

ICON Database Reference Manual

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ii Revision History

This document is based on Revision 21857 of the ICON code, Last changed on 2015-04-15.

Revision History

Revision	Date	Author(s)	Description
0.1.0	10.01.13	DR, FP	Generated preliminary list of available GRIB2 output fields
0.2.0	12.07.13	DR, FP	Added a short section describing the horizontal ICON grid. AUMFL_S, AVMFL_S added to the list of available output fields
0.2.1	15.07.13	DR	Provide newly available output fields in tabulated form. Change levelType of 3D atmospheric fields from 105 (Hybrid) to 150 (Generalized vertical height coordinate)
0.2.2	16.07.13	FP	Short description of ICON's vertical grid.
0.2.3	25.09.13	DR	Added description of available First Guess and analysis fields
0.2.4	17.12.13	DR	Added description of external paramater fields
0.3.0	24.01.14	DR	Added information about horizontal output grids
0.3.1	24.01.14	DR	Added information about newly available output field ${\tt OMEGA}$
0.4.0	22.05.14	HF	Added SKY-database documentation
0.4.1	15.07.14	DR	Some documentation on statistical processing and minor updates. New output fields ASWDIR_S, ASWDIFD_S, ASWDIFU_S, DTKE_CON
0.4.2	10.09.14	DR	New output fields CLCT_MOD, CLDEPTH
0.5.0	01.10.14	DR	Description of IAU initialization method
0.5.1	15.10.14	DR	Updated description of necessary input fields
0.5.2	31.10.14	DR	Add full table with model half level heights
0.6.0	05.12.14	DR	Add short introduction and fix some minor bugs
0.6.1	10.12.14	DR	New output field APAB_S
0.7.0	16.12.14	DR	Revised documentation of time invariant fields and a couple of bug fixes
0.7.2	09.01.15	DR	General GRIB2 description
0.8.0	15.01.15	FP, DR	Couple of bug fixes regarding the available fields on triangular and regular grids
0.8.1	16.01.15	FP, DR	List of pressure-level variables available on triangular grids
0.8.2	16.01.15	FP	List of height-level variables available on regular grids
0.8.3	16.01.15	DR	List of variables exclusively available for $VV=0$
0.8.4	06.02.15	FP, DR	Details of internal interpolation onto lon-lat grids. Details regarding output frequency.
0.8.5	18.02.15	FP	Additional pressure levels for regular grid output.

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0.8.6	23.02.15	FP	Formula for computing non-zero topography level height.
1.0.0	23.02.15	FP	Additional table of model full levels.
1.0.1	24.02.15	DR	Update on available forecast runs and time span.
1.0.2	27.02.15	FP	Added tables for grid point with maximum topo height.
1.0.3	13.03.15	DR, FP	Section on statistically processed fields.
1.1.0	15.04.15	FP, DR	Section on ICON EU nest (preliminary).

Simulations are believed by no one except those who conducted them.

Experimental results are believed by everyone except those who conducted them.

ANONYMOUS

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Chapter 1

Introduction

The **ICO**sahedral **N**onhydrostatic model ICON is the new global numerical weather prediction model at DWD. It became operational at 2015-01-20, replacing the former operational global model GME. The ICON modelling system as a whole is developed jointly by DWD and the Max-Planck Institute for Meteorology in Hamburg (MPI-M). While ICON is the new working horse for short and medium range global weather forecast at DWD, it will serve as the core of a new climate modelling system at MPI-M.

Since 2015-01-20, ICON analysis and forecast fields serve as initial and boundary data for

- the regional model COSMO-EU
- RLMs (Relocatable Local Model) of the German armed forces
- DWD's wave models

This document provides some basic information about ICON's horizontal and vertical grid structure, numerical algorithms and physical parameterizations (the latter two are planned but not yet available). Furthermore, it provides an overview about the available ICON analysis and forecast fields stored in the data base SKY at DWD. Some examples on how to read these data from the data base are given as well.

