(7 May 2014)

TEMPLATE DEFINITIONS USED IN SECTION 1

Identification template 1.0 – calendar definition

Octet No.	Contents	Status
NONE		

Identification template 1.1 – Paleontological offset

Octet No.	Contents	Status
NONE		

Identification template 1.2 – Calendar definition and paleontological offset

Octet No.	Contents	Status
NONE		

TEMPLATE DEFINITIONS USED IN SECTION 3

Grid definition template 3.0 – latitude/longitude (or equidistant cylindrical, or Plate Carrée)

Notes:

(6) In most cases, multiplying Ni (octets 31-34) by Nj (octets 35-38) yields the total number of points in the grid. However, this may not be true, if bit 8 of the scanning mode flags (octet 72) is set to 1. Formality

Grid definition template 3.11 – rotated Mercator projection

Octet No.	Contents	Status
15	Shape of the Earth (see Code table 3.2)	Validation
16	Scale factor of radius of spherical Earth	Validation
17-20	Scaled value of radius of spherical Earth	Validation
21	Scale factor of major axis of oblate spheroid Earth	Validation
22-25	Scaled value of major axis of oblate spheroid Earth	Validation
26	Scale factor of minor axis of oblate spheroid Earth	Validation
27-30	Scaled value of minor axis of oblate spheroid Earth	Validation
31-34	Ni - number of points along a parallel	Validation
35-38	Nj - number of points along a meridian	Validation
39-42	La1 - latitude of first grid point	Validation
43-46	Lo1 - longitude of first grid point	Validation
47	Resolution and component flags (see Flag table 3.3)	Validation
48-51	LaD -latitude(s) at which the Mercator projection intersects the Earth (latitude(s) where Di and Dj are specified)	Validation
52-55	La2 - latitude of last grid point	Validation
56-59	Lo2 - longitude of last grid point	Validation
60	Scanning mode (flags - see Flag table 3.4)	Validation
61-64	Orientation of the grid, angle between i direction on the map and the equator (see Note 1)	Validation
65-68	Di - longitudinal direction grid length (see Note 2)	Validation
69-72	Dj - latitudinal direction grid length (see Note 2)	Validation
73-76	La0 - geographical latitude of the point to be brought to the origin of the projection, in the case of a rotation of the sphere prior to the projection	Validation
77-80	Lo0 - geographical longitude of the point to be brought to the origin of the projection, in the case of a rotation of the sphere prior to the projection	Validation
81-84	beta - tilting angle of the sphere around the origin point of the rotated sphere	Validation
85-nn	List of number of points along each meridian or parallel (These octets are only present for quasi-regular grids as described in Notes 2 and 3 of GDT 3.1)	Validation

Notes:

(1) Limited to the range of 0 to 90 degrees; if the angle of orientation of the grid is neither 0 nor 90 degrees, Di and Dj must be equal to each other.

(2) Grid lengths are in units of 10–3 m, at the latitude specified by LaD.

(3) A scaled value of radius of spherical Earth, or major or minor axis of oblate spheroid Earth is derived from applying appropriate scale factor to the value expressed in metres.

(4) Transformation formulas from geographical (lat,lon) = (θ,λ) to projected grid point coordinates (x,y) :

$$\sin(\theta') = \cos(\theta_0)\sin(\theta) - \sin(\theta_0)\cos(\theta)\cos(\lambda - \lambda_0)$$
$$\cos(\theta') = \sqrt{1 - \sin^2(\theta')}$$
$$C' = \cos(\theta')\cos(\lambda') = \sin(\theta_0)\sin(\theta) + \cos(\theta_0)\cos(\theta)\cos(\lambda - \lambda_0)$$
$$S' = \cos(\theta')\sin(\lambda') = \cos(\theta)\sin(\lambda - \lambda_0)$$
$$\theta'' = \arcsin[\cos(\beta)\sin(\theta') + \sin(\beta)S']$$
$$\cos(\lambda'') = \frac{C'}{\cos(\theta'')}$$
$$\sin(\lambda'') = -\frac{1}{\cos(\theta'')}[\sin(\beta)\sin(\theta') - \cos(\beta)S']$$
$$x = a\lambda''$$
$$y = -a.\ln[tg(\frac{\pi}{4} - \frac{\theta''}{2})]$$

