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Appendix A: The GRIB Binary Data Format used for LM I/O

All input and output arrays of the LM and of the preprocessor programs providing interpolated initial conditions and the boundary values are stored in a compressed binary data format called GRIB-code. GRIB means "gridded binary" and is designed for the international exchange of processed data in the form of grid-point values expressed in binary form.

The GRIB-code is part of the FM-system of binary codes of the World Meteorological Organization (WMO). Currently, we use Edition 1 of the GRIB-code with number FM 92-VIII. For coding details, see the *Manual on Codes, International Codes, Volume 1.2* of WMO (WMO Publication No. 306, 1995). In this section, we describe only the basic features of the GRIB code which are relevant for the I/O of the LM-system.

A.1 Code Form

Each GRIB-coded record (analysis or forecast field) consists of a continuous bit-stream which is made up of a sequence of octets (1 octet = 8 bits). The representation of data by means of series of bits is independent of any particular machine representation. The octets of a GRIB messsage are grouped in sections (see Table 1, where the length of the record and the length of the sections are expressed in octets. Section 0 has a fixed length of 4 octets and section 5 has a fixed length of 4 octets. Sections 1, 2, 3 and 4 have a variable length which is included in the first three octets of each section.

Table 1: *Form of GRIB-code*

Section number	Name	Contents
0	Indicator Section	"GRIB"; length of record; GRIB edition number
1	Product Definition Section	Length of section; identification of the coded analysis/forecast field
2	Grid Description Section (optional)	Length of section; grid geometry, as necessary
3	Bit-map Section (optional)	Length of section; the bit per grid-point, placed in suitable sequence
4	Binary Data Section	Length of section; data values
5	End Section	7777

Octets are numbered 1, 2, 3, etc., starting at the beginning of each section. Bit positions within octets are referred to as bit 1 to 8, where bit 1 is the most significant bit and bit 8 is the least significant bit. Thus, an octet with only bit 8 set to 1 would have the integer value 1.

A.2 Indicator and End Section

The Indicator Section has a fixed length of 8 octets. The first four octets shall always be character coded as "GRIB" (according to the CCITT International Alphabet No.5). The remainder of the section shall contain the length of the entire GRIB-record (including the Indicator Section) expressed in binary form over the left-most 3 octets (i.e. 24 bits in octet 5-7), followed by the GRIB edition number (currently 1), in binary, in the remaining octet 8.

The End Section has a fixed length of 4 octets. These octets are character coded as '7777' according to the International Alphabet No.5.

Thus, the beginning and the end of a GRIB-record can be identified by the character coded words "GRIB" and "7777". All other octets included in the code represent data in binary form. Each input or output array defined on the rotated lat/lon grid of the LM (e.g the surface pressure or the temperature at a specified model level) is coded as a GRIB-record. Various such records can be combined in a single GRIB-file.

A.3 Product Definition Section

The Product Definition Section (PDS) contains the necessary information to identify the binary coded field contained in the GRIB-record. The most important octet in this section is the indicator of the meteorological parameter. The indicator relates a specific meteorological element to an integer number. This indicator number is also referred to as GRIB-number or element-number and is defined in a separate code table. More than one indicator code tables may be used in GRIB-code. Thus, one can have the same element-number but different code table numbers for various fields. The element-numbers and code tables used by LM are described below.

The program `grbin1` of the supplementary GRIB-library `griblib` of the LM-system can be used to decode GRIB binary code. Besides the decoded data set, this program does also retrieve the contents of the octets of the PDS in an integer array `ipds`. To illustrate the structure of the PDS, Table 2 shows the contents of the product definition section of a binary coded LM output array, the total cloud cover (CLCT). The GRIB-record for this field is valid for 28.10.1998 00 UTC + 11 h and was created at 28.10.1998 7.04 UTC by an LM forecast.

Octet 4 (ipds(2)) assigns a table number to the parameter indicator number given in octet 9. Currently, we use 4 additional code tables besides the WMO-table (see Table 3), where table 205 is used to code synthetic satellite products (from LM version 3.7 and higher). A full list of variables defined by these tables is available from DWD.