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Chapter 2

Grid geometry

2.1 Horizontal grid

The horizontal ICON grid consists of a set of spherical triangles that seamlessly span the entire sphere. The grid is constructed from an icosahedron (see Figure 2.1a) which is projected onto a sphere. The spherical icosahedron (Figure 2.1b) consists of 20 equilateral spherical triangles. The edges of each triangle are bisected into equal halves or more generally into n equal sections. Connecting the new edge points by great circle arcs yields 4 or more generally n^2 spherical triangles within the original triangle (Figure 2.2a, 2.2b).



Figure 2.1: Icosahedron before (a) and after (b) projection onto a sphere



Figure 2.2: (a) Bisection of the original triangle edges (b) More general division into n equal sections

ICON grids are constructed by an initial root division into n sections ($\mathbf{R}n$) followed by k bisection steps ($\mathbf{B}k$), resulting in a $\mathbf{R}n\mathbf{B}k$ grid. Figures 2.3a and 2.3b show $\mathbf{R}2\mathbf{B}00$ and $\mathbf{R}2\mathbf{B}02$ ICON grids. Such grids avoid polar singularities of latitude-longitude grids (Figure 2.3c) and allow a high uniformity in resolution over the whole sphere.



Figure 2.3: (a) R2B00 grid. (b) R2B02 grid. (c) traditional regular latitude-longitude grid with polar singularities

Throughout this document, the grid is referred to as the "RnBk grid" or "RnBk resolution". For a given resolution RnBk, the total number of cells, edges, and vertices can be computed from

$$n_c = 20 n^2 4^k$$

 $n_e = 30 n^2 4^k$
 $n_v = 10 n^2 4^k + 2$

The average cell area $\overline{\Delta A}$ can be computed from

$$\overline{\Delta A} = \frac{4\pi \, r_e^2}{n_c} \, ,$$

with the earth radius r_e , and n_c the total number of cells. Based on $\overline{\Delta A}$ one can derive an estimate of the average grid resolution $\overline{\Delta x}$:

$$\overline{\Delta x} = \sqrt{\overline{\Delta A}} = \sqrt{\frac{\pi}{5}} \frac{r_e}{n \, 2^k}$$

Visually speaking, $\overline{\Delta x}$ is the edge length of a square which has the same area as our triangular cell.

In Table 2.1, some characteristics of frequently used ICON grids are given. The table contains information about the total number of triangles (n_c) , the average resolution $\overline{\Delta x}$, and the maximum/minimum cell area. The latter may be interpreted as the area for which the prognosed meteorological quantities (like temperature, pressure, ...) are representative. Some additional information about ICON's horizontal grid can be found in Wan et al. (2013).

2.2. Vertical grid 5

Table 2.1: Characteristics of frequently used ICON grids.	ΔA_{max} and ΔA_{min}	refer to the maximum
and minimum area of the grid cells, respectively.		

Grid	number of cells (n_c)	avg. resolution [km]	$\Delta A_{max} [km^2]$	$\Delta A_{min} [km^2]$
R2B04	20480	157.8	25974.2	18777.3
R2B05	81920	78.9	6480.8	4507.5
R2B06	327680	39.5	1618.4	1089.6
R2B07	1310720	19.7	404.4	265.1
R3B07	2949120	13.2	179.7	116.3

The first operational version of ICON is based on the R3B07 grid, thus, having a horizontal resolution of about 13 km!

2.2 Vertical grid

The vertical grid consists of a set of vertical layers with height-based vertical coordinates. Each of these layers carries the horizontal 2D grid structure, thus forming the 3D structure of the grid. The ICON grid employs a Lorenz-type staggering with the vertical velocity defined at the boundaries of layers (half levels) and the other prognostic variables in the center of the layer (full levels).

To improve simulations of flow past complex topography, the ICON model employs a smooth level vertical (SLEVE) coordinate (Leuenberger et al., 2010). It allows for a faster transition to smooth levels in the upper troposphere and lower stratosphere, as compared to the classical height-based Gal-Chen coordinate. In the operational setup, the transition from terrain following levels in the lower atmosphere to constant height levels is completed at $z=16\,\mathrm{km}$. Model levels above are flat. The required smooth large-scale contribution of the model topography is generated by digital filtering with a ∇^2 -diffusion operator. Figure 2.4 shows the (half) levels of the planned operational ICON setup with 90 vertical levels. The table to the right shows the height above ground of selected half levels (for zero height topography) and the corresponding pressure, assuming the US standard atmosphere. Standard heights for all 91 half levels are given in Table A.1.