Reverse transformation formulas from grid point (x,y) to (lat,lon):

$$\lambda'' = \frac{x}{a}$$
$$\theta'' = \frac{\pi}{2} - 2.arctg[\exp(-\frac{y}{a})]$$
$$\sin(\theta'') = \frac{1 - \exp(-2y/a)}{1 + \exp(-2y/a)}$$
$$\sin(\theta') = \cos(\theta_0)\sin(\theta) - \sin(\theta_0)\cos(\theta)\cos(\lambda - \lambda_0)$$
$$\cos(\theta') = \sqrt{1 - \sin^2(\theta')}$$
$$C' = \cos(\theta'')\cos(\lambda'')$$
$$S' = \sin(\beta)\sin(\theta'') + \cos(\beta)\cos(\theta'')\sin(\lambda'')$$
$$\theta = \arcsin[\cos(\theta_0)\sin(\theta') + \sin(\theta_0)C']$$
$$\cos(\lambda - \lambda_0) = \frac{1}{\cos(\theta)}[-\sin(\theta_0)\sin(\theta') + \cos(\theta_0)C']$$
$$\sin(\lambda - \lambda_0) = \frac{S'}{\cos(\theta)}$$

Where:

a. La0 is θ_0
b. Lo0 is λ_0
c. Beta is β
d. x and y are metric coordinates in the i and j direction, in standard units (m). (x,y)=(0,0) corresponds to the coordinate of the reference point (La0,Lo0), provided this point is kept as the center of the grid point domain.
e. the other variables are intermediate ones. More explanation can be found in the Technical Note by P. Bénard (2011), "*rotated/tilted Mercator geometry in Aladin*".

Grid definition template 3.1010 – 4–D trajectory grid definition

Octet No.	Contents	Status
15	Shape of the Earth (see Code table 3.2)	Validation
16	Scale factor of radius of spherical Earth	Validation
17-20	Scaled value of radius of spherical Earth	Validation
21	Scale factor of major axis of oblate spheroid Earth	Validation
22-25	Scaled value of major axis of oblate spheroid Earth	Validation
26	Scale factor of minor axis of oblate spheroid Earth	Validation
27-30	Scaled value of minor axis of oblate spheroid Earth	Validation
31-32	Number of horizontal points in slice (see Note 1)	Validation
33-34	Number of vertical points in slice (see Note 1)	Validation
35-38	Di - slice horizontal grid length (see Note 2)	Validation
39-42	Dj - slice vertical grid length (see Note 2)	Validation
43-46	Pi - horizontal location of trajectory point within slice (see Note 3)	Validation
47-50	Pj - vertical location of trajectory point within slice (see Note 3)	Validation
51	Scanning mode (flags - see Flag table 3.4) (see Note 1)	Validation
52-53	NW - Number of way points (see Note 4)	Validation

	54-(53+NW×24) Waypoint descriptions to define 4-D coordinates	Validation
	Waypoint descriptions:	Validation
30+(N×24+0-N×24+3)	LaN - latitude of Nth trajectory way point	Validation
30+(N×24+4-N×24+7)	LoN - longitude of Nth trajectory way point	Validation
30+(N×24+8)	Type of Nth's trajectory way point surface (see Code table 4.5 and Note 5)	Validation
30+(N×24+9)	Scale factor of Nth's trajectory way point surface	Validation
30+(N×24+10-N×24+13)	Scaled value of Nth's trajectory way point surface	Validation
30+(N×24+14)	Indicator of unit of time range (see Code table 4.4)	Validation
30+(N×24+15-N×24+18)	Waypoint time in units defined by octet N×24+14 (see Note 6)	Validation
30+(N×24+19-N×24+22)	Number of slices per trajectory segment (see Note 7)	Validation
30+(N×24+23)	Number of additional leading and trailing slices(see Note 8)	Validation

Notes:

(1) Horizontal and vertical points in slice indicate orthogonal grid slice perpendicular to point along the trajectory segment. Therefore scanning mode describes scanning within single slice.

(2) Grid lengths are in units of 10^{-3} m. Trajectory is always positioned in the centre of the slice.

(3) Location of trajectory point within slice is in units of 10^{-3} m relative from first grid point of this slice.

(4) Type of line for way segments is assumed to be Great Circle.

(5) Each of waypoints can be in different types of surface coordinates. For the purpose of light transition level, point of transition can be repeated in both meters above surface and isobaric level equivalent to height reduction based on QNH valid for FIR at that moment. Waypoint can be also repeated for stopover on the trajectory with same 3-D coordinates but different waypoint time. First point of transition level or stopover description can have MISSING slices in this case.

(6) Waypoint time is relative to reference time of data defined in Section 1.

