GRIB2 conversion and its usage at NCEP

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10th Workshop on Meteorological Operational Systems ECMWF User Orientation
14-18 November 2005

Room 302, WWB
Camp Springs, MD

Overview

- GRIB1 and GRIB2
- Format differences between GRIB1 and GRIB2
- NCEP GRIB2 encode/decode routines & utilities
- Operational GRIB2 products
- Data Packing – Compression Experiments
- General questions on challenges/issues on GRIB2

GRIB1 Sections

0 – Indicator Section

- **'GRIB' (octet 1-4 = 32bits), length of message (octet 5-7=24bits), edition number -1 (octet 8=8bits)**
- **1 octet = 1byte = 8bits**
- **octets are numbered 1, 2, 3, etc., Bit positions within octets are from bit 1 to bit 8.**
- **bit 1 = most significant bit & bit 8 = least significant)**

1 – Product Definition Section (PDS)

- **Length of PDS, parameter table version number, ID of center, generating process ID, grid identification (Table B), Ref time, parameter and units, level, valid time …**

2 – Grid Definition Section (GDS) – optional

- **Length of sec., sec. no, defn of grid surf and geometry of data values within the surface**

3 – Bit-Map Section (BMS) – optional

- **Length of sec., sec. no, indication of presence or absence of data at each of the grid points, as applicable example sst**

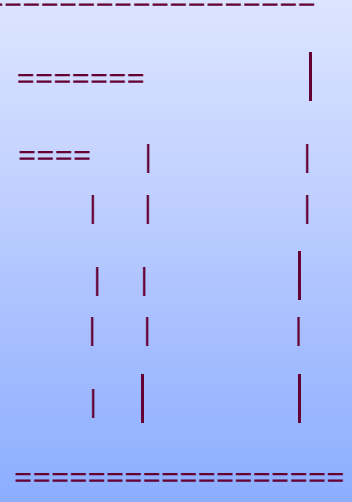
4 – Binary Data Section (BDS)

- **Length of sec., sec. no, data values**

5 – End Section = '7777'

GRIB2 Sections

- 0 – Indicator Section
  - **‘GRIB’, length, version, discipline – (16 octets long)**
- Section 1 – Identification
  - **Ref time, orig center, table versions, …(length of the section is expressed as the first four octets (32 bits) -the section number in the fifth octet and octets beyond 21 are reserved for future use)**
- 2 – Local Use Section – optional
- 3 – Grid Definition Section
- 4 – Product Definition Section
  - **parameter, level, valid time**
- 5 – Data Representation Section
  - **packing algorithm used, info needed to unpack**
- 6 – Bit Map Section
- 7 – Data Section
  - **packed data**
- 8 – End Section = ‘7777’



GRIB2 – Documentation

- GRIB2 specification from WMO contains template definitions and table entries: http://www.wmo.ch/web/www/DPS/grib-2.html
- Local Tables: http://www.nco.ncep.noaa.gov/pmb/docs/grib2
- NCEP source files and utilities on the web for decoding and encoding data in GRIB2 format

  http://www.nco.ncep.noaa.gov/pmb/codes/GRIB2/

GRIB1 & GRIB2 Major Differences

- One GRIB2 message can contain multiple fields.

  - Sequences of GRIB sections 2 to 7, sections 3 to 7 or sections 4 to 7 may be repeated within a single GRIB message.

  - Once a section is repeated all the following sections must appear in order.

  - A section remains in effect until redefined.

  - Could be used for vector fields such as u & v components, or ensemble members

  - IEEE single precision floating point representation used instead of standard IBM representation. The representation occupies four octets.

- GDS, PDS, DRS, and DS are all template driven.

  Octet assignments within a section are based on the Template specified.

- Parameters are defined by three values:

  Discipline (specified in Section 0)

  Category (PDS)

  Parameter number (PDS).

GRIB1 and GRIB2 Major differences contd.

- Table versions, originating center, initial reference time and grid ID removed from GRIB1 PDS. Most are now in Identification Section.
- All longitudes MUST be in degrees East and be between 0 and 360 degrees. No negatives. No degrees West. No change in latitude definitions -90^0 to 90^0.
- GDS and BMS no longer optional. They must be included. Only Section 2 (Local Use) is optional.
- Latitudes, Longitudes are in units of micro-degrees (10^{-6} degrees). Includes distance between grid points for Lat/Lon grids (GRIB1 was milli-degrees)
- All other grid point increments are in millimeters (GRIB1 was in meters)
- Floating point values are now stored in IEEE format (GRIB1 was IBM 360/195 format HDS)

GRIB2 in NCEP operations

Encoding Routines

GRIB2 message can contain gridded fields for many parameters on a number of different grids.

Start a new GRIB2 message with a call to:

(1) call GRIBCREATE – encodes sections 0 and 1 at the beginning of message.

(2) call ADDLOCAL – adds a Local Use Section (Section 2) optional

(3) call ADDGRID – encodes a grid definition into Section 3. Defines the geometry of the data values in the fields that follow it. ADDGRID can be called again to change the grid definition describing subsequent data fields.

(4) call ADDFIELD – adds each data field which adds Sections 4, 5, 6, and 7 to the message.

(5) call GRIBEND – adds the final section 8 to the message which updates the length of the message. GRIBEND is required for each GRIB2 message.

GRIB2 in NCEP operations contd.

Decoding Routines

call GB_INFO – finds out how many Local Use sections and data fields are contained in a given GRIB2 message. Also returns the number of octets of the largest Local Use section in the message. Ensures the dimensionality of the input array of GETLOCAL

call GETLOCAL – returns the requested occurrence of Section 2 from a given GRIB2 message.

call GF_GETFLD – gets all information pertaining to the nth data field in the message – returns all the unpacked values for each Section and Template in a f90 "type gribfield" with options to unpack the Bit-map (if applicable) and the data values or just return the field description information.

call GF_FREE(gfld) – frees up memory held by gfld as many elements in derived type gribfield are dynamically allocated when decoded.

Example:

```
use grib_mod
type(gribfield) ::gfld
  …
  …
call gf_getfld(cgrib,lengrib,1,.true.,.false.,gfld,ierr)
print*,'Num of grid points =',gfld%ngrdpts
print*,'First data value=',gfld%fld(1)
call gf_free(gfld)
```

How to extract GRIB2 fields from a GRIB2 file?

GETGB2 – extracts a specified field from a file containing many GRIB2 messages.

GRIB2 in NCEP operations contd.

Create GRIB2 Message

call PUTGB2 – if a variable of derived type of "gribfield" already exists, this subroutine can be used to pack it up and write it to a file.

NCEP GRIB2 Utilities

/grb2index grib2file grib2indexfile

- creates a GRIB2 index file

/cnvgrib –h (packing options: 1 => 2, 2=>1, 2=>2)

-converts all fields in a file between GRIB1 and GRIB2

/degrib2 grib2file

-dumps the meta-data for each GRIB2 field in grib2file

- basically prints contents of each element in derived type gribfield

- wgrib2 for Grads in development

```
$ /nwprod/util/exec/cnvgrib -h
Usage: cnvgrib [-h] {-g12|-g21|-g22} [-m]
            [{-p0|-p2|-p31|-p32|-p40|-p41|-p40000|-p40010}] ingribfile outgribfile
cnvgrib:  version cnvgrib-1.1.1
Must use one of the following options:
   -g12     converts GRIB1 to GRIB2
   -g21     converts GRIB2 to GRIB1
   -g22     converts GRIB2 to GRIB2  (used to change packing option)
Optional packing options: (for use with  -g12 and -g22 only)
   -p0      simple packing
   -p2      complex packing
   -p31     complex pack with 1st order diffs
   -p32     complex pack with 2nd order diffs
   -p40     JPEG2000 encoding
   -p41     PNG encoding
   -p40000  JPEG2000 encoding (Obsolete)
   -p40010  PNG encoding (Obsolete)
Other Optional options:
   -m       Use missing values instead of bitmap
                                    (valid with -p2, -p31 or -p32 options only)
```

GRIB MESSAGE 1 starts at 1

SECTION 0: 0 2 60463
SECTION 1: 7 0 2 1 1 2005 11 9 6 0 0 0 1
Contains 0 Local Sections and 1 data fields.

FIELD 1
SECTION 0: 0 2
SECTION 1: 7 0 2 1 1 2005 11 9 6 0 0 0 1
SECTION 3: 0 65160 0 0 0
GRID TEMPLATE 3. 0 : 6 0 0 0 0 0 0 360 181 0 0 90000000 0 48 -90000000 359000000 1000000 1000000 0
NO Optional List Defining Number of Data Points.
PRODUCT TEMPLATE 4. 0 : 3 5 2 0 96 0 0 1 36 100 0 100000 255 0 0
TEXT: HGT 1000 mb valid at 36 hr after 2005110906:00:00
NO Optional Vertical Coordinate List.
Num. of Data Points = 65160 NO BIT-MAP
DRS TEMPLATE 5. 3 : -979087360 0 1 11 0 1 0 0 0 5124 0 4 1 1 32 5 1 2
Data Values:
MIN= -525.79998779 AVE= 70.36888123
MAX= 313.10000610

GRIB MESSAGE 2 starts at 60464

SECTION 0: 0 2 59574
SECTION 1: 7 0 2 1 1 2005 11 9 6 0 0 0 1
Contains 0 Local Sections and 1 data fields.

FIELD 1
SECTION 0: 0 2
SECTION 1: 7 0 2 1 1 2005 11 9 6 0 0 0 1
SECTION 3: 0 65160 0 0 0
GRID TEMPLATE 3. 0 : 6 0 0 0 0 0 0 360 181 0 0 90000000 0 48 -90000000 359000
000 1000000 1000000 0
NO Optional List Defining Number of Data Points.
PRODUCT TEMPLATE 4. 0 : 3 5 2 0 96 0 0 1 36 100 0 97500 255 0 0
TEXT: HGT 975 mb valid at 36 hr after 2005110906:00:00
NO Optional Vertical Coordinate List.
Num. of Data Points = 65160 NO BIT-MAP
DRS TEMPLATE 5. 3 : -984977408 0 1 11 0 1 0 0 0 5130 0 4 1 1 32 5 1 2
Data Values:
MIN= -323.89999390 AVE= 278.48535156
MAX= 514.00000000

GRIB MESSAGE 149 starts at 7050617

SECTION 0: 0 2 93572
SECTION 1: 7 0 2 1 1 2005 11 9 6 0 0 0 1
Contains 0 Local Sections and 2 data fields.

