following mnemonic lists come from *read_prepbufr.f90* and are used in PrepBUFR sample code.

```
integer, parameter :: mxmn=35, mxlv=250
character(80):: hdstr='SID XOB YOB DHR TYP ELV SAID T29'
character(80):: obstr='POB QOB TOB ZOB UOB VOB PWO CAT PRSS'
character(80):: qcstr='PQM QQM TQM ZQM WQM NUL PWQ      '
character(80):: oestr='POE QOE TOE NUL WOE NUL PWE      '
real(8) :: hdr(mxmn),obs(mxmn,mxlv),qcf(mxmn,mxlv),oer(mxmn,mxlv)
```

```
call ufbint(unit_in,hdr,mxmn,1   ,iret,hdstr)
call ufbint(unit_in,obs,mxmn,mxlv,iret,obstr)
call ufbint(unit_in,oer,mxmn,mxlv,iret,oestr)
call ufbint(unit_in,qcf,mxmn,mxlv,iret,qcstr)
```

NCEP DX BUFR table

- DX BUFR table structure and examples
- DX BUFR table application examples

Detailed information is in BUFR user guide.

DX BUFR table

- Define report structures in any kind of BUFR/ PrepBUFR files.
- Report structures for various types of observations are defined by "NCEP BUFR Tables" when using the NCEP BUFRLIB software.
- In NCEP BUFR files, the BUFR tables are embedded at the top of the files.
- Excellent reference for NCEP BUFR Tables: http://www.nco.ncep.noaa.gov/sib/decoders/BUFRLIB/toc/dfbftab/

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                           |
`-------------------------------------------------------------------------------'
```

Section 1:
Table A mnemonic
Table D mnemonic
Table B mnemonic

Section 2:
Table A and Table D sequences

Section 3:
Table B mnemonics defined in term of 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 description.

Table A mnemonic:
Refer to report types

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

Table B mnemonic:
Refer to basic data values

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

Table D mnemonic:
Constituents of a particular Table A 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 application examples: 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               |-------------|
`-------------------------------------------------------------------------------'
```

DX BUFR table application examples: 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 application examples: 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

DX BUFR table application examples: 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

DX 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)

Reference

- http://www.dtcenter.org/com-GSI/BUFR/docs/index.php
  - BUFR User's Guide version 1.0:

    [pdf (1M), last update: Jan. 13, 2012];

- GSI summer tutorial 2013
  - Observation processing

    [Dennis Keyser & Jeff Whiting (NCEP/EMC)] [pdf]

- WMO BUFR User's Guide
  - https://www.wmo.int/pages/prog/gcos/documents/gruanmanuals/ECMWF/bufr_user_guide.pdf

Questions?

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