(7) Slices are defined as perpendicular planes which are equidistantly spaced along the trajectory segment. First slice is always located in first point of trajectory segment and last slice in last point of trajectory segment. Therefore minimum number of slices is 2, unless set to MISSING (for last point of trajectory or for transition level repeated point).

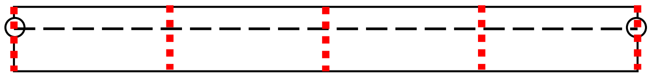

Figure 3: Example of trajectory segment with 5 slices (circles represent trajectory waypoints)

(8) Number of leading slices is same as number of trailing slices, and represents additional slices outside the trajectory segment but within its direction using same equidistant spacing as for corresponding trajectory segment itself.

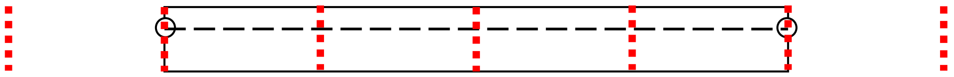

Figure 4: Example of trajectory segment with 5 slices and 1 leading and trailing slice (circles represent trajectory waypoints)

(9) A scaled value of radius of spherical Earth, or major or minor axis of oblate spheriod Earth, is derived by applying the appropriate scale factor to the value expressed in metres.

TEMPLATE DEFINITIONS USED IN SECTION 4

Product definition template 4.44 – analysis or forecast at a horizontal level or in a horizontal layer at a point in time for aerosol

Notes:

(1) Hours greater than 65534 will be coded as 65534.

(2) It is recommended not to use this template. PDT 4.48 should be used instead with optical wave length range set to missing. Formality

Product definition template 4.50 – analysis or forecast of a multi component parameter or matrix element at a point in time

Octet No.	Contents	Status
10	Parameter category (see Code table 4.1)	Validation
11	Parameter number (see Code table 4.2)	Validation
12	Type of generating process (see Code table 4.3)	Validation
13	Background generating process identifier (defined by originating centre)	Validation
14	Analysis or forecast generating process identifier (defined by originating centre)	Validation
15-16	Hours of observational data cut-off after reference time (see Note 1)	Validation
17	Minutes of observational data cut-off after reference time	Validation
18	Indicator of unit of time range (see Code table 4.4)	Validation
19-22	Forecast time in units defined by octet 18	Validation
23	Type of first fixed surface (see Code table 4.5)	Validation
24	Scale factor of first fixed surface	Validation
25-28	Scaled value of first fixed surface	Validation
29	Type of second fixed surface (see Code table 4.5)	Validation
30	Scale factor of second fixed surface	Validation
31-34	Scaled value of second fixed surface	Validation
35	First dimension physical significance (Code table 5.3) (see Note 2)	Validation
36	Second dimension physical significance (Code table 5.3) (see Note 2)	Validation
37-40	First dimension coordinate value (IEEE 32-bit floating-point value)	Validation
41-44	Second dimension coordinate value (IEEE 32-bit floating-point value)	Validation
45-48	First dimension (rows) of the complete matrix (see Note 3)	Validation
49-52	Second dimension (columns) of the complete matrix (see Note 3)	Validation

Notes:

(1) Hours greater than 65534 will be coded as 65534.

(2) In case of ocean wave spectra e.g., according to Code Table 5.3, the physical significance values are 1 (Direction Degrees true) and 2 (Frequency (s–1).

(3) The dimensions define the number of GRIBs needed for reconstruction of a complete matrix (e.g. wave spectrum) at one or more grid points. In case of vectors (1-dim-matrices), the second dimension must be set to 1 and the second dimension physical significance must be set to 255 (missing).

In case of multi component parameter (e.g. no matrix or vector element), first and second dimension are set to 1.

Product definition template 4.55 – spatio-temporal changing tiles at a horizontal level or horizontal layer at a point in time

Octet No.	Contents	Status
10	Parameter category (see Code table 4.1)	Validation
11	Parameter number (see Code table 4.2)	Validation

