conv_jma_grib2

— a tool to convert GRIB2 provided for UNSCEAR by JMA —
Users' Manual

by the Japan Meteorological Agency

1 Introduction: what does the tool do?

The Japan Meteorological Agency (JMA) has provided the operational mesoscale analysis (MA) in the GRIB2 format to members of the task team. MA employs the Lambert conformal conic projection as a horizontal coordinate, but it has been revealed that the projection might not be familiar to some people. In addition, a terrain following hybrid coordinate adopted by MA could be another factor to hamper members' work.

Furthermore, while the GRIB2 format is regulated by the WMO and established as a common format to exchange meteorological data, it might not an easy task to decode and process them.

Considering the situation, JMA has decided to provide a tool to convert horizontal and vertical coordinates as well as the data format. The tool provides functions

- to convert the GRIB2 format to the FORTRAN sequential format which is much more familiar and can be visualized by the GrADS, a popular tool in the meteorological society.
- to re-project data in the GRIB2 to other projection.
- to convert the terrain following hybrid vertical coordinate to the isobaric coordinate with arbitrary pressure planes.

The tool is applicable for the following GRIB2 files provided to the UNSCEAR task team.

- `jma_ma_met_hybrid-coordinate_201103DDHH00.grib2.bin`
  (MA for the atmosphere)
- `jma_ma_land-surface_201103DDHH00.grib2.bin`
  (MA for the land surface)
- `jma_ma_ocean_sst_201103DDHH00.grib2.bin`
  (MA for the sea surface temperature)
- `Z__C_RJTD_201103DDHHMN00_SRF_GPV_Ggis1km_Prr60lv_ANAL_grib2.bin`
  (Radar/Raingauge analyzed precipitation)

2 Setup

The source codes described in C can be complied as the following.

```
$ tar xvzf conv_jma_grib2.tar.gz
$ cd conv_jma_grib2
$ ./configure
$ make
```

After the compilation finishes successfully, the executable file `conv_jma_grib2` is generated in `src` directory. You can copy the executable to another directory you like.

The `configure` script automatically determines endian of your computer and the executable built is compatible to your computer.

Note that `makedepend` (a tool to generate dependencies automatically) is used in the compilation. Even if `makedepend` is not installed in your computer, the codes are compiled successfully using the prescribed dependencies in `src/.depend.default` as long as no modifications are added into the codes. If you are going to add some modifications but `makedepend` is not installed, you might need to update the dependencies by hand, which `makedepend` automatically does. `config.log` generated after running `configure` tells you whether `makedepend` is installed in your computer and used in compiling them.

3 Basic Usage

As the first practice, just type as follows with a GRIB2 file provided by JMA.

```
$ conv_jma_grib2 grib2_file
```

You obtain a converted file in the FORTRAN sequential format with a GrADS ctl file. The converted file is put with a file name combined the original GRIB2 file name (including a directory path) and "`.dat`" and "`.ctl`", that is, if your GRIB2 file is named as `/home/john/sample.grib2`, file names of the converted ones are `/home/john/sample.grib2.ctl` and `/home/john/sample.grib2.dat`. If `-o output_file` is added to the option line, the output file name can be altered to `output_file`.

You can see what elements are stored by looking at the ctl file. This operation just converts file formats and no coordinate transformations are done. By opening the ctl file with GrADS, you can draw elements stored in the file. In the case of converting GRIB2 files of the Radar/Raingauge-Analyzed Precipitation (R/A), converted files contain precipitation intensity (parameter category:1, number:8), while discritized levels of precipitation intensity (parameter category:1, number:200) is stored in the original GRIB2 files. It is also the case when you convert the original GRIB2 to the GRIB2 again with `-g` option.

Note that converted FORTRAN sequential files are described in the big endian even if the byte order of your computer is the little endian. While the GrADS can recognize the endian because the endian is specified in a "OPTION" line in the ctl file, take care of that when you try to read the file by your own programs (FORTRAN compilers usually have a "big endian" mode, with which `read/write` statement in FORTRAN read/write sequential files in the big endian even on little-endian machines).

Furthermore, the first point of the GRIB2 is at the northwest edge (j increases from north to south), however, converted files in the FORTRAN sequential format have the first point at the southwest edge (j increases from south to north). That is why no "`yrev`" option is placed in the OPTION line in ctl files.