FIELD 1
SECTION 0: 0 2
SECTION 1: 7 0 2 1 1 2005 11 9 6 0 0 0 1
SECTION 3: 0 65160 0 0 0
GRID TEMPLATE 3. 0 : 6 0 0 0 0 0 0 360 181 0 0
90000000 0 48 -90000000 359000000 10
00000 1000000 0
NO Optional List Defining Number of Data Points.
PRODUCT TEMPLATE 4. 0 : 2 2 2 0 96 0 0 1 36
100 0 100000 255 0 0
TEXT: U GRD 1000 mb valid at 36 hr after
2005110906:00:00
NO Optional Vertical Coordinate List.
Num. of Data Points = 65160 NO BIT-MAP
DRS TEMPLATE 5. 3 : -1014333440 0 1 9 0 1 0 0
0 4835 0 4 1 1 32 5 1 2
Data Values:
MIN= -27.70000076 AVE= .24823742
MAX= 27.20000076

FIELD 2
SECTION 3: 0 65160 0 0 0
GRID TEMPLATE 3. 0 : 6 0 0 0 0 0 0 360 181 0 0
90000000 0 48 -90000000 359000000 10
00000 1000000 0
NO Optional List Defining Number of Data Points.
PRODUCT TEMPLATE 4. 0 : 2 3 2 0 96 0 0 1 36
100 0 100000 255 0 0
TEXT: V GRD 1000 mb valid at 36 hr after
2005110906:00:00
NO Optional Vertical Coordinate List.
Num. of Data Points = 65160 NO BIT-MAP
DRS TEMPLATE 5. 3 : -1015873536 0 1 9 0 1 0 0
0 4934 0 4 1 1 16 5 1 2
Data Values:
MIN= -24.30000114 AVE= .03596115
MAX= 30.39999962

GRIB MESSAGE 150 starts at 7144189

GRIB2 in NCEP Operations

- So far we have only offered new products in GRIB2 format. We are starting planning for transition from GRIB1 to GRIB2.
- To ease users' transition to GRIB2, we have conversion utility that can be used for existing applications that read only GRIB1.

GRIB2 Section 7 – Data Section

- Data coded with the minimum number of bits necessary to provide the accuracy.
- Simple scaling – data multiplied by an appropriate power of 10 before forming the non-negative differences, and then using the binary scaling to select the precision of the transmitted value.
- Data coded in the form of non-negative scaled differences from a reference value of the whole field plus, if applicable, a local reference value. (reference value is normally the minimum value of the data set which is represented).

GRIB2 Section 7 – Data Section contd.

- Complex packing for grid-point values – split the whole set of scaled data values into groups on which local references (local minima) are removed – pre-processing may be needed on the scaled data.
- Complex packing for spectral data.
- The original data value Y can be recovered with the formula

  $Y*10^{D}=R+(X1+X2)*2^{E}$

  where E=Binary scale factor, D=Decimal scale factor, R=Reference value of the whole field, X1=0, X2=Scaled (encoded) value.

GRIB2 – Packing Methods

- GRIB2_com – Group packing – DR Template 5.2
- GRIB2_1od – Group packing –with 1st order differencing Template 5.3
- GRIB2_2od – Group packing – with 2nd order differencing Template 5.3

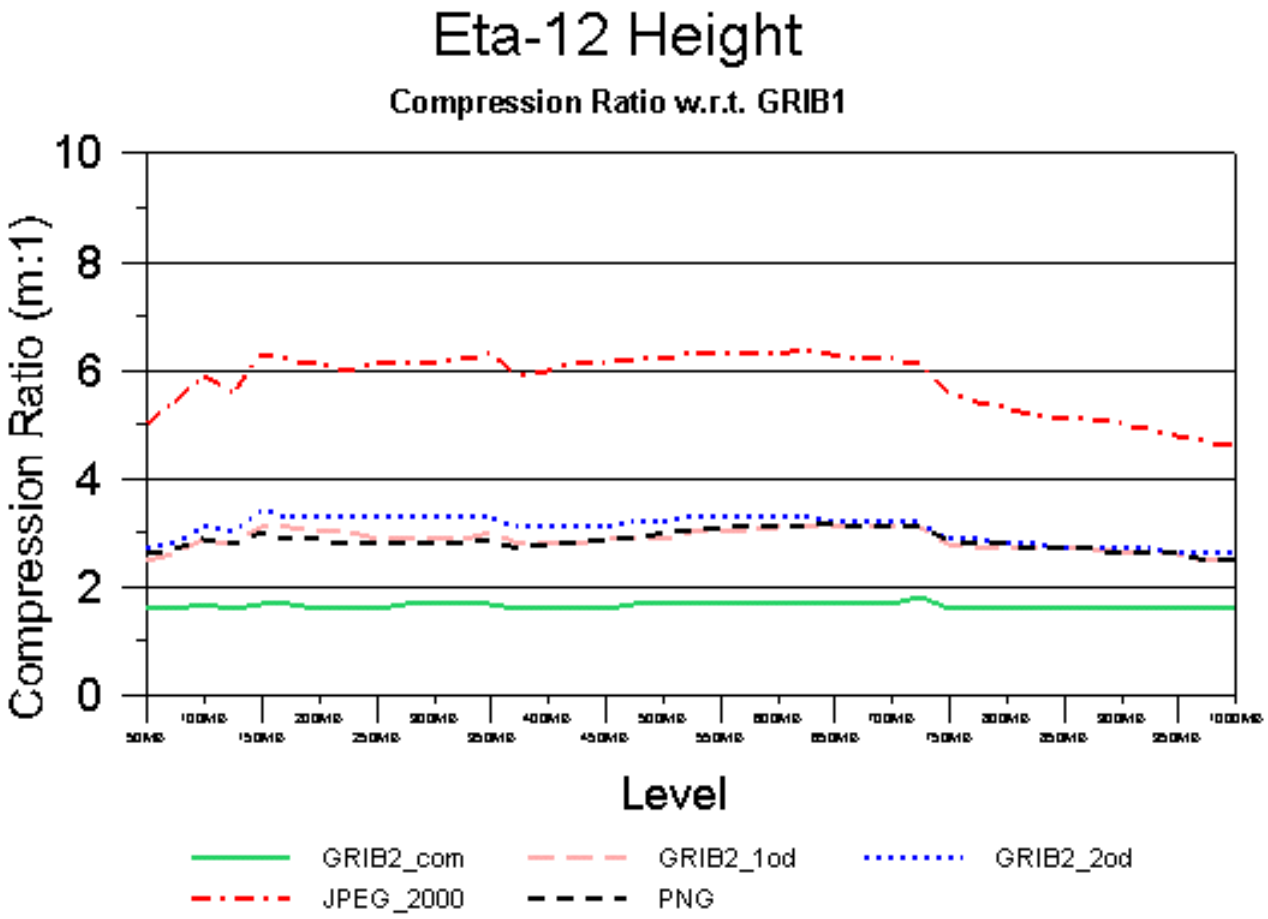
Image compression algorithms within the GRIB2 standard.

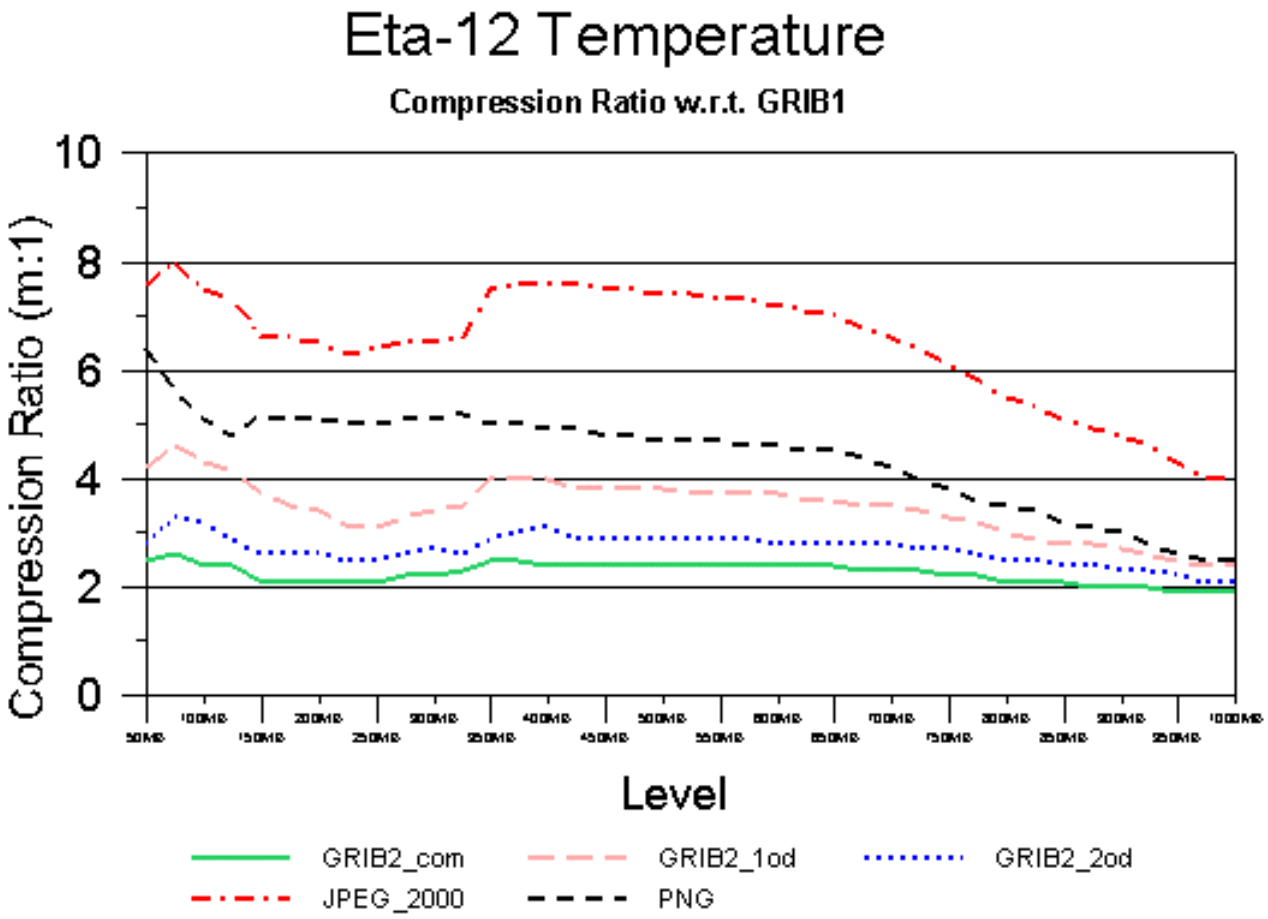
Both treat grid point data as a grey scale image (single component)