12	Tile classification (see Code table 4.242)	Validation
13	Number of used tiles (NUT) (see Notes 2 and 3)	Validation
14	Identification number of tile (ITN = {1,…, NUT}) (see Note 2)	Validation
15	Number of used tile attributes (NAT) for tile ITN (see Note 2)	Validation
16	Identification number of tile attribute (IAN = {1,…, NAT(ITN)}) (see Note 2)	Validation
17	Attribute of tile (see Code table 4.241)	Validation
18	Type of generating process (see Code table 4.3)	Validation
19	Background generating process identifier (defined by originating centre)	Validation
20	Analysis or forecast generating process identifier (defined by originating centre)	Validation
21-22	Hours of observational data cut-off after reference time (see Note)	Validation
23	Minutes of observational data cut-off after reference time	Validation
24	Indicator of unit of time range (see Code table 4.4)	Validation
25-28	Forecast time in units defined by octet 24	Validation
29	Type of first fixed surface (see Code table 4.5)	Validation
30	Scale factor of first fixed surface	Validation
31-34	Scaled value of first fixed surface	Validation
35	Type of second fixed surface (see Code table 4.5)	Validation
36	Scale factor of second fixed surface	Validation
37-40	Scaled value of second fixed surface	Validation

Notes:

(1) Hours greater than 65534 will be coded as 65534.

(2) The number of used Tiles (NUT) is the number of used different tiles, defining the cover structure of a point. As each of these tiles do have one or more different tile attributes NAT(ITN) (ITN=1,…,NUT), e.g. unmodified, snow-covered,…), there are $\sum_{ITN=1}^{NUT} NAT(ITN)$ fields with identification numbers (ITN, IAN) with the following meaning:

1,1	First tile – first attribute (e.g. unmodified)
….	….
1,NAT(1)	First tile – NAT of first tile (last, e.g. snow-covered) attribute
2,1	Second tile – first attribute (e.g. unmodified)
….	….
2,NAT(2)	Second tile – NAT of second tile (last, e.g. snow-covered) attribute
.	.
.	.
NUT,1	NUT tile – first attribute (e.g. unmodified)
….	...
NUT,NAT(NUT)	NUT tile – NAT of last tile (last) attribute

A single tile index (ITN, IAN) with code value ITN (1,…,NUT) and attribute identification IAN (1,…,NAT(ITN)) is represented in the template. All partitions are linked by the normalisation formula stating that the sum of all partitions must be equal to a normalisation term (N=1 for fractions and N=100 for percentage) on each point of the grid.

To get the tile structure of each grid point, the fields “tile class” and “tile fraction” have to be provided.

Product definition template 4.56 – individual ensemble forecast, control and perturbed, at a horizontal level or in a horizontal layer at a point in time for spatio-temporal changing tile parameters

Octet No.	Contents	Status
10	Parameter category (see Code table 4.1)	Validation
11	Parameter number (see Code table 4.2)	Validation
12	Tile classification (see Code table 4.242)	Validation
13	Number of used tiles (NUT) (see Notes 2 and 3)	Validation
14	Identification number of tile (ITN = {1,…, NUT}) (see Note 2)	Validation
15	Number of used tile attributes (NAT) for tile ITN (see Note 2)	Validation

16	Identification number of tile attribute (IAN = {1,…, NAT(ITN)}) (see Note 2)	Validation
17	Attribute of tile (see Code table 4.241)	Validation
18	Type of generating process (see Code table 4.3)	Validation
19	Background generating process identifier (defined by originating centre)	Validation
20	Analysis or forecast generating process identifier (defined by originating centre)	Validation
21-22	Hours of observational data cut-off after reference time (see Note)	Validation
23	Minutes of observational data cut-off after reference time	Validation
24	Indicator of unit of time range (see Code table 4.4)	Validation
25-28	Forecast time in units defined by octet 24	Validation
29	Type of first fixed surface (see Code table 4.5)	Validation
30	Scale factor of first fixed surface	Validation
31-34	Scaled value of first fixed surface	Validation
35	Type of second fixed surface (see Code table 4.5)	Validation
36	Scale factor of second fixed surface	Validation
37-40	Scaled value of second fixed surface	Validation
41	Perturbation number	Validation
42	Number of forecasts in ensemble	Validation

Notes:

(1) Hours greater than 65534 will be coded as 65534.

(2) See note (2) under product definition template 4.55.

Product definition template 4.57 – analysis or forecast at a horizontal level or in a horizontal layer at a point in time for atmospheric chemical constituents based on a distribution function