Octet 6 (ipds(4)) indicates the process identification number which is allocated by the originating centre. Currently, we use only two different process numbers for forecasts or analyses (see Table 4).

The level or layer for which the data are included in the GRIB-record is coded in octets 10 - 12 (ipds(8) - ipds(10)), where octet 10 indicates the type of level and octets 11 and 12 indicate the value of this level. Table 5 shows the code figures used for LM. For reserved values, or if not defined, octets 11 and 12 shall contain zero.

All 3-D variables of LM except the vertical velocity are defined on terrain-following main levels. In GRIB, these main levels are coded as level-type 110: hybrid layers between two adjacent hybrid levels - which are the LM half levels, i.e the layer interfaces. In this case, octet 11 contains the level index of the upper half level and octet 12 contains the level index of the lower half level. The vertical velocity and the height of the half levels are coded as level type 109: hybrid levels, i.e. the LM half levels. In this case, octet 11 contains zero and octet 12 contains the level index of the model half level. Pressure levels (ipds(8) = 100) and height levels (ipds(8) = 105) are used when the interpolation from model to specified p- or z-surfaces is switched on for model output. For synthetic satellite images (table number 205 and level-type 222), the octets 11 - 12 are used to code the channel of a satellite: ipds(9) = 0 and ipds(10) contains the channel number.

Table 2: ***Contents of the Product Definition Section***

array ipds(i)	**Octet number**	**Contents of PDS**	
		Value	**Remarks**
1	1-3	54	Length of the PDS (in octets)
2	4	2	Version number of the GRIB indicator table (see Table 3)
3	5	78	Identification of originating/generating centre (DWD has WMO number 78)
4	6	132	Generating process identification number (allocated by originating centre, see Table 4)
5	7	255	Number of grid used - from catalogue defined by the originating centre. Octet 7 set to 255 indicates a non-cataloged grid, in which case the grid is defined in the grid description section.
6	8	128	Block-flag; the value 128 indicates that the grid description section is included.
7	9	71	Indicator of parameter (element number) from GRIB-table in ipds(2); see Section 3.7
8	10	1	Indicator of type of level, see Table 5
9-10	11-12	0	Value of level (height, pressure, etc.) for which the data are included (see Table 5)
11	13	98	Year (start time of forecast; analysis time)
12	14	10	Month (start time of forecast; analysis time)
13	15	28	Day (start time of forecast; analysis time)
14	16	0	Hour (start time of forecast; analysis time)
15	17	0	Minute (start time of forecast; analysis time)
16	18	1	Indicator of unit of time range (see Table 6)
17	19	11	P1 - period of time (number of time units);
			time units given by octet 18 (ipds(16))
18	20	0	P2 - period of time (number of time units);
			time units given by octet 18 (ipds(16))
19	21	0	time range indicator (see Table 7)
20	22-23	0	Number of forecasts included in average, when octet 21 (ipds(19)) indicates an average or accumulation of forecasts (or analyses); otherwise set to zero.
21	24	0	Number of forecasts missing from averages or accumulations.
22	25	20	Century of reference time of data given by octets 13- 17
23	26	255	Sub-centre identification, national use
24	27-28	0	Units decimal scale factor (D)
25-36	29-40	0	Reserved: need not to be present
37	41	254	Octets 41-54 are reserved for the originating centre. The integer value 254 indicates that additional data follow. We use this part as follows:
38	42	0	not used
39	43-45	0	not used
40	46	0	not used
41	47	0	Additional indicator for a GRIB element number
42	48	98	Year of production of GRIB-record
43	49	98	Month of production of GRIB-record
44	50	11	Day of production of GRIB-record
45	51	2	Hour of production of GRIB-record
46	52	0	Minute of production of GRIB-record
47	53-54	1	Version number, currently 1 for LM

Table 3: *GRIB-tables for parameter (element) indicator number*

Version number of GRIB-table; ipds(2)	**Comment**
2	WMO-table of indicator parameters
201	national table of DWD for internal use
202	national table of DWD for internal use
203	national table of DWD for internal use
205	national table of DWD for internal use

Table 4: *Process identification numbers*

process id-number; ipds(4)	**Comment**
131	LM-analyses from data assimilation cycle
132	LM-forecasts and initialized analyses