By default, ctl files for GrADS assume a linear grid even if the Lambert projection is employed. The generated ctl file should be like the following:

```
#pdef 719 575 LCCR 30.000 140.000 487.977067 168.019156 30.000 60.000 140.000 5000.000 5000.000
#xdef 963 linear 107.000000 0.051922
#ydef 668 linear 19.000000 0.044966
xdef 719 linear 1.000000 1.000000
ydef 575 linear 1.000000 1.000000
```

Although the GrADS ignores lines starting with `#`, parameters related to the Lambert projection is written down in a `pdef` statement. In this case, the numbers of grids specified by `xdef` and `ydef` is real grid numbers. You can draw this file with GrADS but map drawn is not correct.

If `-c` option is specified, the parameters in the ctl files will be

```
pdef 719 575 LCCR 30.000 140.000 487.977067 168.019156 30.000 60.000 140.000 5000.000 5000.000
xdef 963 linear 107.000000 0.051922
ydef 668 linear 19.000000 0.044966
#xdef 719 linear 1.000000 1.000000
#ydef 575 linear 1.000000 1.000000
```

This time, the GrADS interprets the `pdef` statement, and draw figures interpolating the Lambert projected grids to linear Latitude/Longitude coordinate. Real grid numbers are appeared in the `pdef` statement, but numbers specified by `xdef` and `ydef` are not related to the real grid numbers (they are adjusted so that the entire domain can be drawn).

4 Coordinate transform

This tool has a function to transform horizontal and vertical coordinates.

All options explained in the Section 3 are also available when options for a horizontal and/or vertical coordinate transform are specified.

Of course, the vertical transform is valid only for the atmospheric analysis (not for land, sst, and R/A analysis).

4.1 Horizontal transform

If you are going to change a horizontal coordinate of the provided GRIB2 data, you should create a configuration file describing parameters of the destination projection. The configuration file is put as an option in the command line with `-h` like

```
$ conv_jma_grib2 -h config_h.txt grib2_file
```

4.1.1 Converting to the Latitude/Longitude coordinate

When converting data in the GRIB2 to those on the Latitude/Longitude coordinate, an example of the configuration file content should be like the following,

```
proj = LL
nx = 201
ny = 201
dx = 0.05
dy = 0.05
xlat = 40.0
xlon = 120.0
xi = 1.0
xj = 1.0
```

- `proj` must be `LL` (Latitude/Longitude)
- `nx`, `ny`: the numbers of grids of x- and y-direction.
- `dx`, `dy`: grid spacing of x- and y- direction. (unit: degree)
- `xlat`, `xlon`, `xi`, `xj`: (`xi`, `xj`) on the coordinate corresponds to the point identified by `xlat` and `xlon`. In the coordinate the configuration file assumes, a point of (1, 1) is located at the northwest edge and `xj` increases from north to south (the coordinate value of the first point is 1, not 0).

  When a coordinate you want to convert to is the Latitude/Longitude, it is easy and understandable to set the latitude and longitude of the first point (i.e. the most northwestern point) to `xlat` and `xlon`, and `xi` = `xj` = 1.0.

4.1.2 Converting to the Lambert Coordinate

When you are going to convert the JMA GRIB2 data (ex. Radar/Raingauge Analyzed Precipitation) to those on the Lambert coordinate, a configuration file on parameters for the target coordinate is required. An example of what should be described in the configuration is as follows.

```
proj = LMN
nx = 719
ny = 575
dx = 5000.0
dy = 5000.0
xlat = 30.0
xlon = 140.0
xi = 488.0
xj = 408.0
slat1 = 30.0
slat2 = 60.0
slon = 140.0
```

The format of the configuration file is similar to that for converting to the Latitude/Longitude coordinate, mentioned in the previous subsection. This time, `proj` must be `LMN` (Lambert North). In addition to parameters used also for the Latitude/Longitude coordinate, two standard latitude and a standard longitude must be set to `slat1`, `slat2` and `slon` in degree. Along the standard latitudes and longitude, no expansion or shrink occurs in the projection from the Earth sphere to the plane. It is strongly recommended that when you would like to use the Lambert projection, `slat1` = 30, `slat2` = 60 and `slon` = 140. In the case of the Lambert projection, `dx` and `dy` mean grid spacings at the standard latitude and longitude at the points identified by `slat1`, `slat2` and `slon`. (Parameters in the example shown above is used in the JMA meso analysis).

Wind components u and v in the GRIB2 depict x- and y- direction winds on the Lambert projection, respectively (not zonal and meridional winds). When the Lambert coordinate is converted to the Latitude/Longitude one, u and v are rotated so that the rotated winds u' and v' can be interpreted as zonal and meridional winds. The details of the rotation are described in Appendix A.