Octet No.	Contents	Status
10	Parameter category (see Code table 4.1)	Validation
11	Parameter number (see Code table 4.2)	Validation
12-13	Atmospheric chemical constituent type (see Code table 4.230)	Validation
14-15	Number of mode (N) of distribution (see Note 2)	Validation
16-17	Mode number (l)	Validation
18-19	Type of distribution function (see Code table 4.240)	Validation
20	Number of following function parameters (Np), defined by type given in octets 18-19 (Type of distribution function)	Validation
	Repeat the following 5 octets for the number of function parameters (n=1,Np), if Np > 0	Validation
(21+5(n-1))	List of scale factor of fixed distribution function parameter (p1-pNp), defined by type of distribution in octets 18-19	Validation
(22+5(n-1))-(25+5(n-1))	List of scaled value of fixed distribution function parameter (p1-pNp), defined by type of distribution in octets 18-19	Validation
(21+5Np)	Type of generating process (see Code table 4.3)	Validation
(22+5Np)	Background generating process identifier (defined by originating centre)	Validation
(23+5Np)	Analysis or forecast generating process identifier (defined by originating centre)	Validation
(24+5Np)-(25+5Np)	Hours of observational data cut-off after reference time (see Note 1)	Validation
(26+5Np)	Minutes of observational data cut-off after reference time	Validation
(27+5Np)	Indicator of unit of time range (see Code table 4.4)	Validation
(28+5Np)-(31+5Np)	Forecast time in units defined by the previous octet	Validation
(32+5Np)	Type of first fixed surface (see Code table 4.5)	Validation
(33+5Np)	Scale factor of first fixed surface	Validation

(34+5Np)-(37+5Np)	Scaled value of first fixed surface	Validation
(38+5Np)	Type of second fixed surface (see Code table 4.5)	Validation
(39+5Np)	Scale factor of second fixed surface	Validation
(40+5Np)-(43+5Np)	Scaled value of second fixed surface	Validation

Notes:

(1) Hours greater than 65534 will be coded as 65534.

(2) If Number of mode (N) > 1, then between x*N fields with mode number I=1,…, N define the distribution function. x is the number of variable parameters in the distribution function.

As the Attachment II to FM 92 GRIB, (see next three pages)

Distribution functions in GRIB2

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Sibylle Krebber, Michael Baldauf, Dörte Liermann (Deutscher Wetterdienst, Offenbach),
24.04.2014

Goal: representation of fields, that depend not only from space and time, but also from an additional continuous parameter, e.g. diameter d or particle mass m. Such fields at the end are (density) distribution functions $f(x, y, z, t; d) \equiv f(\mathbf{r}, t; d)$. They describe e.g. the distribution of particles with different particle sizes in the air. For simplicity, the time variable t is omitted in the following; in GRIB, times are noted in the PDS, anyway.

Furthermore, this is a try to describe unimodal and multimodal distribution functions in a common GRIB2-framework.

In a GRIB-file one or several fields are contained, which describe the distribution function (concentrations, number densities, ...). The purpose of this GRIB-template is to enable the user to calculate additional interesting variables (these are mostly integrals) from these fields, if he knows the underlying distribution function. Examples are the mass density of cloud droplets

$$\rho(\mathbf{r}) = \int_0^\infty \frac{1}{6}\pi d^3 \rho_w \, f(\mathbf{r}, d) \, dd \tag{1.1}$$

(with the density of water $\rho_w = 1000$ kg/m^3) or the radar reflectivity of rain droplet distributions

$$Z(\mathbf{r}) = const. \int_0^\infty d^6 \, f(\mathbf{r}, d) \, dd \tag{1.2}$$

In the following some examples of distribution functions are listed:

1. bin-model with concentrations $c_l(\mathbf{r})$ in the class (or mode) l. A concentration distribution function is described by

$$f(\mathbf{r}; d) = \sum_{l=1}^{N} c_l(\mathbf{r}) \delta(d - D_l). \tag{1.3}$$

   In this model, the numbers D_l for the diameter in these N classes are fixed and prescribed.
   ($p1 = D_l$)

   Area of application: bin-models in the cloud microphysics, volcanic ash, ...

2. N-modal concentration distribution function, composed by Gaussian functions

$$f(\mathbf{r}; d) = \sum_{l=1}^{N} c_l(\mathbf{r}) \frac{1}{\sqrt{2\pi}\sigma_l} e^{-\left(\frac{d - D_l}{\sigma_l}\right)^2}. \tag{1.4}$$

   Again, N concentrations $c_l(\mathbf{r})$ must be stored. The N modes are defined by fixed values for diameter D_l and width σ_l.
   (therefore, $p1 = D_l$ and $p2 = \sigma_l$)

3. N-modal concentration distribution function, composed by Gaussian function, whose diameter and width can vary from grid point to grid point:

$$f(\mathbf{r}; d) = \sum_{l=1}^{N} c_l(\mathbf{r}) \frac{1}{\sqrt{2\pi}\sigma_l(\mathbf{r})} e^{-\left(\frac{d - D_l(\mathbf{r})}{\sigma_l(\mathbf{r})}\right)^2} \tag{1.5}$$

   Now, $3N$ fields $c_l(\mathbf{r})$, $D_l(\mathbf{r})$ and $\sigma_l(\mathbf{r})$ must be stored.