Table 5: *Types of fixed levels or layers used by LM*

level type ipds(8)	**Meaning**	**ipds(9)**	**ipds(10)**
1	Ground or water surface	0	0
2	Cloud base level	0	0
3	Level of cloud tops	0	0
4	Level of $0°C$ isotherm	0	0
8	Top of atmosphere	0	0
100	Pressure (isobaric) level	0	Pressure in hPa
102	Mean sea level	0	0
103	Specified height above mean sea level	0	Height in m
105	Specified height level above ground	0	Height in m
109	Hybrid level (half levels)	0	Level number (k)
110	Hybrid layer (main level) between two hybrid levels	Level number of top (k)	Level number of bottom (k+1)
111	Depth below land surface	0	Depth in cm
112	Layer between two depths below land surface	Depth of upper surface in cm	Depth of lower surface in cm
222	Satellite images	0	Satellite Channel

Octets 13-17 contain the reference time of the data: the start of a forecast, the time for which an analysis is valid or the start of an averaging or accumulation period. The year of the century is coded in octet 13 and the century (100 years) in octet 25. For a reference time within the year 2000, octet 13 will contain the integer value 100 and octet 25 will contain the integer value 20.

The time or time interval for which the data are valid with respect to the reference time is coded in octets 18-21 (ipds(16)-ipds(19)). Octets 19 and 20 contain two periods of time, P1 and P2. The units of the values of P1 and P2 are defined in octet 18. Currently, we use hours as the time unit, but other values may be more appropriate for special applications of the model as the maximum integer number in an octet is 256. Thus, for long-term climate runs or short-term cloud simulations, other time units must be chosen. In LM version 3.15 time units of 15 minutes (`ipds(16)=13`) and 30 minutes (`ipds(16)=14`) have been implemented.

Note, that these values are DWD extensions and not GRIB standard. The WMO code-table for the unit of time in P1 and P2 is given in Table 6.

Table 6: *Code table for unit of time*

ipds(16)	Meaning	ipds(16)	Meaning	ipds(16)	Meaning
0	Minute	5	Decade	11	6 hours
1	Hour	6	Normal	12	12 hours
2	Day	7	Century	13(!)	15 minutes
3	Month	8-9	Reserved	14(!)	30 minutes
4	Year	10	3 hours	15-253	reserved
				254	second

The meaning of the time period P1 in octet 19 (ipds(17)) and of the time period P2 in octet 20 (ipds(18)) - given in the units coded in octet 18 - depends on the time-range indicator, which is contained in octet 21 (ipds(19)). The WMO code-table allows for a large number of indicators including averages and accumulation over a number of forecasts and analyses. For the LM-system, we use only a few standard indicators as shown in Table 7. In order to distinguish output from the nudging assimilation cycle from other external analysis products, as e.g. the sea surface temperature or snow depth, all nudging products will have a time-range indicator 13.

Table 7: *Time range indicators used by LM*

`ipds(19)`	Meaning
0	Forecast product valid for reference time + P1 (if P1 > 0) or uninitialized analysis product valid for reference time (P1 = 0)
1	initialized analysis product valid for reference time (P1 = 0)
2	Product with a valid time ranging between reference time + P1 and reference time + P2
3	Average from reference time + P1 to reference time + P2
4	Accumulation from reference time + P1 to reference time + P2; product valid for reference time + P2
13	Nudging analysis product, valid for reference time (P1 = 0) Note: All output from a nudging assimilation cycle will have time-range indicator 13, also fields which usually have ipds(19) = 2, 3 or 4.

A.4. Grid Description Section

Section 2 of a GRIB-record, the grid description section GDS, contains all information about the geometry of the grid on which the data are defined. For all input and output files of the LM, this section is coded completely for every field contained in the file. The program `grbin1` of the supplementary GRIB-library `griblib` retrieves the contents of the GDS in an integer array `igds`.

The contents of the grid description section of an LM GRIB-record is illustrated in Table 8 for the model domain used operationally at DWD. The octets corresponding to the integer array `igds` are numbered relative to this section.