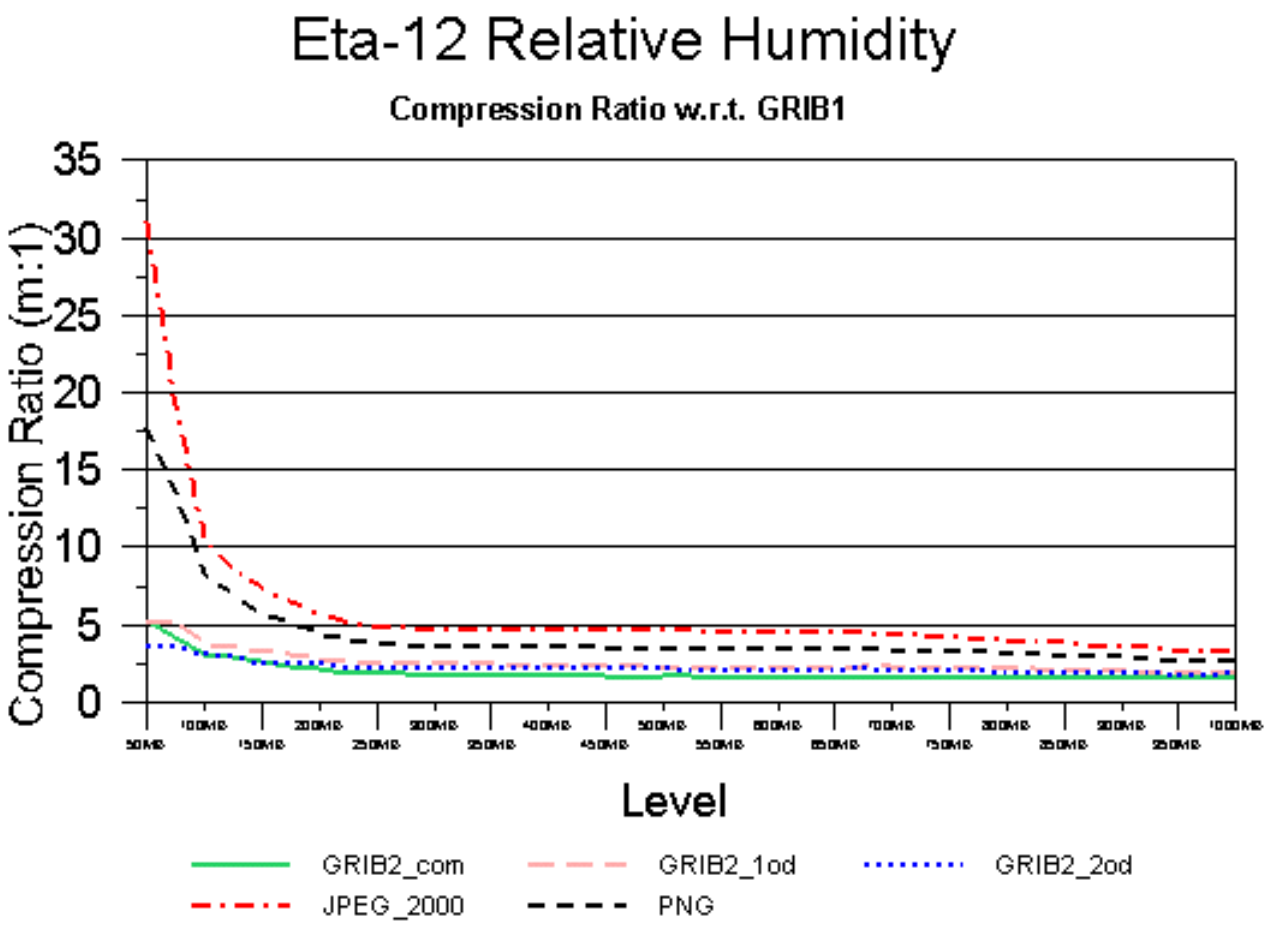
- JPEG_2000 (Part-1 standard) (ISO/IEC 15444-1)
  http://www.jpeg.org/JPEG2000.html
- PNG (Portable Network Graphics image compression format)
  http://www.libpng.org/pub/png/.

Some GRIB2 packing results

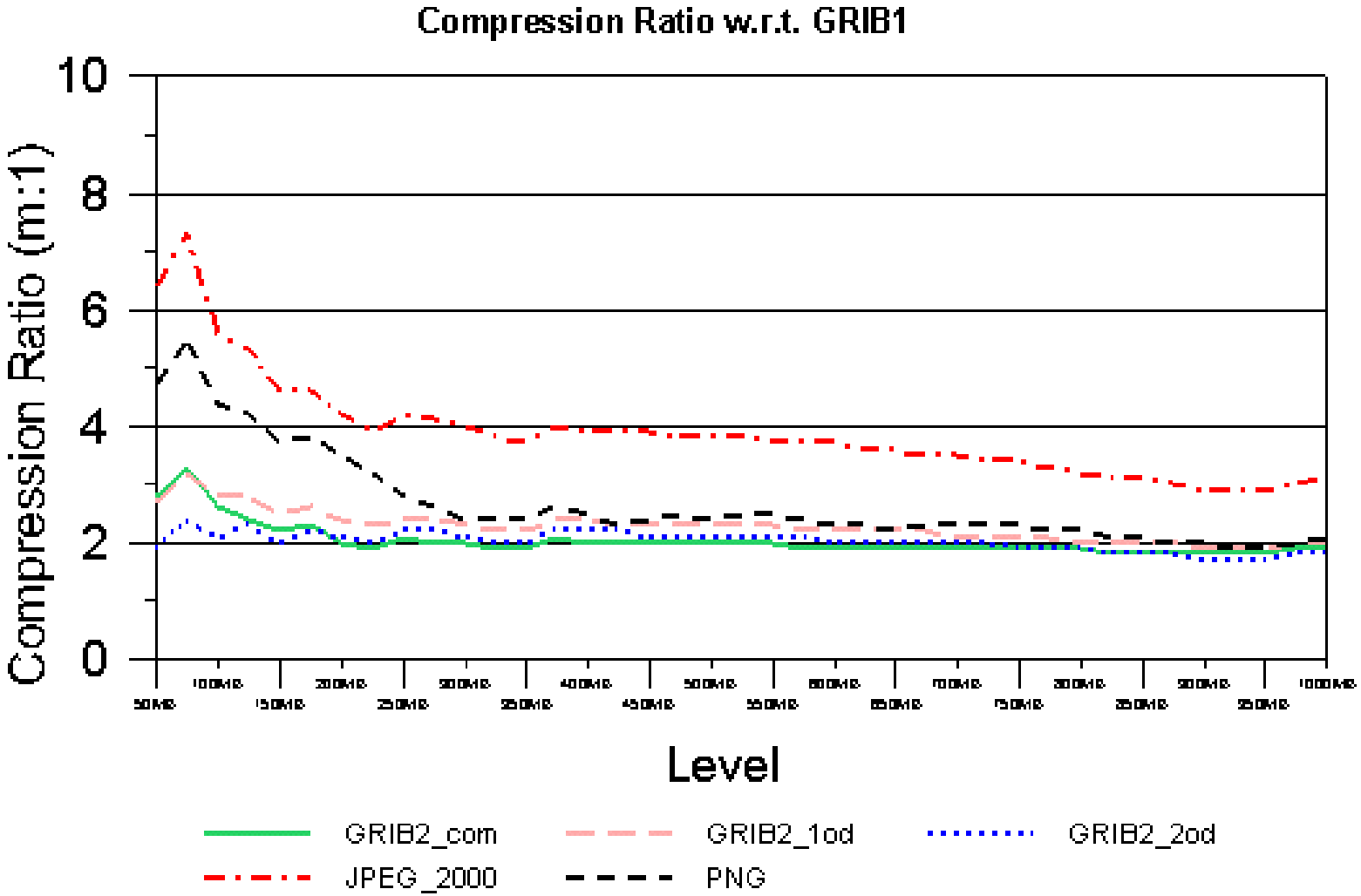
- Packing results are sensitive to the grouping algorithms one chooses. More sophisticated grouping algorithms may result in better overall compression. The following results are based on a small constant group size.
- Since then a more sophisticated grouping algorithm (from Dr. Glahn, Meteorological Developmental Lab) has been incorporated resulting in better compression.


Eta-12 Height
Compression Ratio w.r.t. GRIB1
Compression Ratio (m:1)
10
8
6
4
2
0
Level
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG

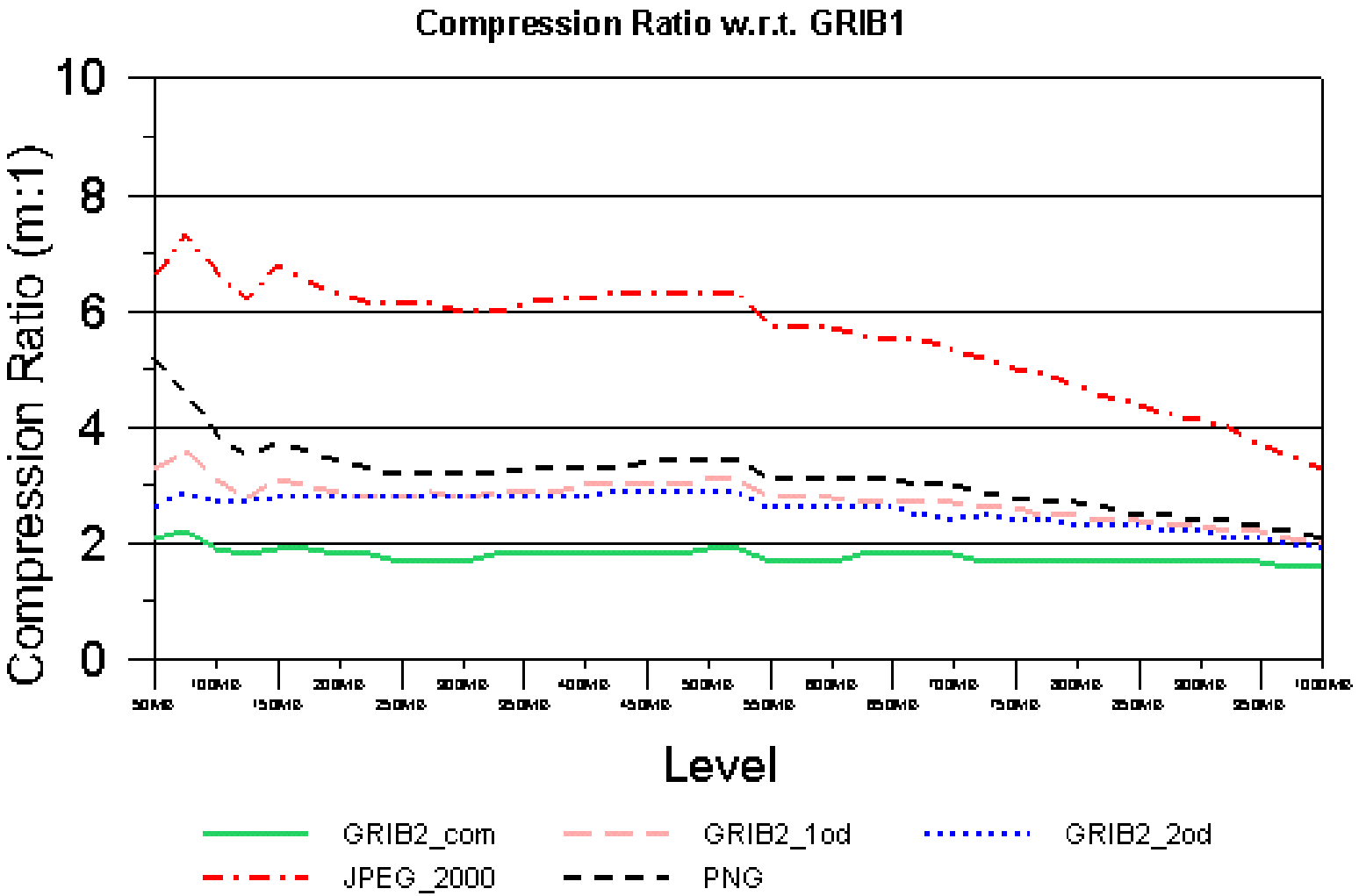

Eta-12 Temperature
Compression Ratio w.r.t. GRIB1
Compression Ratio (m:1)
10
8
6
4
2
0
Level
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG


Eta-12 Relative Humidity
Compression Ratio w.r.t. GRIB1
Compression Ratio (m:1)
35
30
25
20
15
10
5
0
Level
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG

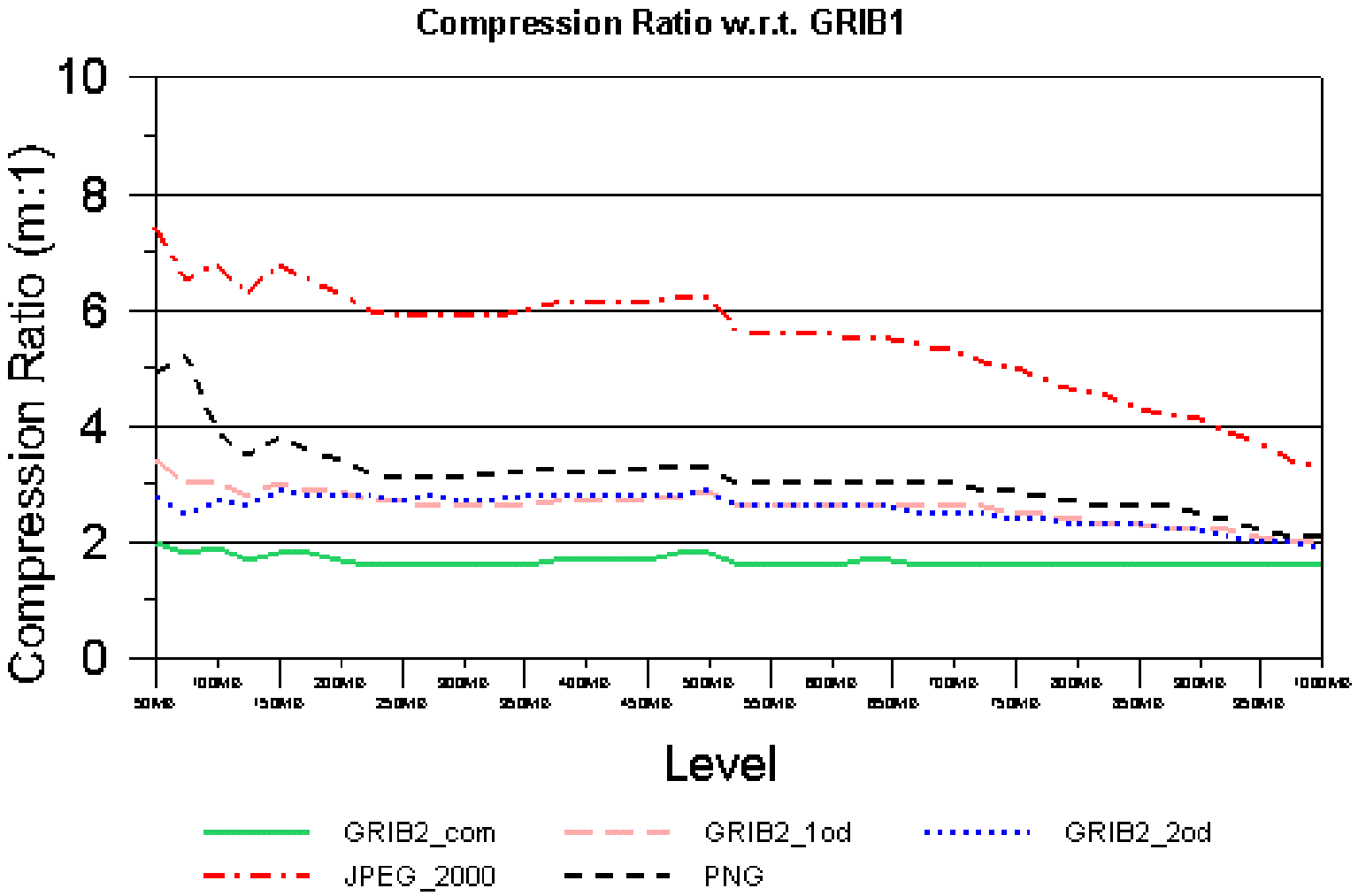
Eta-12 Vertical Velocity

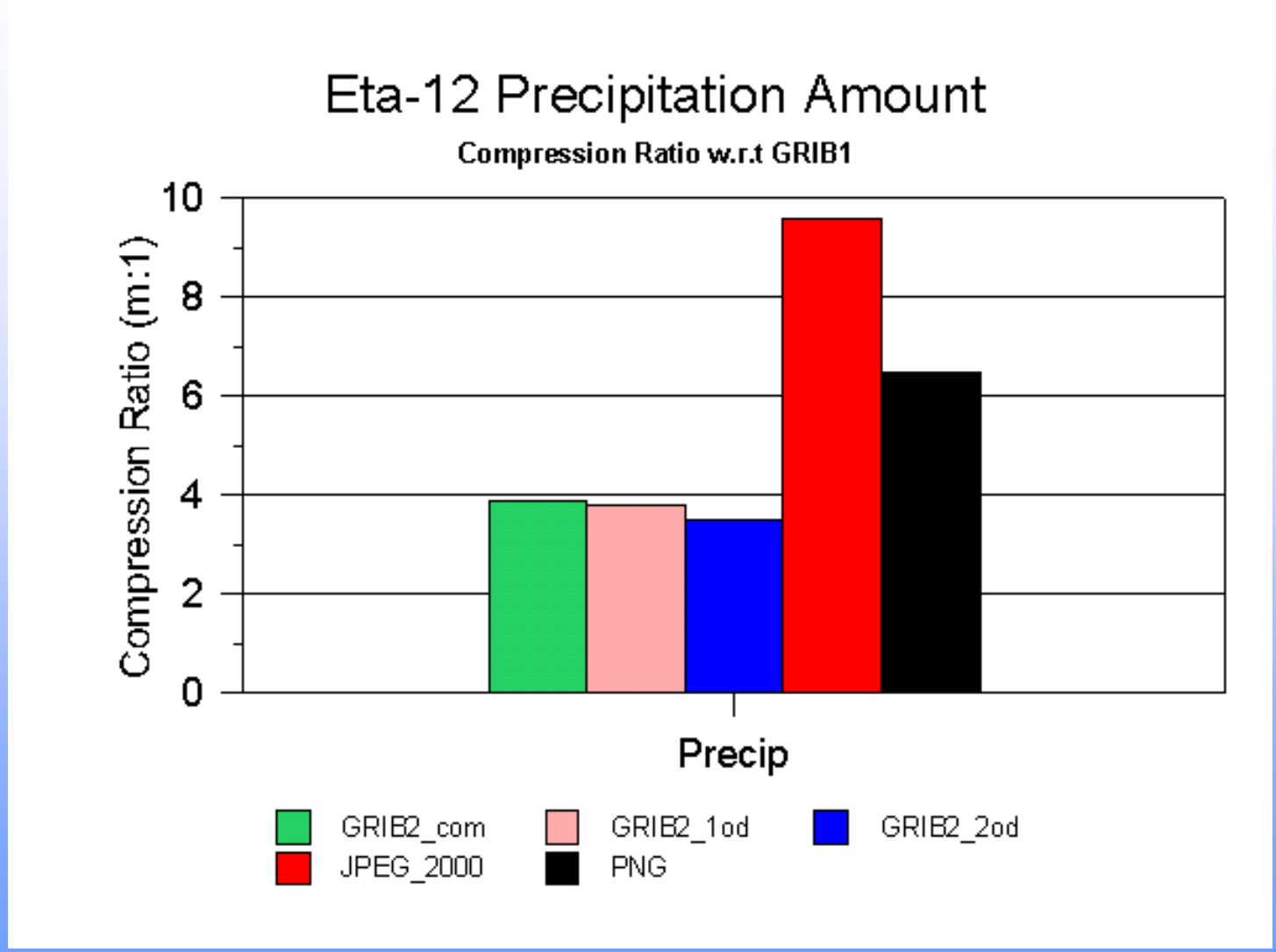


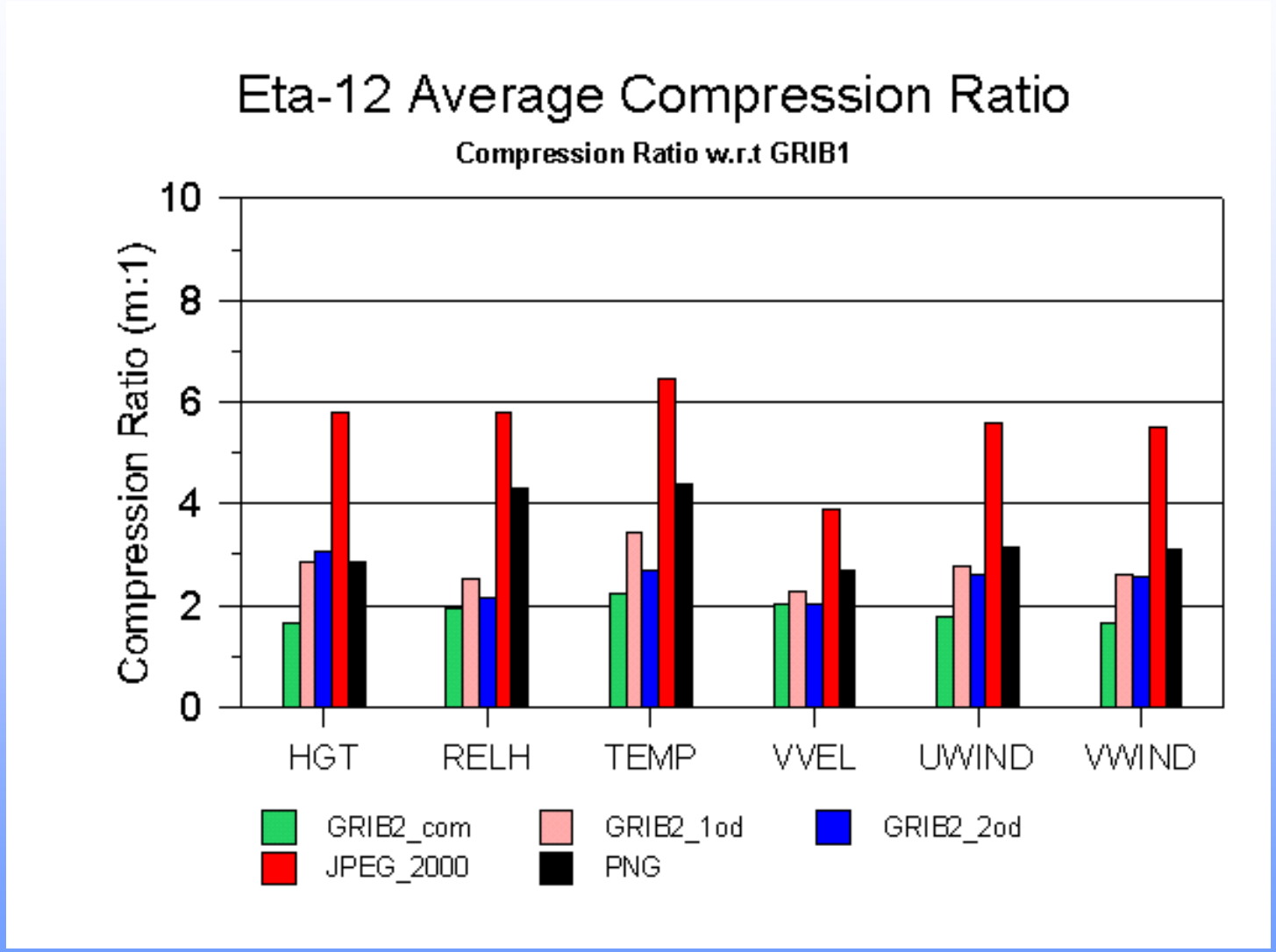
Eta-12 Wind U-Component

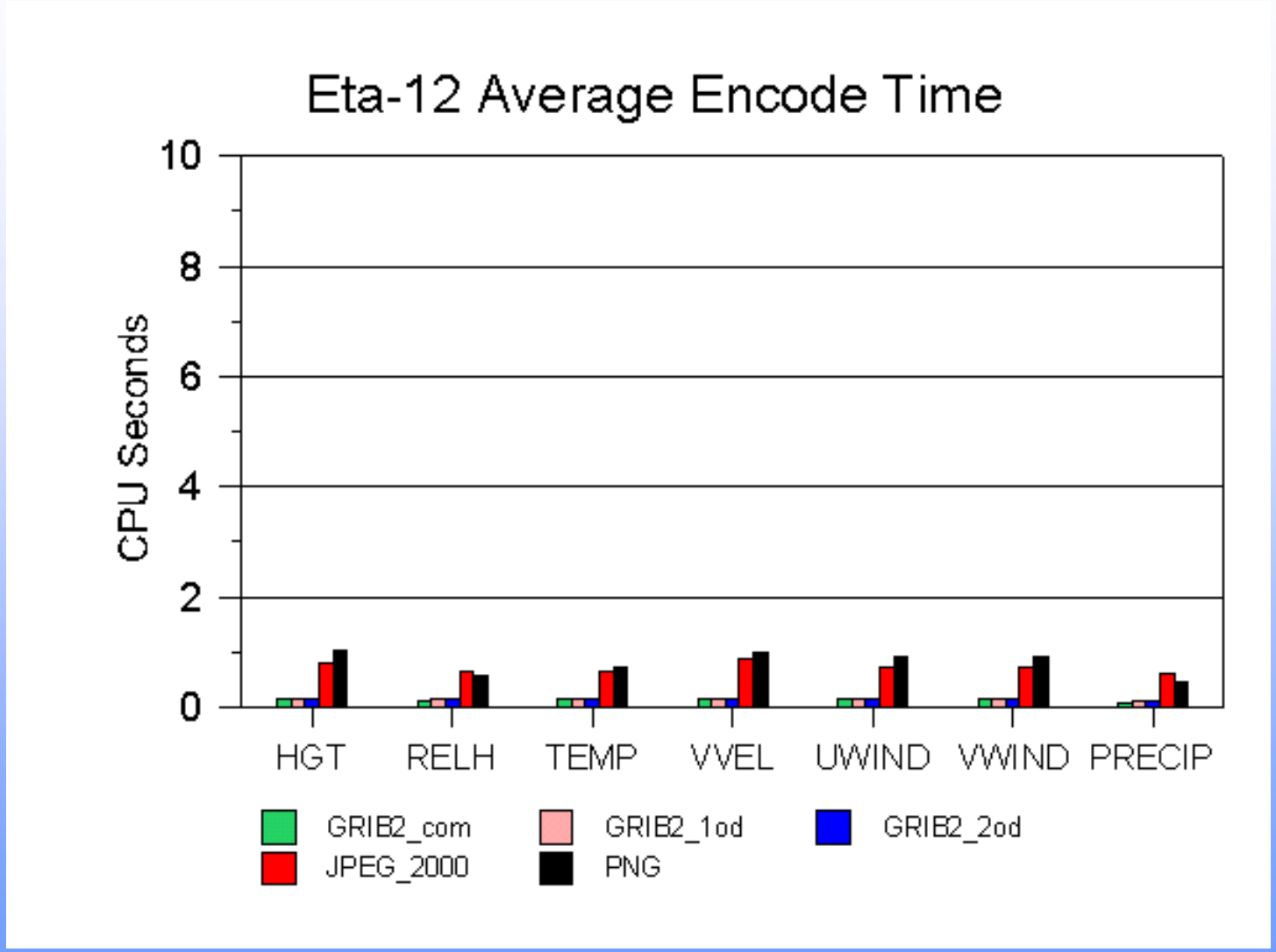