4. N-modal log-normal distribution for the number density

$$f(\mathbf{r};d) = \sum_{l=1}^{N} \frac{n_l(\mathbf{r})}{\sqrt{2\pi}\log\sigma_l(\mathbf{r})} e^{-\frac{\log^2 \frac{d}{D_l(\mathbf{r})}}{2\log^2\sigma_l(\mathbf{r})}} \tag{1.6}$$

It is described by $3N$ fields $n_l(\mathbf{r})$, $D_l(\mathbf{r})$ and $\sigma_l(\mathbf{r})$.

5. N-modal log-normal distribution for the number density at fixed variance

$$f(\mathbf{r};d) = \sum_{l=1}^{N} \frac{n_l(\mathbf{r})}{\sqrt{2\pi}\log\sigma_l} e^{-\frac{\log^2 \frac{d}{D_l(\mathbf{r})}}{2\log^2\sigma_l}} \tag{1.7}$$

It is described by $2N$ fields $n_l(\mathbf{r})$, $D_l(\mathbf{r})$ and N fixed numbers σ_l. (therefore, $p1 = \sigma_l$)

6. N-modal log-normal distribution for the number density at fixed variance and the prescription of number density and mass density. Again, equation (1.7) is used. However, it is not the field $D_l(\mathbf{r})$ that is stored, but it is expressed via

$$D_l = \left(\frac{m_l}{n_l \frac{\pi}{6} \rho_{p,l} e^{\frac{9}{2}\log^2\sigma_l}} \right)^{1/3} \tag{1.8}$$

by the mass density $m_l(\mathbf{r})$.
It is described by $2N$ fields number density $n_l(\mathbf{r})$ and mass density $m_l(\mathbf{r})$, N values σ_l and N values for the particle densities $\rho_{p,l}$.
($p1 = \sigma_l$ and $p2 = \rho_{p,l}$)

(C. Hoose (2004) master thesis, Univ. Karlsruhe)

Application area: aerosol fields

7. N-modal exponential distribution function with prescribed specific mass $q(\mathbf{r})$:

$$f(\mathbf{r};d) = \sum_{l=1}^{N} N_{0,l}\, e^{-\lambda_l(\mathbf{r})\, d} \tag{1.9}$$

with a fixed intercept-parameter $N_{0,l}$ for the mode l.

For the case of spherical particles and $N = 1$ (cloud droplets, rain droplets) the inverse length $\lambda(\mathbf{r})$ depends from the specific mass $q(\mathbf{r})$ and from the air density $\rho(\mathbf{r})$ by

$$\lambda_l(\mathbf{r}) = \sqrt[4]{\frac{\pi \rho_{w,l} N_{0,l}}{\rho(\mathbf{r})\, q(\mathbf{r})}}. \tag{1.10}$$

This formula also contains the density $\rho_{w,l}$ (e.g. density of liquid water, in general this value is the same for all modes l).
($p1 = N_{0,l}$, $p2 = \rho_{[w,l}$).

Application area: for $N = 1$ an exponential distribution is assumed for the most cloud physics particles (cloud ice, graupel, ...)

8. skew Gaussian function (e.g. for temperature distributions)

$$f(\mathbf{r};T) = \begin{cases} c_r e^{-\frac{(T-T_0(\mathbf{r}))^2}{\sigma_r^2(\mathbf{r})}}, T > T_0(\mathbf{r}), \\ c_l e^{-\frac{(T-T_0(\mathbf{r}))^2}{\sigma_l^2(\mathbf{r})}}, T \leq T_0(\mathbf{r}) \end{cases} \tag{1.11}$$

with 3 fields $T_0(\mathbf{r})$, $\sigma_r(\mathbf{r})$, $\sigma_l(\mathbf{r})$. The 'left-sided' and 'right-sided' variances $\sigma_{l,r}$ have the same physical dimension (temperature). To distinguish them, it is recommended to define two different GRIB-elements. c_l and c_r are approriate norms (not given here).

9. . . .

Though the possible functional forms of distribution functions is extremely huge, in practice, only a few of them are used. However, the shown examples indicate, that even for the same underlying distribution function, there can exist differences about which parameter and fields are prescribed or derived by others or which variable is the independent one (in these examples this has been the diameter d, the particle mass m could be another one, ...). Consequently, this list can become quite large during the lifetime of GRIB2. In the end, this GRIB-template is a possible ansatz, to deliver a minimum of order together with *complete* information for the user of GRIB-data.