Table 8: ***Contents of the Grid Description Section***

array igds(i)	Octet number	Contents of GDS	
		Value	**Meaning**
1	1-3	202	Length of GDS (in octets) including the vertical coordinate parameters. (here for $ke = 35$ layers, i.e. $ke + 1 = 36$ half levels)
2	4	40	NV: Number of vertical coordinate parameters (four base state parameters + $(ke + 1)$ values of the vertical coordinates of the half levels)
3	5	43	PV: Location (octet number) of the list of vertical coordinate parameters
4	6	10	Data representation type according to WMO code-table 6; '10' assigns a rotated latitude/longitude grid
5	7-8	325	Number of gridpoints in 'zonal' direction
6	9-10	325	Number of gridpoints in 'meridional' direction
7	11-13	-17000	Rotated latitude of the first gridpoint in millidegrees
8	14-16	-12500	Rotated longitude of the first gridpoint in millidegrees
9	17	0	Resolution flag according to WMO code-table 7; '0' means that the grid spacing is not given
10	18-20	3250	Rotated latitude of the last gridpoint in millidegrees
11	21-23	7750	Rotated longitude of the last gridpoint in millidegrees
12	24-25	0	Longitudinal direction increment (grid spacing in λ-direction, not given)
13	26-27	0	Meridional direction increment (grid spacing in ϕ-direction, not given)
14	28	64	Scanning mode flag according to WMO code-table 8 '64' means that points scan in +i and +j direction and adjacent points in i-direction are consecutive
15-19	29-32	0	Reserved (set to zero)
20	33-35	-32500	Geographical latitude of rotated southern pole in millidegrees
21	36-38	10000	Geographical longitude of rotated southern pole in millidegrees
22	39-42	0	Angle of rotation
26-65	43-202	.....	List of vertical coordinate parameters, each packed on 4 octets (length = 4 x NV octets). first the three parameters defining the base state: `igds(26)=p0sl`, `igds(27)=t0sl`, `igds(28)=dt0lp`; then the parameter `igds(29)=vcflat` of the hybrid coordinate system; and finally the $ke + 1$ values of the vertical coordinate $\eta(k)$ of the model half levels for $k = 1, \ldots, ke + 1$ in `igds(30)`,..., `igds(65)`.

Appendix B: Available LM Output Fields

This appendix summarizes the GRIB parameter indicators (element numbers), the table numbers and the dimensions of the direct model output variables. Any changes will be updated in the next COSMO Newsletter.

B.1 General Remarks

For direct model output, we distinguish between so-called *multi-level fields* which are defined on model layers or levels or on fixed pressure or height levels, and *single level fields* which are defined at the surface or on another fixed level.

The fields contained in the model output GRIB-files can be freely chosen by the user: The names of the model variables to be written out have to be specified on the following NAMELIST input character arrays:

- `yvarml` for output on the model grid and for single level data,
- `yvarpl` for output on constant pressure levels
- `yvarzl` for output on constant height levels.

If latter two variables are empty, the model-internal interpolation to pressure and height levels is omitted. If they are set, the values of the corresponding pressure and height levels can be specified by the NAMELIST input arrays `plev` and `zlev`. By default, some multi-level variable are interpolated to 10 pressure levels and 4 height levels:

- p-levles: 1000, 950, 850, 700, 600, 500, 400, 300, 250, 200 hPa.
- z-levles: 1000, 2000, 3000, 5000 m (above sea level).

B.2 Element and Table Numbers used by LM

The name of an input/output field is specified as a CHARACTER variable (in capital letters, names must be 8 characters long, filled with blanks) in NAMELIST input. The model then relates this name internally to a corresponding GRIB element number and table number as well as the corresponding global model variable (which has usually the same name but with small letters). However, some names of output variables are not related to a globally defined model variable. In these cases, the output array is calculated locally only at the output time step.

Table 1 shows the GRIB-element numbers (ee) and table numbers (tab) for the multi-level fields available for LM output files. The level-types (lty) and the corresponding values in octet 11 (lvt) and octet 12 (lv) as well as the physical units (unit) are also included. For variables with level-types 109 and 110, the integer level numbers denoted by k (and k+1) are stored in octets 11 and 12. For pressure levels the constant pressure value in hPa is stored in octet 12 (denoted by pres), and for height levels the constant height level in m above sea level (denoted by z) is stored in octet 12.