Note that conversion of the original MA GRIB2 described in the Lambert projection to another Lambert projection with different parameters (ex. smaller region) is also possible.

The original domain is expected to cover the entire domain of the converted one. If the tool finds a point on the target coordinate locating out of the original domain, it abnormally halts with an error message by default. However, adding `-d` to the command line option allows you to include points which are not covered by the original coordinate. MISSING (`undef` in GrADS) are stored into these points.

For almost elements in the GRIB2, the tool calculated values on the target coordinate by the linear interpolation of values on four adjacent points on the original coordinate. There are two exceptions.

1. In converting `KIND` (surface kind such as land, sea, land covered by snow, sea covered by ice) stored in the land surface analysis, the tool uses a value on the nearest point selected from the four adjacent points (because a fractional "`KIND`" obtained by the linear interpolation as the other elements is meaningless.)

2. In converting Radar/Raingauge Analyzed precipitation originally on the Latitude/Longitude coordinate to other coordinate, three options for the interpolation are available. The following characters should be placed in the command line after `-r`.

    - `m`: averaged values over grids on the original projection which are covered by the grid on the target projection are adopted.
    - `x`: maximum values over grids on the original projection which are covered by the grid on the target projection are adopted.
    - `n`: values on the nearest grids on the original projection is adopted.

4.2 Vertical transform

When you are going to transform the original terrain following hybrid coordinate of MA to the isobaric coordinate, the configuration file describing a list of pressures of the isobaric planes is required like the following.

```
pout = 1000.0, 950.0, 925.0, 850.0, 700.0, 500.0, 300.0, 250.0, 200.0, 100.0
```

Each value in the list is separated by a comma, and the unit of pressure is hPa. No line breaks should be inserted. Pressures in the list should be in descending order. Arbitrary pressure (but note that the top of MA is located around 40hPa) can be specified as long as the number of pressures in the list is less than 100.

With the configuration file describing a list of pressures, you can run the tool like

```
$ conv_jma_grib2 -v config_v.txt grib2_file
```

If surface pressure of one point on one isobaric plane is less than that of the isobaric plane, it means that the point is located underground. Because extrapolated (physically meaningless) values are stored to underground points by default, you should determine validness of each point by comparing surface pressure and that of a isobaric plane. If `-u` is added in the command line, values on underground points are set to MISSING (`undef`) instead of the extrapolated values.

When converting to the isobaric coordinate, temperature is stored instead of potential temperature in the original GRIB2.

Note that you would like to transform horizontal and vertical coordinate simultaneously, both `-h config_h` and `-h config_v` should be placed in the command line. If the both are requested, the vertical coordinate is transformed before the horizontal one.

5 Other Command line options

-l

If `-l` is specified in the command line, a file containing values of latitudes and longitudes of all points in the domain is generated in the GrADS format with a ctl file.

-p

If `-p` is specified in the command line, records in the GRIB2 are printed. After printing them, the tool exits. No files are generated besides the printed information.

6 Quick reference

```
conv_jma_grib2 grib2_file [-h config_h_file] [-v config_v_file] [-o output_file]
               [-g] [-p] [-d] [-r m|x|n] [-l] [-c] [-u]
      -g: output in GRIB2 format
      -p: only print records in grib2_file
      -d: allow out of domain in coordinate conversion
      -c: use pdef in GrADS ctl files
      -u: set MISSING to values located underground
      -r: RA interpolation option
          m: mean
          x: max
          n: nearest
      -l: output lat and lon in GrADS format
```

The identical explanation can be obtained by just executing the tool without any arguments.

One or more options can be specfied in general.

7 Examples

1. Just convert the GRIB2 file format to the GrADS one.

   ```
   $ conv_jma_grib2 /home/john/jma_ma_met_XXXX.grib2.bin
   ```

   The tool generates `jma_ma_met_XXXX.grib2.bin.dat` and `jma_ma_met_XXXX.grib2.bin.ctl` in a directory `/home/john`.

2. Just convert the GRIB2 file format to the GrADS one, but a file name of outputs is specified.

   ```
   $ conv_jma_grib2 /home/john/jma_ma_met_XXXX.grib2.bin -o after
   ```

   Files named `after.dat` and `after.ctl` in the current directory.