Product definition template 4.62 - statistics over an ensemble reforecast, at a horizontal level or in a horizontal layer in a continuous or non-continuous time interval

Octet No.	Contents	Status
10	Parameter category (see Code table 4.1)	Validation
11	Parameter number (see Code table 4.2)	Validation
12	Type of generating process (see Code table 4.3)	Validation
13	Background generating process identifier (defined by originating centre)	Validation
14	Forecast generating process identifier (defined by originating centre)	Validation
15	Indicator of unit of time range (see Code table 4.4)	Validation
16-19	Forecast time in units defined by octet 15 (see Note 1)	Validation
20	Type of first fixed surface (see Code table 4.5)	Validation
21	Scale factor of first fixed surface	Validation
22-25	Scaled value of first fixed surface	Validation
26	Type of second fixed surface (see Code table 4.5)	Validation
27	Scale factor of second fixed surface	Validation
28-31	Scaled value of second fixed surface	Validation
32	Type of ensemble forecast (see Code table 4.6)	Validation
33	Number of forecasts in ensemble	Validation
34	Number of years in the ensemble reforecast period (see Note 2)	Validation
35	First year of ensemble reforecast period	Validation
36	Last year of ensemble reforecast period	Validation
37	Total number of data values possible (or expected) in statistical process over the ensemble reforecast	Validation
38-39	Total number of data values missing in statistical process over the ensemble reforecast	Validation
40	Statistical process used to calculate the processed field over the ensemble reforecast (see Code table 4.10)	Validation
41-42	Year of model version date (see Note 3)	Validation
43	Month of model version date	Validation
44	Day of model version date	Validation
45	Hour of model version date	Validation
46	Minute of model version date	Validation
47	Second of model version date	Validation
48	Month of end of overall time interval (see Note 5)	Validation
49	Day of end of overall time interval	Validation
50	Hour of end of overall time interval	Validation
51	Minute of end of overall time interval	Validation
52	Second of end of overall time interval	Validation
53	n - number of time range specifications describing the time intervals used to calculate the statistically processed field	Validation
54-57	Total number of data values missing in statistical process	Validation
	58-69 Specification of the outermost (or only) time range over which statistical processing is done	Validation
58	Statistical process used to calculate the processed field from the field at each time increment during the time range (see Code table 4.10)	Validation
59	Type of time increment between successive fields used in the statistical processing (see Code table 4.11)	Validation

60	Indicator of unit of time for time range over which statistical processing is done (see Code table 4.4)	Validation
61-64	Length of the time range over which statistical processing is done, in units defined by the previous octet	Validation
65	Indicator of unit of time for the increment between the successive fields used (see Code table 4.4)	Validation
66-69	Time increment between successive fields, in units defined by the previous octet (see Note 3)	Validation
	70-nn These octets are included only if n>1, where nn = 69 + 12 x n	Validation
70-81	As octets 58 to 69, next innermost step of processing	Validation
82-nn	Additional time range specifications, included in accordance with the value of n. Contents as octets 58 to 69, repeated as necessary	Validation

Notes:

(1) The reference time in section 1 and the forecast time together define the beginning of the overall time interval.

(2) Octets 34-40 define a statistical process over both time and ensemble.

(3) This is the date to identify the model version that is used to generate the reforecast.

(4) An increment of zero means that the statistical processing is the result of a continuous (or near continuous) process, not the processing of a number of discrete samples. Examples of such continuous processes are the temperatures measured by analogue maximum and minimum thermometers or thermographs, and the rainfall measured by a rain gauge. The reference and forecast times are successively set to their initial values plus or minus the increment, as defined by the type of time increment (one of octets 59, 71. 83 ...). For all but the innermost (last) time range, the next inner range is then processed using these reference and forecast times as the initial reference and forecast time.

Product definition template 4.1010 – 4-D trajectory

Octet No.	Contents	Status
10	Parameter category (see Code table 4.1)	Validation
11	Parameter number (see Code table 4.2)	Validation
12	Type of generating process (see Code table 4.3)	Validation
13	Background generating process identifier (defined by originating centre)	Validation
14	Analysis or forecast generating process identifier (defined by originating centre)	Validation
15–16	Hours of observational data cutoff after reference time (see Note)	Validation
17	Minutes of observational data cutoff after reference time	Validation

Note: Hours greater than 65534 will be coded as 65534.