Some of the multi-level fields in Table 1 can only be put on the output list if certain parameterization schemes are switched on. These variables are denoted as optional fields. All variables on the list for constant pressure and constant height levels are in the default output list.

Table 1: ***Multi-level fields of LM GRIB-output***

Name	Meteorological Element	ee	tab	lty	lvt	lv	unit
	Multi-level fields on model layers/levels k						
U	Zonal wind component (rotated grid)	33	2	110	k	k+1	m/s
V	Meridional wind component (rotated grid)	34	2	110	k	k+1	m/s
W	Vertical wind component	40	2	109	-	k	m/s
P	Pressure	1	2	110	k	k+1	Pa
PP	Pressure perturbation	139	201	110	k	k+1	Pa
T	Temperature	11	2	110	k	k+1	K
QV	Specific humidity	51	2	110	k	k+1	kg/kg
QC	Specific cloud water content	31	201	110	k	k+1	kg/kg
CLC	Fractional cloud cover	29	201	110	k	k+1	%
HHL	Height of half levels (i.e. layer interfaces) constant with time, written only at t=0	8	2	109	-	k	m
	Optional multi-level fields on model layers/levels k						
QI	Specific cloud ice content	33	201	110	k	k+1	kg/kg
QR	Specific water content of rain	35	201	110	k	k+1	kg/kg
QS	Specific water content of snow	36	201	110	k	k+1	kg/kg
QG	Specific water content of graupel	39	201	110	k	k+1	kg/kg
QRS	Specific content of rain and snow	99	201	110	k	k+1	kg/kg
TKE	Specific turbulent kinetic energy	152	201	109	-	k	m^2/s^2
TKVM	Turbulent diffusion coefficient for vertical momentum transport	153	201	109	-	k	m^2/s
TKVH	Turbulent diffusion coefficient for vertical heat transport	154	201	109	-	k	m^2/s
	Optional multi-level fields of soil layers m between depth z_m and z_{m+1}						
T_SO	Temperature of soil layer m	197	201	112	z_m	z_{m+1}	K
W_SO	Water content of soil layer m	198	201	112	z_m	z_{m+1}	kg/m^2
W_ICE	Ice content of soil layer m	199	201	112	z_m	z_{m+1}	kg/m^2
	Multi-level fields interpolated on pressure levels pres (in hPa)						
U	Zonal wind component (rotated grid)	33	2	100	-	pres	m/s
V	Meridional wind component (rotated grid)	34	2	100	-	pres	m/s
OMEGA	Vertical motion	39	2	100	-	pres	Pa/s
T	Temperature	11	2	100	-	pres	K
RELHUM	Relative humidity	52	2	100	-	pres	%
FI	Geopotential	6	2	100	-	pres	m^2/s^2
	Multi-level fields interpolated on height levels z (in m)						
U	Zonal wind component (rotated grid)	33	2	103	-	z	m/s
V	Meridional wind component (rotated grid)	34	2	103	-	z	m/s
W	Vertical wind component	40	2	103	-	z	m/s
T	Temperature	11	2	103	-	z	K
P	Pressure	1	2	103	-	z	Pa
RELHUM	Relative humidity	52	2	103	-	z	%

Table 2 shows the GRIB-element numbers (ee) and table numbers (tab) for the single-level forecast fields available for LM output files. As in the previous table, the level-types (lty) and the corresponding values in octet 11 (lvt) and octet 12 (lv) as well as the physical units (unit) of the fields are also included. See Table 5 in Appendix A for the units of the numbers stored in lvt and lv for the corresponding level-type.