3. The original GRIB2 files for R/A depict precipitation intensity with discrete integer level values. The following operation produces a GRIB2 file again, but the discrete level values are interpreted to real-number values using the conversion table in the original GRIB2 files. The generated GRIB2 files do not employ any local-use templates, while the original ones use some of them.

   ```
   $ conv_jma_grib2 /home/john/Z__C_RJTD_XXXX_Prr60lv_ANAL_grib2.bin -g
   ```

   A GRIB2 file containing real-number precipitation intensity is created with a name `/home/john/Z__C_RJTD_XXXX_Prr60lv_ANAL_grib2.bin.grib2.bin`.

4. Convert a horizontal coordinate following a configuration file

   ```
   $ conv_jma_grib2 /home/john/jma_ma_met_XXXX.grib2.bin -h config_h.txt
   ```

   where `config_h.txt` should be prepared in advance.

   The tool generates `jma_ma_met_XXXX.grib2.bin.dat` and `jma_ma_met_XXXX.grib2.bin.ctl` in a directory `/home/john`.

   ```
   $ conv_jma_grib2 /home/john/jma_ma_met_XXXX.grib2.bin -h config_h.txt -d
   ```

   By adding `-d` in the command line, points which the original data do not contain is fulfilled by `undef` instead that the tool abnormally aborts.

   ```
   $ conv_jma_grib2 /home/john/jma_ma_met_XXXX.grib2.bin -h config_h.txt -g
   ```

   this operation generates a GRIB2 file `jma_ma_met_XXXX.grib2.bin.grib2.bin` instead of the file in the GrADS format.

   ```
   $ conv_jma_grib2 Z__C_RJTD_XXXX_Prr60lv_ANAL_grib2.bin -h config_h.txt -r n
   ```

   Transform a coordinate of R/A following a configuration file `config_h.txt`. In interpolating, values on the nearest grids on the original projection is adopted.

5. Convert a vertical coordinate following a configuration file

```
$ conv_jma_grib2 /home/john/jma_ma_met_XXXX.grib2.bin -v config_v.txt
```

A rule to name files are the same as former examples.

```
$ conv_jma_grib2 /home/john/jma_ma_met_XXXX.grib2.bin -v config_v.txt -u
```

Values located underground in the generated file is set to `undef`.

6. Convert horizontal and vertical coordinate simultaneously

```
$ conv_jma_grib2 jma_ma_met_XXXX.grib2.bin -h config_h.txt -v config_v.txt
```

A Lambert conformal conic projection

Coordinates x and y on the projected rectangular plane are given by:

$$(x - x_0)D_X = \rho(\phi)\sin[\alpha(\lambda - \overline{\lambda})] - \rho(\phi_0)\sin[\alpha(\lambda_0 - \overline{\lambda})],$$
$$(y - y_0)D_Y = \rho(\phi)\cos[\alpha(\lambda - \overline{\lambda})] - \rho(\phi_0)\cos[\alpha(\lambda_0 - \overline{\lambda})]$$

where

$$\rho(\phi) = \frac{R\cos\phi_1 U(\phi)^\alpha}{\alpha U(\phi_1)^\alpha}, \quad (R = 6371000 \text{ m: Radius of the Earth})$$
$$\alpha = \frac{\ln(\cos\phi_1) - \ln(\cos\phi_2)}{\ln U(\phi_1) - \ln U(\phi_2)}$$
$$U(\phi) = \tan\left(45^\circ - \frac{\phi}{2}\right),$$
$$D_X, D_Y : \texttt{dx},\ \texttt{dy},$$
$$\phi_1, \phi_2 : \texttt{slat1},\ \texttt{slat2},$$
$$\overline{\lambda} : \texttt{slon},$$
$$\phi_0, \lambda_0 : \texttt{xlat}, \texttt{xlon},$$
$$x_0, y_0 : \texttt{xi}, \texttt{xj}.$$

The symbols used above (`dx`, `dy`, `slat1`, `slat2`, `slon`, `xlat`, `xlon`, `xi` and `xj`) are explained in Section 4.1.2.

When you would like to convert x- and y- direction winds on the Lambert projection to zonal and meridional winds, you should rotate the wind vectors by the following angle θ ($\theta > 0$: clockwise rotation)

$$\theta = \alpha(\lambda - \overline{\lambda}),$$

where λ is the longitude of the point. Under the usual and recommended condition (`slat1` $= 30^\circ$, `slat1` $= 60^\circ$ and `slon` $= 140^\circ$), $\alpha \simeq 0.715$.