Please note that for grid cells with non-zero topography these values only represent rough estimates of the true level height. Actual heights may vary considerably from location to location, due to grid level stretching/compression over non-zero topography.

2.3 Refined subregion over Europe ("local nest")

ICON has the capability for running global simulations with refined domains (so called *nests*). The triangular mesh of the refined area is generated by bisection of triangles in the global "parent" grid, see Fig. 2.5. In the vertical the global grid extends into the mesosphere (which greatly facilitates the assimilation of satellite data) whereas the nested domains extend only into the lower stratosphere in order to save computing time. For each nesting level, the time step is automatically divided by a factor of two. Note that the grid nests are computed in a concurrent fashion:

 Points that are covered by the refined subdomain additionally contain data for the global grid state.

	ICON-EU nest	COSMO-EU
geogr. coordinates	23.5° W – 62.5° E	$\lambda_{\rm N} = 170^{\circ} {\rm W}, \phi_{\rm N} = 40^{\circ} {\rm N},$
	29.5° N – 70.5° N	$18.0^{\circ} \text{ W} - 23.5^{\circ} \text{ E}$
		$20.0^{\circ} \text{ S} - 21.0^{\circ} \text{ N}$
mesh size	$\approx 6.5 \text{ km (R3B8)}$	$0.0625^{\circ} \ (\approx 7 \ \mathrm{km})$
	659156 triangles	$665 \times 657 = 436905$ grid points
vertical levels	60 levels	40 levels
upper boundary	22.5 km	22.5 km

• The data points on the triangular grid are the cell circumcenters. Therefore the global grid data points are closely located to nest data sites, but they do not coincide exactly (see Fig. 2.5).

Currently, a refined subregion over Europe is in preparation, which is comparable to the COSMO-EU region of DWD's COSMO model. The geographical location of the nest is shown in Fig. 2.6a and Fig. 2.6b.

A test version of model simulations including the nesting region over Europe are running regularly, starting from

Currently only main forecasts at 00 and 12 UTC are performed, reaching out to $120\,h$, while forecasts starting at 06 and 18 UTC are limited to $33\,h$.

Simulation on the global grid and the regional (Europe) domain are tightly coupled (*two-way nesting*): Boundary data for the nest area is updated every time step (120 s). Feedback of atmospheric prognostic variabes (except precipitation) is computed via relaxation on a 3 h time scale.



level	[m]	[Pa]
1	75 000	2.1
5	64946	10.0
10	53878	46.3
15	44198	158.8
20	35958	487.2
25	29039	1355.0
30	23409	3211.8
35	19202	6209.4
40	16 108	10113.6
45	13822	14504.3
50	11822	19882.1
55	9822	27166.6
60	7822	36528.6
65	5822	48347.1
70	3954	62009.2
75	2432	75325.6
80	1255	87126.2
85	436	96190.0
90	20	101085.0

Figure 2.4: Vertical half levels (blue) and layer thickness (red) of the ICON operational setup. The table of selected pressure values (for zero height) is based on the 1976 US standard atmosphere.



Figure 2.5: ICON grid refinement (zoom view). Blue and red dots indicate the cell circumcenters for the global ("parent") and the refined ("child") domain, respectively.



Figure 2.6: 2.6a: Horizontal extent of the ICON-EU nest (orange shaded area) in a cylindrical equidistant projection. For comparison, the outline of the COSMO-EU nest is shown in red. 2.6b: Same as 2.6a but in a polar stereographic projection.

Chapter 3

Mandatory input fields

Several input files are needed to perform runs of the ICON Model. These can be divided into three classes: Grid files, external parameters, and initialization (analysis). The latter will be described in Chapter 4.

3.1 Grid Files

In order to run ICON, it is necessary to load the horizontal grid information as an input parameter. This information is stored within so-called grid files. For an ICON run, at least one global grid file is required. For model runs with nested grids, additional files of the nested domains are necessary. Optionally, a reduced radiation grid for the global domain may be used.