Table 2: ***Single-level fields of LM GRIB-output***

Name	Meteorological Element	ee	tab	lty	lvt	lv	unit
	Single-level fields: valid at output time						
PS	Surface pressure	1	2	1	-	-	Pa
PMSL	Mean sea level pressure	2	2	102	-	-	Pa
U_10M	Zonal 10m-wind	33	2	105	-	10	m/s
V_10M	Meridional 10m-wind	34	2	105	-	10	m/s
T_2M	2m-temperature	11	2	105	-	2	K
TD_2M	2m-dewpoint temperature	17	2	105	-	2	K
T_G	Temperature at the interface surface-atmosphere	11	2	1	-	-	K
T_SNOW	Temperature of snow surface (surface temperature if no snow)	203	201	1	-	-	K
T_S	Temperature below snow (surface temperature if no snow	85	2	111	-	0	K
T_M	Temperature at the bottom of first soil layer	85	2	111	-	9	K
QV_S	Specific humidity at the surface	51	2	1	-	-	kg/kg
W_SNOW	Water content of snow	65	2	1	-	-	kg/m^2
W_I	Water content of interception store	200	201	1	-	-	kg/m^2
W_G1	Water content of upper soil layer	86	2	112	0	10	kg/m^2
W_G2	Water content of middle soil layer	86	2	112	10	100	kg/m^2
TCM	Turbulent transfer coefficient for momentum at the surface	170	201	1	-	-	-
TCH	Turbulent transfer coefficient for heat and moisture at the surface	171	201	1	-	-	-
Z0	Roughness length (land and water)	83	2	1	-	-	m
ALB_RAD	Surface albedo (shortwave radiation)	84	2	1	-	-	%
CLCT	Total cloud cover	71	2	1	-	-	%
CLCH	High cloud cover (0 - 400 hPa)	75	2	1	-	-	%
CLCM	Middle cloud cover (400-800 hPa)	74	2	1	-	-	%
CLCL	Low cloud cover (800hPa-surface)	73	2	1	-	-	%
CLCT_MOD	Total cloud cover (modified for graphics)	204	203	1	-	-	-
CLDEPTH	Normalized cloud depth (modified for graphics)	203	203	1	-	-	-
HTOP_DC	Top height of dry convection (height above mean sea level)	82	201	1	-	-	m
HZEROCL	Height of $0°C$ isotherm (above mean sea level)	84	201	1	-	-	m
MFLX_CON	Massflux at convective cloud base	240	201	1	-	-	$kg/(m^2s)$
CAPE_CON	Convective available potential energy	241	201	1	-	-	J/kg
QCVG_CON	Moisture convergence below convective cloud base	242	201	1	-	-	1/s
TKE_CON	Convective turbulent kinetic energy	243	201	1	-	-	J/kg
TWATER	Total column water	41	201	1	-	-	kg/m^2
TQV	Total column water vapour	54	2	1	-	-	kg/m^2
TQC	Total column cloud water	76	2	1	-	-	kg/m^2
TQI	Total column cloud ice	58	2	1	-	-	kg/m^2
SNOWLMT	Height of Snow-fall limit	85	201	1	-	-	m