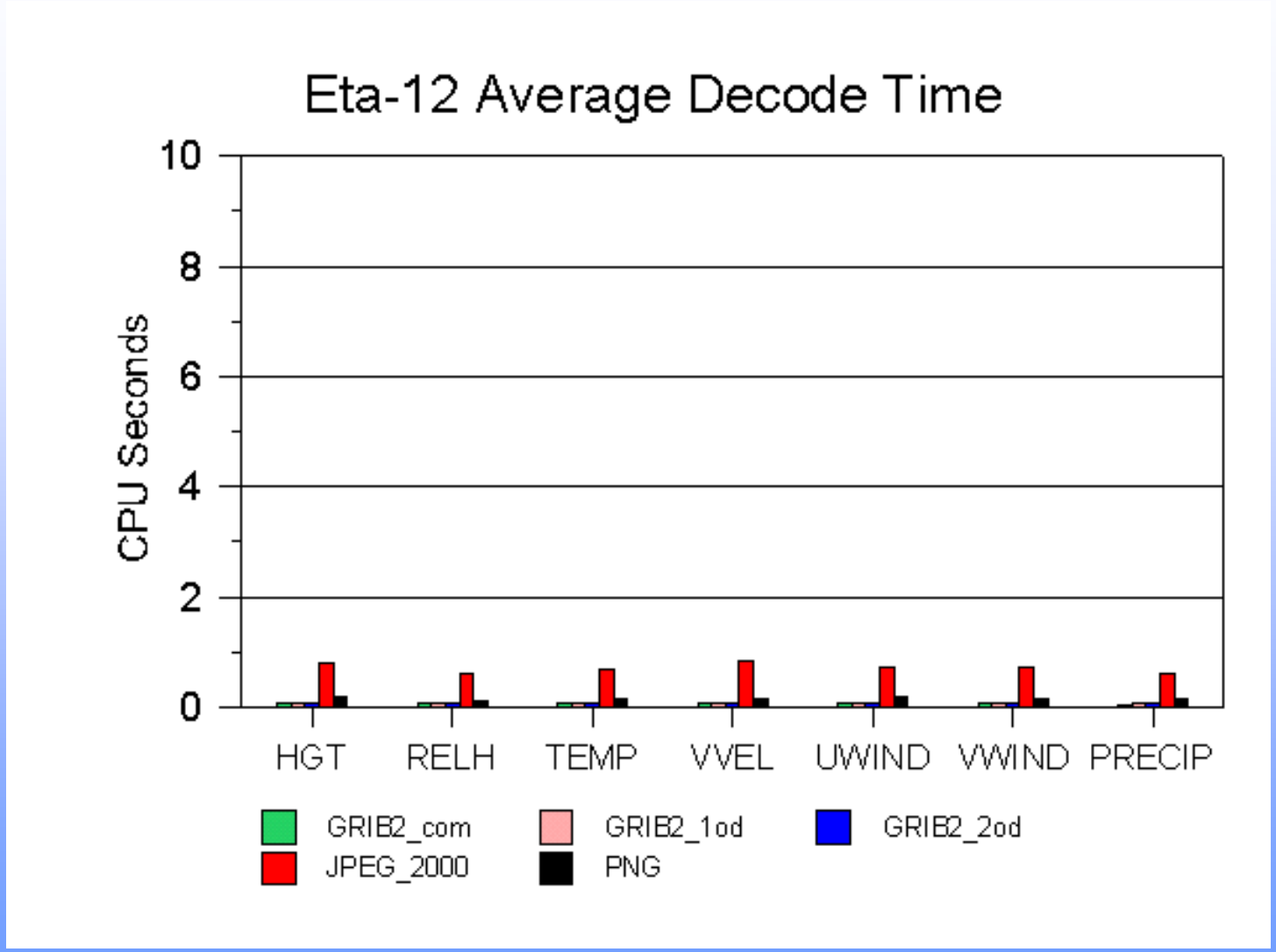
Eta-12 Wind V-Component

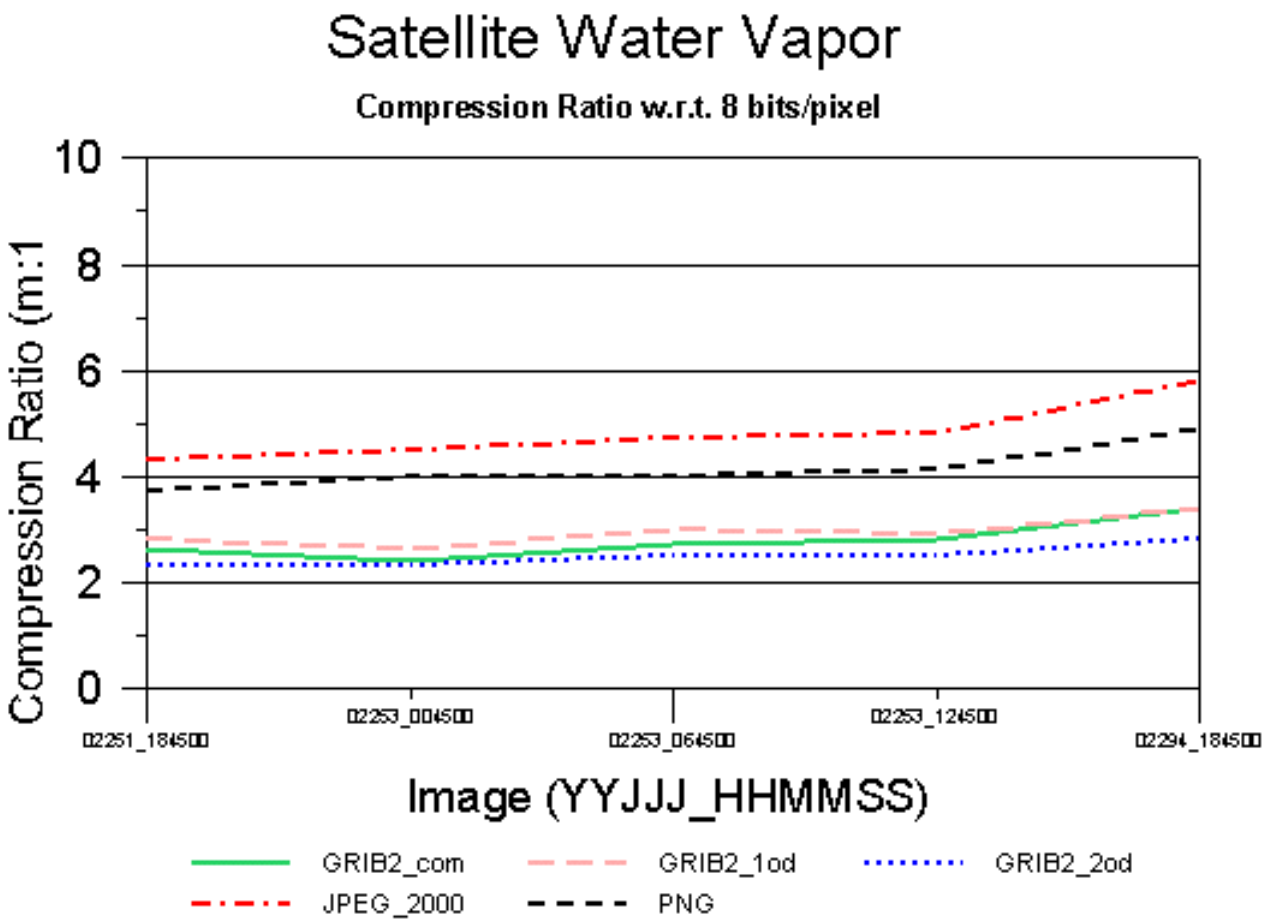


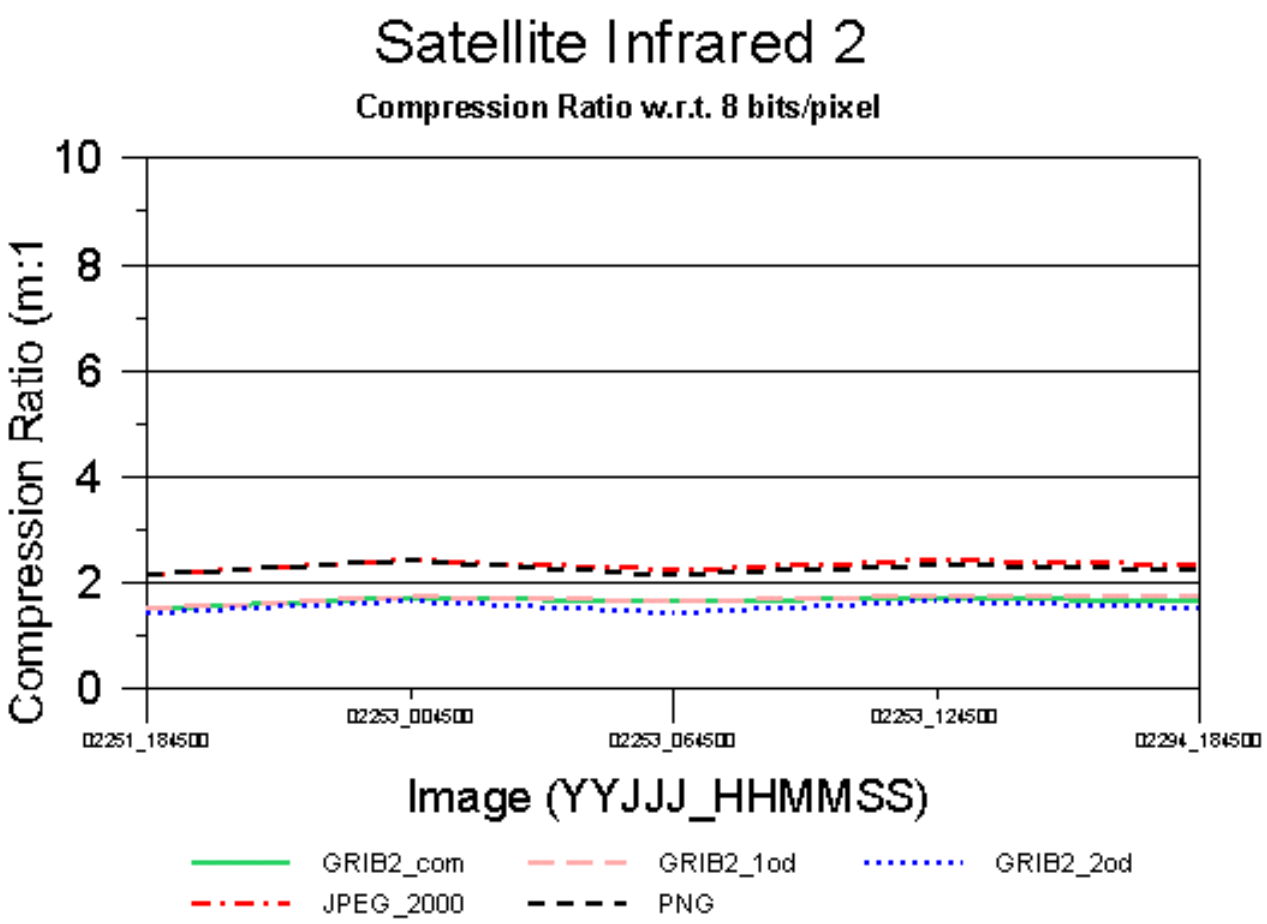

Eta-12 Precipitation Amount
Compression Ratio w.r.t GRIB1
Compression Ratio (m:1)
10
8
6
4
2
0
Precip
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG

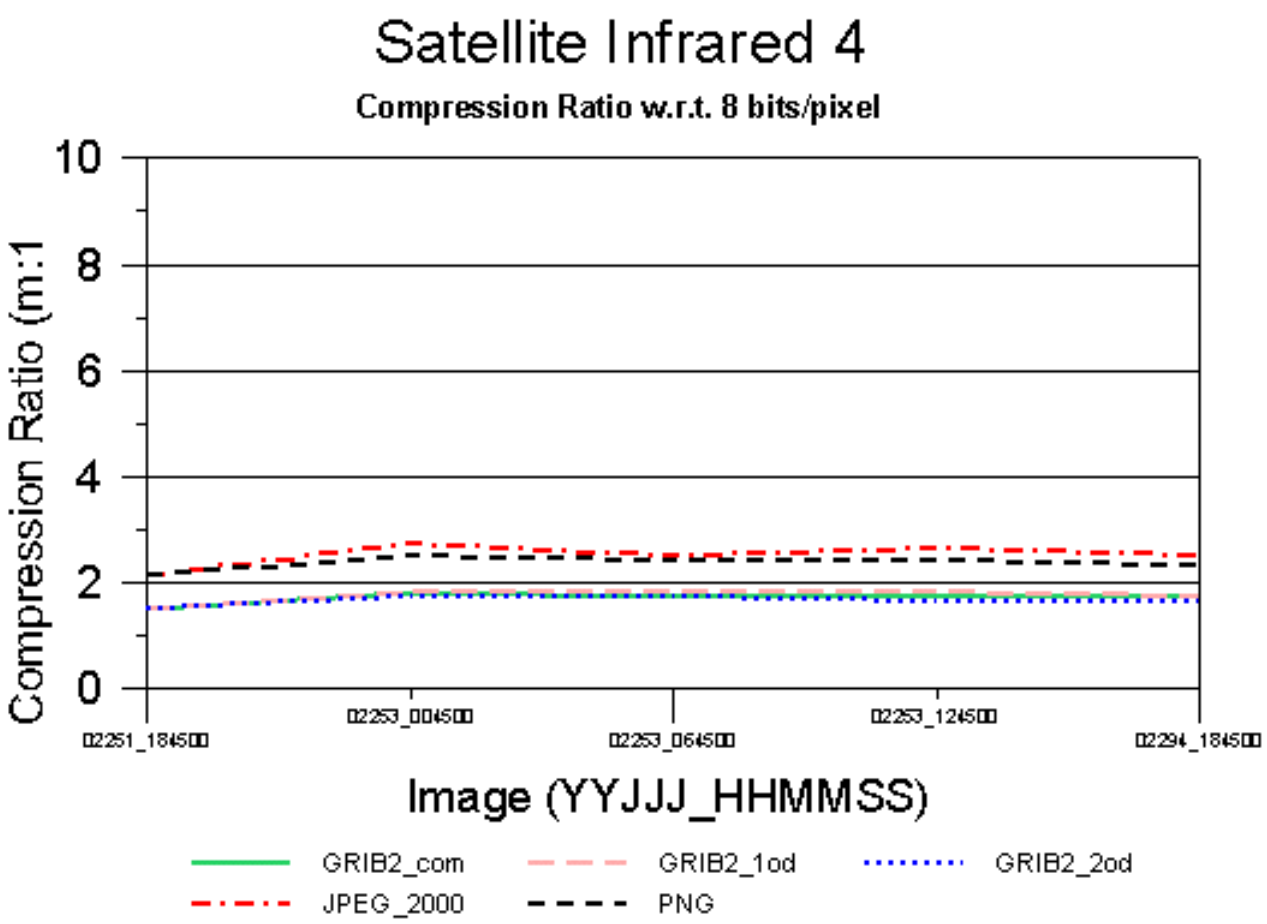