Product definition template 4.1011 – 4-D trajectory ensemble forecast, control and perturbed

Octet No.	Contents	Status
10	Parameter category (see Code table 4.1)	Validation
11	Parameter number (see Code table 4.2)	Validation
12	Type of generating process (see Code table 4.3)	Validation
13	Background generating process identifier (defined by originating Centre)	Validation
14	Forecast generating process identifier (defined by originating Centre)	Validation
15–16	Hours after reference time of data cut-off (see Note)	Validation
17	Minutes after reference time of data cut-off	Validation
18	Type of ensemble forecast (see Code table 4.6)	Validation
19	Perturbation number	Validation
20	Number of forecasts in ensemble	Validation

Note: Hours greater than 65534 will be coded as 65534.

Product definition template 4.1015 – 4-D trajectory probability forecasts

Octet No.	Contents	Status
10	Parameter category (see Code table 4.1)	Validation
11	Parameter number (see Code table 4.2)	Validation
12	Type of generating process (see Code table 4.3)	Validation
13	Background generating process identifier (defined by originating centre)	Validation
14	Forecast generating process identifier (defined by originating centre)	Validation
15–16	Hours after reference time of data cut-off (see Note)	Validation
17	Minutes after reference time of data cut-off	Validation
18	Forecast probability number	Validation
19	Total number of forecast probabilities	Validation
20	Probability type (see Code table 4.9)	Validation
21	Scale factor of lower limit	Validation
22–25	Scaled value of lower limit	Validation
26	Scale factor of upper limit	Validation
27–30	Scaled value of upper limit	Validation

Note: Hours greater than 65534 will be coded as 65534.

TEMPLATE DEFINITIONS USED IN SECTION 5

Note: For most templates, details of the packing process are described in Regulation 92.9.4.

Data representation template 5.42 – Grid point and spectral data – CCSDS recommended lossless compression

Octet No.	Contents	Status
12–15	Reference value (R) (IEEE 32-bit floating-point value)	Validation
16–17	Binary scale factor (E)	Validation
18–19	Decimal scale factor (D)	Validation
20	Number of bits required to hold the resulting scaled and referenced data values (see Note 1)	Validation
21	Type of original field values (see Code table 5.1)	Validation
22	Compression scheme version number of CCSDS 121.0-B recommended standard blue book (currently 2) (see Note 3)	Validation
23	Compression options mask (see Note 3)	Validation
24	Compression input/output bits per pixel (see Note 3)	Validation
25–26	Compression input/output pixels per block (see Note 3)	Validation
27–28	Compression input/output pixels per scan line (see Note 3)	Validation
29–36	Length of the uncompressed GRIB message in octets	Validation
37–40	Size of uncompressed data in octets	Validation

Notes:

(1) The intent of this template is to scale the grid point data to obtain the desired precision, if appropriate, and then subtract out reference value from the scaled field as is done using Data Representation Template 5.0. After this, the resulting grid point field can be treated as a grayscale image and is then encoded into the CCSDS recommended standard for lossless data compression code stream format. To unpack the data field, the CCSDS recommended standard for lossless data compression code stream is decoded back into an image, and the original field is obtained from the image data as described in regulation 92.9.4 Note (4).

(2) The Consultative Committee for Space Data Systems (CCSDS) recommended standard for lossless data compression is the standard used by space agencies for the compression of scientific data transmitted from satellites and other space instruments. CCSDS recommended standard for lossless data compression is a very fast predictive compression algorithm based on the extended-Rice algorithm. It uses Golomb-Rice codes for entropy coding. The sequence of prediction errors is divided into blocks. Each block is compressed using a two-pass algorithm. In the first pass the best coding method for the whole block is determined. In the second pass, output of the marker of the selected coding method as a side information is done along with prediction errors encoded.

The coding methods include:

- Golomb-Rice codes of a chosen rank
- Unary code for transformed pairs of prediction errors
- Fixed-length natural binary code if the block is found to be incompressible
- Signaling to the decoder empty block if all prediction errors are zeroes

(3) Consultative Committee for Space Data Systems: Lossless Data Compression. CCSDS Recommendation for Space Data System Standards, CCSDS 121.0-B-2, Blue Book, May 2012.

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TEMPLATE DEFINITIONS USED IN SECTION 7

Data template 7.42 – Grid point and spectral data – CCSDS recommended lossless compression

Octet No.	Contents	Status
6-nn	CCSDS recommended standard for lossless data compression code stream	Validation