Name	Meteorological Element	ee	tab	lty	lvt	lv	unit
PRR_GSP	Grid-Scale surface rain flux	100	201	1	-	-	$kg/(m^2s)$
PRS_GSP	Grid-Scale surface snow flux	101	201	1	-	-	$kg/(m^2s)$
PRS_CON	Convective surface rain flux	111	201	1	-	-	$kg/(m^2s)$
PRS_CON	Convective surface snow flux	112	201	1	-	-	$kg/(m^2s)$
FRESHSNW	Indicator for age of snow	129	201	1	-	-	-
ZTD	Total zenith delay	121	202	1	-	-	-
ZWD	Wet zenit delay	122	202	1	-	-	-
ZHD	Hydrostatic zenith delay	123	202	1	-	-	-
Single-level fields: Accumulated since start of the forecast							
RAIN_GSP	Amount of grid-scale rain	102	201	1	-	-	kg/m^2
SNOW_GSP	Amount of grid-scale snow	79	2	1	-	-	kg/m^2
RAIN_CON	Amount of convective rain	113	201	1	-	-	kg/m^2
SNOW_CON	Amount of convective snow	78	2	1	-	-	kg/m^2
TOT_PREC	Total precipitation amount	61	2	1	-	-	kg/m^2
RUNOFF_S	Surface water run-off	90	2	112	0	10	kg/m^2
RUNOFF_G	Ground water run-off	90	2	112	10	100	kg/m^2
TDIV_HUM	Total column divergence of specific humidity	42	201	1	-	-	kg/m^2
AEVAP_S	Accumulated flux of surface moisture	57	2	1	-	-	kg/m^2
Single-level fields: Averaged over the forecast period							
AUMFL_S	Surface u-momentum flux	124	2	1	-	-	N/m^2
AVMFL_S	Surface v-momentum flux	125	2	1	-	-	N/m^2
ASHFL_S	Surface sensible heat flux	122	2	1	-	-	W/m^2
ALHFL_S	Surface latent heat flux	121	2	1	-	-	W/m^2
ASOB_S	Solar radiation budget at the earth surface	111	2	1	-	-	W/m^2
ASOB_T	Solar radiation budget at the top of the atmosphere	113	2	8	-	-	W/m^2
ATHB_S	Thermal radiation budget at the earth surface	112	2	1	-	-	W/m^2
ATHB_T	Thermal radiation budget at the top of the atmosphere	114	2	8	-	-	W/m^2
APAB_S	Budget of photosynthetic active radiation at the earth surface	5	201	1	-	-	W/m^2
Single-level fields: Extreme values over certain time intervals							
TMIN_2M	Minimum of 2m-temperature	16	2	105	-	2	K
TMAX_2M	Maximum of 2m-temperature	15	2	105	-	2	K
VMAX_10M	Maximum of 10m-wind speed	187	201	105	-	10	m/s
HTOP_CON	Top height of convective clouds (above mean sea level)	69	201	3	-	-	m
HBAS_CON	Base height of convective clouds (above mean sea level)	68	201	2	-	-	m
TOP_CON	Main-level index of convective cloud top	73	201	1	-	-	-
BAS_CON	Half-level index of convective cloud base	72	201	1	-	-	-
Single-level fields: Constant and climatological fields							
FIS	Geopotential of earth surface	6	2	1	-	-	m^2/s^2

Name	Meteorological Element	ee	tab	lty	lvt	lv	unit
HSURF	Geometrical height of surface	8	2	1	-	-	m
FR_LAND	Land fraction of a grid area	81	2	1	-	-	-
SOILTYP	Soil texture for land fraction (key number 1-8, over water =9)	57	202	1	-	-	-
RLAT	Geographical latitude	114	202	1	-	-	° N
RLON	Geographical longitude	115	202	1	-	-	° E
PLCOV	Fractional plant cover	87	2	1	-	-	-
LAI	Leaf area index of vegetation	61	2	1	-	-	-
ROOTDP	Root depth of vegetation	62	202	1	-	-	m
FC	Coriolis parameter	113	202	1	-	-	s^{-1}
T_CL	Temperature of the lowest soil layer (climatological value)	85	2	111	-	36	K
W_CL	Water content of the lowest soil layer (climatological value)	86	2	112	100	190	kg/m^2
VIO3	Vertically integrated ozone	65	202	1	-	-	Pa O3
HMO3	Height of ozone maximum	64	202	1	-	-	Pa
Single-level fields: Synthetic satellite products							
SYNME5	METEOSAT-5, MVIRI instrument	1	205	222	0	nc	-
SYNME6	METEOSAT-6, MVIRI instrument	2	205	222	0	nc	-
SYNME7	METEOSAT-7, MVIRI instrument	3	205	222	0	nc	-
SYNMSG	MSG, SEVIRI instrument	4	205	222	0	nc	-

With respect to synthetic satellite images, only the element numbers 3 and 4, i.e. the MVIRI instrument on METEOSAT-7 and the SEVIRI on MSG, respectively, are supported by LM at present. To each channel number 'nc' coded in octet 12 (ipds(10) or 'lv' in the table above) corresponds a physical channel with a specific wavelength, as shown in Table 3.