Eta-12 Average Compression Ratio
Compression Ratio w.r.t GRIB1
Compression Ratio (m:1)
10
8
6
4
2
0
HGT
RELH
TEMP
VVEL
UWIND
VWIND
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG

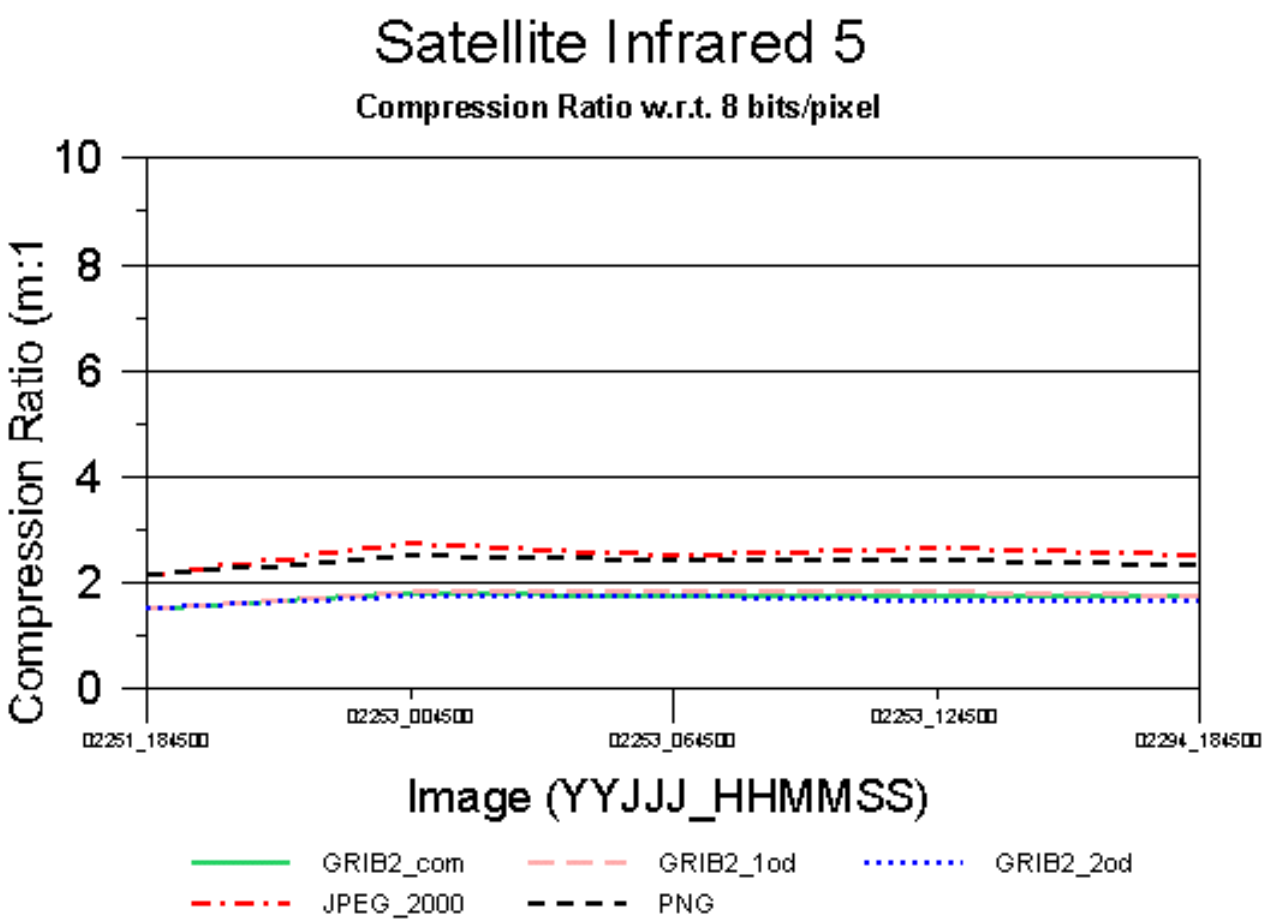

Eta-12 Average Encode Time
CPU Seconds
10
8
6
4
2
0
HGT
RELH
TEMP
VVEL
UWIND
VWIND
PRECIP
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG

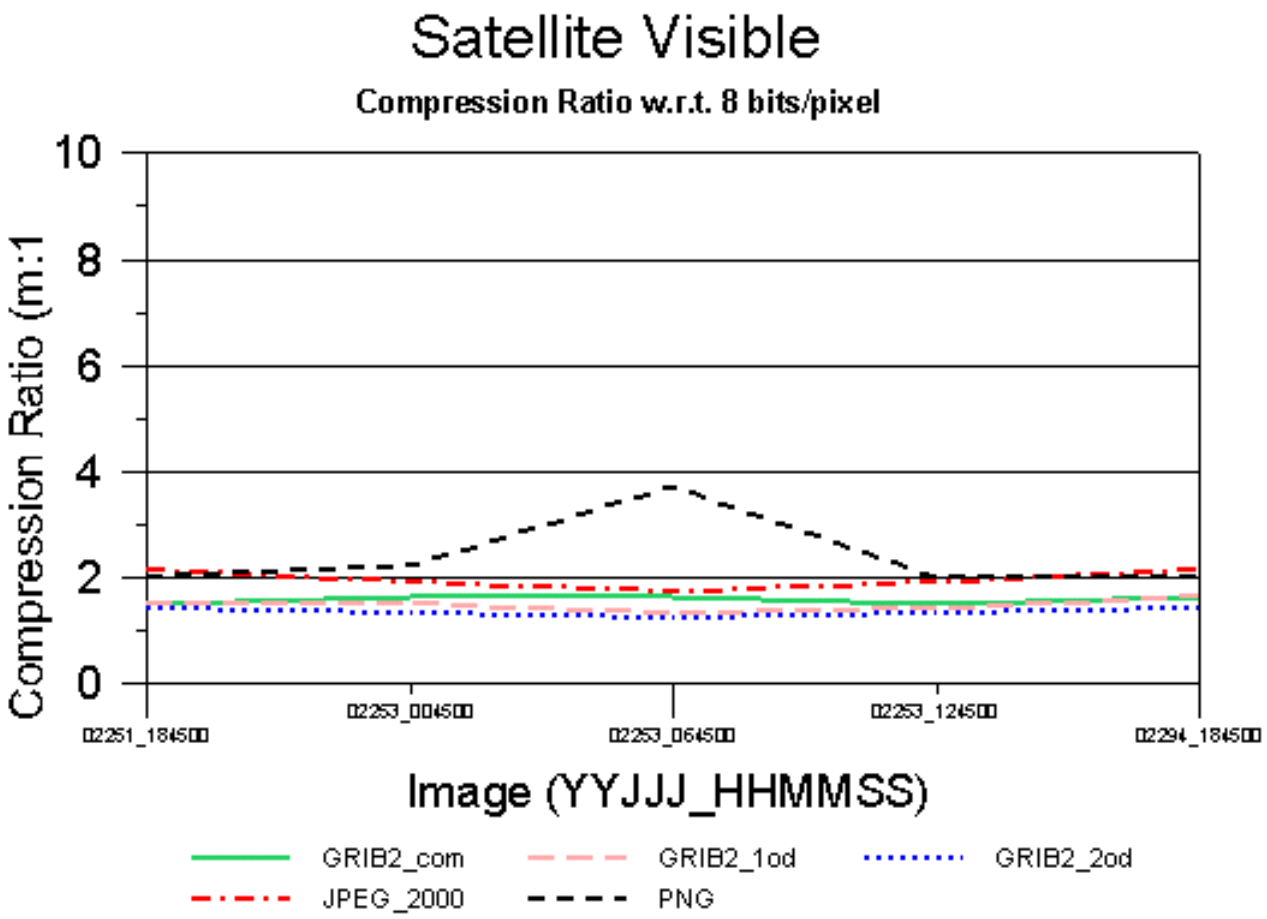

Eta-12 Average Decode Time
CPU Seconds
10
8
6
4
2
0
HGT
RELH
TEMP
VVEL
UWIND
VWIND
PRECIP
GRIB2_com
JPEG_2000
GRIB2_1od
PNG
GRIB2_2od

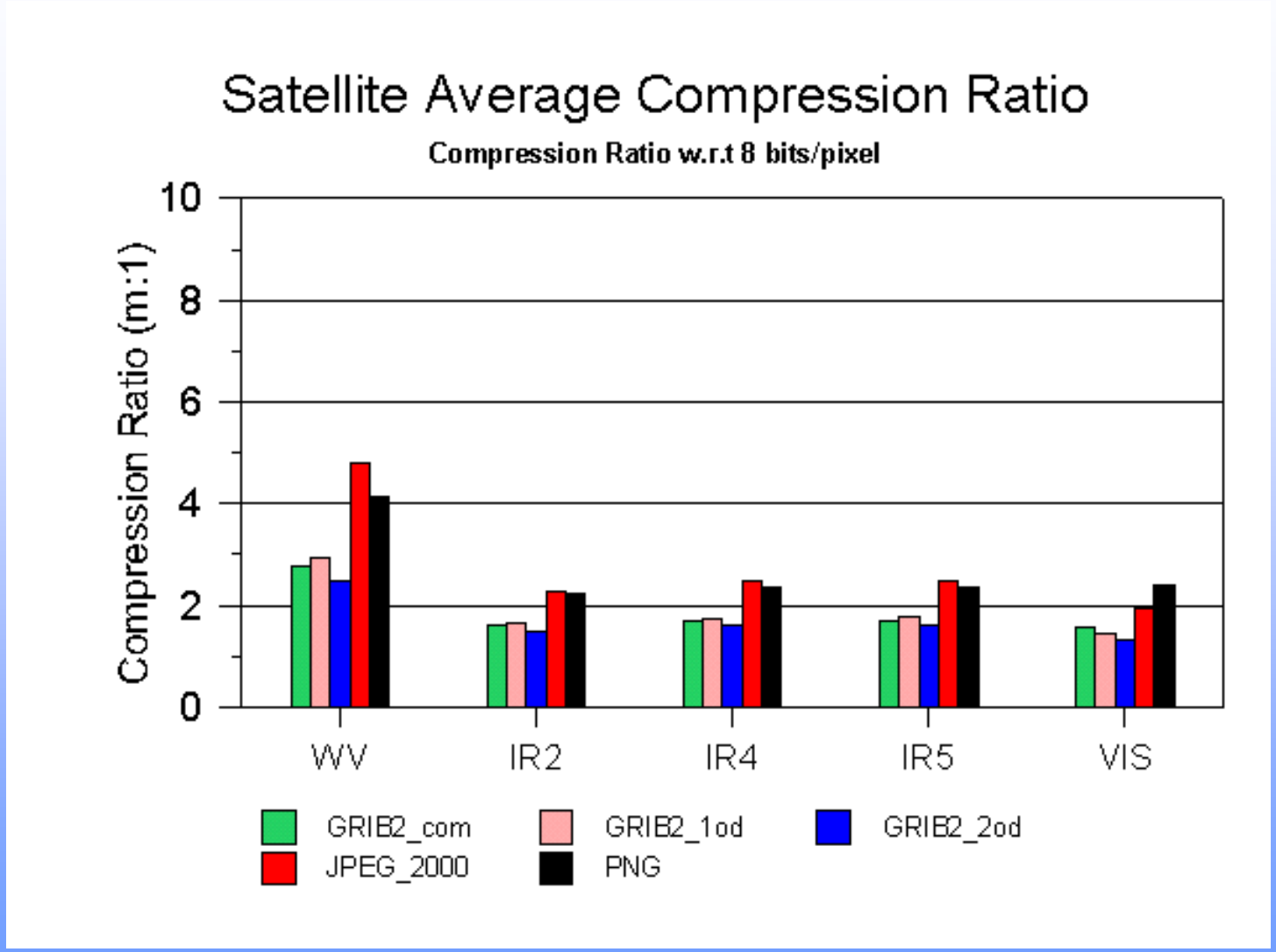

Satellite Water Vapor
Compression Ratio w.r.t. 8 bits/pixel
Compression Ratio (m:1
10
8
6
4
2
0
02251_184500
02253_004500
02253_064500
02253_124500
02294_184500
Image (YYJJJ_HHMMSS)
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG

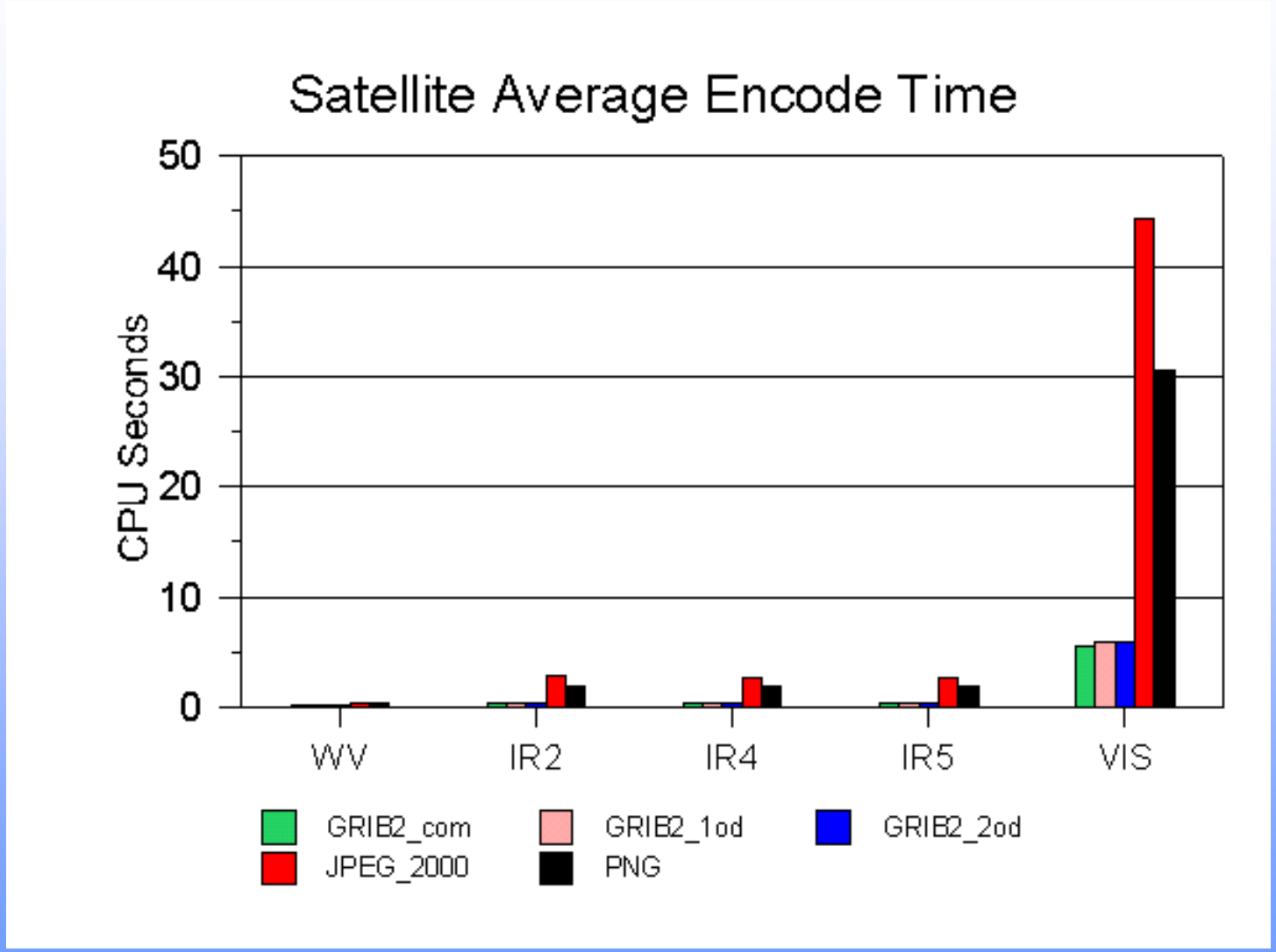

Satellite Infrared 2
Compression Ratio w.r.t. 8 bits/pixel
Compression Ratio (m:1
10
8
6
4
2
0
02251_184500
02253_004500
02253_064500
02253_124500
02294_184500
Image (YYJJJ_HHMMSS)
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG

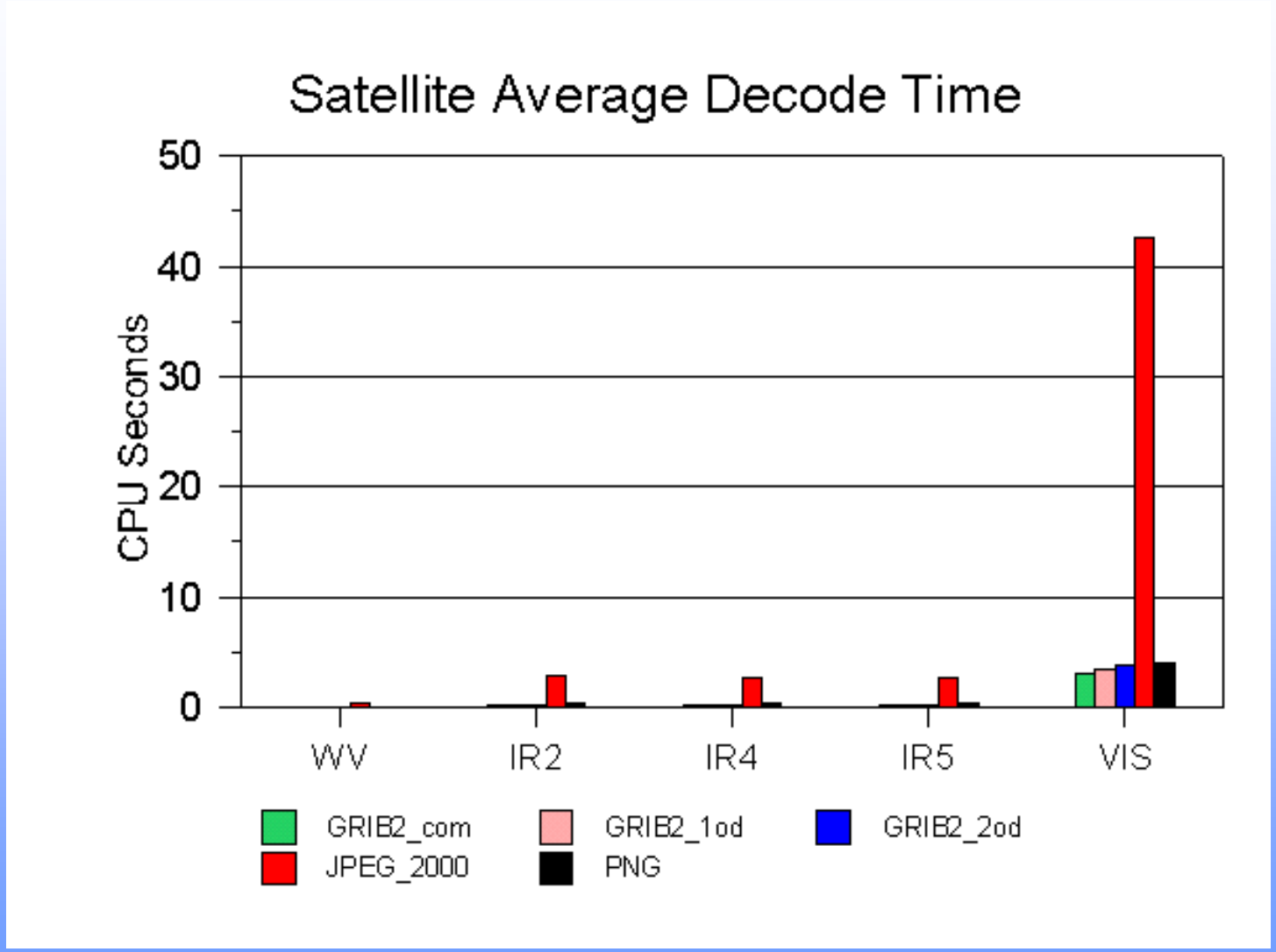

Satellite Infrared 4
Compression Ratio w.r.t. 8 bits/pixel
Compression Ratio (m:1
10
8
6
4
2
0
02251_184500
02253_004500
02253_064500
02253_124500
02294_184500
Image (YYJJJ_HHMMSS)
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG


Satellite Infrared 5
Compression Ratio w.r.t. 8 bits/pixel
Compression Ratio (m:1
10
8
6
4
2
0
02251_184500
02253_004500
02253_064500
02253_124500
02294_184500
Image (YYJJJ_HHMMSS)
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG


Satellite Visible
Compression Ratio w.r.t. 8 bits/pixel
Compression Ratio (m:1
10
8
6
4
2
0
02251_184500
02253_004500
02253_064500
02253_124500
02294_184500
Image (YYJJJ_HHMMSS)
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG


Satellite Average Compression Ratio
Compression Ratio w.r.t 8 bits/pixel
Compression Ratio (m:1)
10
8
6
4
2
0
WV
IR2
IR4
IR5
VIS
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG


Satellite Average Encode Time
CPU Seconds
50
40
30
20
10
0
WV
IR2
IR4
IR5
VIS
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG


Satellite Average Decode Time
CPU Seconds
50
40
30
20
10
0
WV
IR2
IR4
IR5
VIS
GRIB2_com
GRIB2_1od
GRIB2_2od
JPEG_2000
PNG

NCEP conversion to GRIB2

- NCEP is currently making available high resolution GFS and NAM output in GRIB2 format on its FTP servers and on NOAAPORT
- These include:
  - GFS 0.5 degree global grid (F00-F180)
  - NAM 12 km CONUS grid (F00-F84)
  - NAM 12 km AK grid (F00-F84)

NCEP conversion to GRIB2

- Transition to GRIB2 is ongoing
- All new products added to NOAAPORT & FTP servers since July 2004 have been in GRIB2 format.
- Tentatively planning to make GRIB2 data sets available for all existing GRIB1 data sets on FTP servers by April 2006.
- The GRIB1 data sets will then be phased out over the following 6-12 month period.

General questions & some answers!!!

- **Defined local extensions in GRIB2?**

  NCEP hasn't used any local extension.

- **Defined local parameter tables for GRIB2?**

  Yes. http://www.nco.ncep.noaa.gov/pmb/docs/grib2/GRIB2_parameter_conversion_table.html

- **How do you map GRIB1 parameters to GRIB2 parameters?**

  table.param to discipline.category.param

- **Use of decimal scale factor and its rational behind the choice of value?**

Not completely sure. Modelers chose these values for their grids

.

- **Use of multi-field GRIBs?**

We have U and V wind components in the same GRIB2 message. AWIPS users didn't like it and made us stop.

- **How do users cope with the multitude of templates that GRIB2 offers?**

  ☹ ☹ ☹

- **Do you offer tools that support GRIB1 and GRIB2 simultaneously? How do users handle different units (i.e., millidegrees vs. millionth of degrees for latitudes/longitudes)?**

No, so far we have separate GRIB1 and GRIB2 applications. The only one that recognizes both is the cnvgrib converter.

Milli vs Millionth again ☹

General questions & some answers!!! Contd.

- Do you plan to convert your archive?

Tentatively planning to make GRIB2 data sets available for all existing GRIB1 data sets on FTP servers by April 2006.

- When centers start producing GRIB2, what will happen with those applications/users that have not migrated to GRIB2? Do you envisage a tool to convert GRIB2 to GRIB1 so they can still work?

We have made a utility available so users can convert GRIB2 to GRIB1 for their existing applications. The GRIB1 data sets will then be phased out over the following 6-12 month period.

- Conversely, how will new applications work with archived GRIB1?

Same

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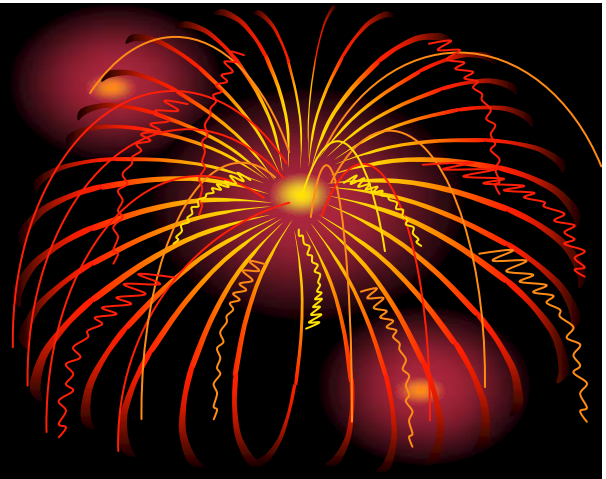
- Do you have a planned date for switching to produce GRIB2?

  How much notice have you given your users?

All new products added to NOAAPORT & FTP servers since July 2004 have been in GRIB2 format. Tentatively planning to make GRIB2 data sets available for all existing GRIB1 data sets on FTP servers by April 2006. The GRIB1 data sets will then be phased out over the following 6-12 month period.



THANK YOU