Table 3: ***Coding of channels for synthetic satellite products***

ee	Satellite/Instrument	lv	channel	wavelength (μm)
3	METEOSAT-7 / MVIRI	1	1	WV 6.4
3	METEOSAT-7 / MVIRI	2	2	IR 11.5
4	MSG / SEVIRI	1	4	IR 3.9
4	MSG / SEVIRI	2	5	WV 6.2
4	MSG / SEVIRI	3	6	WV 7.3
4	MSG / SEVIRI	4	7	IR 8.7
4	MSG / SEVIRI	5	8	IR 9.7
4	MSG / SEVIRI	6	9	IR 10.8
4	MSG / SEVIRI	7	10	IR 12.1
4	MSG / SEVIRI	8	11	IR 13.4

Table 4: ***Specific synthetic satellite products***

ipds(41)	Product	unit
1	Cloudy brightness temperature	K
2	Clear-sky brightness temperature	K
3	Cloudy radiance	$mW/(m^2$ sr cm)
4	Clear-sky radiance	mW/m^2 sr cm)

For each channel on a specified satellite instrument, four different fields are calculated. These products are distinguished by a value for the additional element number (ipds(41), octet 47) in the product definition section, as indicated in Table 4.

All variables required on the input and boundary data files use also the corresponding GRIB table and element numbers from the above tables. The preprocessor programs to interpolate initial and/or boundary conditions to the LM-grid require the GRIB-files containing the external parameter data sets. The table and element numbers of the external parameter fields are shown in Table 5.

Table 5: ***Single-level fields in the LM external parameter files***

Name	Meteorological Element	ee	tab	lty	lvt	lv	unit
FIS	Geopotential of earth surface	6	2	1	-	-	m^2/s^2
HSURF	Geometrical height of surface	8	2	1	-	-	m
FR_LAND	Land fraction of a grid area	81	2	1	-	-	-
Z0	Roughness length (land and water)	83	2	1	-	-	m
SOILTYP	Soil texture for land fraction (key number 1-8, over water =9)	57	202	1	-	-	-
PHI	Geographical latitude	114	202	1	-	-	° N
RLA	Geographical longitude	115	202	1	-	-	° E
PLCOV_MX	Plant cover, vegetation period	67	202	1	-	-	%
PLCOV_MN	Plant cover, rest period	68	202	1	-	-	%
LAI_MX	Leaf area index, vegetation period	69	202	1	-	-	-
LAI_MN	Leaf area index, rest period	70	202	1	-	-	-
ROOTDP	Root depth of vegetation	62	202	1	-	-	m

Appendix C: List of COSMO Newsletters and Technical Reports

All Newsletters and Technical Reports are available for download from the COSMO Website: www.cosmo-model.org (or the mirror site cosmo-model.cscs.ch).

COSMO Newsletters

Newsletter No. 1, February 2001.

Newsletter No. 2, February 2002.

Newsletter No. 3, February 2003.

Newsletter No. 4, February 2004.

Newsletter No. 5, April 2005.

COSMO Technical Reports

No. 1, Dmitrii Mironov and Matthias Raschendorfer (2001):
Evaluation of Empirical Parameters of the New LM Surface-Layer Parameterization Scheme. Results from Numerical Experiments Including the Soil Moisture Analysis.

No. 2, Reinhold Schrodin and Erdmann Heise (2001):
The Multi-Layer Version of the DWD Soil Model TERRA_LM.

No. 3, Günther Doms (2001):
A Scheme for Monotonic Numerical Diffusion in the LM.

No. 4, Hans-Joachim Herzog, Ursula Schubert, Gerd Vogel, Adelheid Fiedler and Roswitha Kirchner (2002):
LLM - the High-Resolving Nonhydrostatic Simulation Model in the DWD - Project LITFASS. Part I: Modelling Technique and Simulation Method.

No. 5, Jean-Marie Bettems (2002):
EUCOS Impact Study Using the Limited-Area Non-Hydrostatic NWP Model in Operational Use at MeteoSwiss.

No. 6, Heinz-Werner Bitzer and Jürgen Steppeler (2004):
Documentation of the Z-Coordinate Dynamical Core of LM.

No. 7, Hans-Joachim Herzog and Almut Gassmann (2005):
Lorenz- and Charney-Phillips vertical grid experimentation using a compressible nonhydrostatic toy-model relevant to the fast-mode part of the 'Lokal-Modell'

No. 8, Chiara Marsigli, Andrea Montani and Tiziana Paccagnella (2005):
Evaluation of the Performance of the COSMO-LEPS System