The unstructured triangular ICON grid resulting from the grid generation process is represented in NetCDF format. The most important data entries are

- cell (INTEGER dimension) number of (triangular) cells
- vertex (INTEGER dimension) number of triangle vertices
- edge (INTEGER dimension) number of triangle edges
- clon, clat (double array, dimension: #triangles, given in radians) longitude/latitude of the triangle circumcenters
- vlon, vlat (double array, dimension: #triangle vertices, given in radians) longitude/latitude of the triangle vertices
- elon, elat (double array, dimension: #triangle edges, given in radians) longitude/latitude of the edge midpoints
- cell_area (double array, dimension: #triangles) triangle areas
- vertex_of_cell (INTEGER array, dimensions: [3, #triangles])
 The indices vertex_of_cell(:,i) denote the triangle vertices that belong to the triangle i.
- edge_of_cell (INTEGER array, dimensions: [2, #triangles])
 The indices edge_of_cell(:,i) denote the triangle edges that belong to the triangle i.

3.2 External parameter

External parameters are used to describe the properties of the earth's surface. These data include the orography and the land-sea-mask. Also, several parameters are needed to specify the dominant land use of a grid box like the soiltype or the plant cover fraction.

The ExtPar software (ExtPar – External parameter for Numerical Weather Prediction and Climate Application) is able to generate external parameters for the ICON model. The generation is based on a set of raw-datafields which are listed in Table 3.1. For a more detailed overview of ExtPar, the reader is referred to the *User and Implementation Guide* of Extpar.

Table 3.1: Raw	datasets from	which tl	he ICON	external	parameter	fields are	derived.

Dataset	Source	Resolution
GLOBE orography	NOAA/NGDC	30"
GlobCover 2009	ESA	10"
GLCC land use	USGS	30"
HWSD Harmonized World Soil Database	FAO/IIASA/ISRIC/ISSCAS/JRC	30"
NDVI Climatotology, SeaWiFS	NASA/GSFC	2.5'
CRU near surface climatology	CRU University of East Anglia	0.5°
GACP Aerosol Optical thickness	NASA/GISS (Global Aerosol Climatology Project)	$4x5^{\circ}$
GLDB Global lake database	${\rm DWD/RSHU/MeteoFrance}$	30"
MODIS albedo	NASA	5'

GlobCover 2009 is a land cover database covering the whole globe, except for Antarctica. Therefore, we make use of GlobCover 2009 for $90^{\circ} > \phi > -56^{\circ}$ (with ϕ denoting latitude) and switch to the coarser, however globally available dataset GLCC for $-56^{\circ} > \psi > -90^{\circ}$.

The products generated by the ExtPar software package are listed in Table 3.2 together with the underlying raw dataset. Note that these are mandatory input fields for assimilation- and forecast runs.

Table 3.2: External parameter fields for ICON, produced by the ExtPar software package (in alphabetical order)

ShortName	Description	Raw dataset
AER_SS12	Sea salt aerosol climatology (monthly fields)	GACP
AER_DUST12	Total soil dust aerosol climatology (monthly fields)	GACP
AER_ORG12	Organic aerosol climatology (monthly fields)	GACP
AER_SO412	Total sulfate aerosol climatology (monthly fields)	GACP
AER_BC12	Black carbon aerosol climatology (monthly fields)	GACP
ALB_DIF12	Shortwave $(0.3-5.0\mu\mathrm{m})$ albedo for diffuse radiation (monthly fields)	MODIS

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Table 3.2: continued

ALB_UV12	UV-visible $(0.3-0.7\mu\mathrm{m})$ albedo for diffuse radiation (monthly fields)	MODIS
ALB_NI12	Near infrared $(0.7-5.0\mu\mathrm{m})$ albedo for diffuse radiation (monthly fields)	MODIS
DEPTH_LK	Lake depth	GLDB
EMIS_RAD	Surface longwave (thermal) emissivity	GlobCover 2009
FOR_D	Fraction of deciduous forest	GlobCover 2009
$FOR_{-}E$	Fraction of evergreen forest	GlobCover 2009
FR_LAKE	Lake fraction (fresh water)	GLDB
FR_LAND	Land fraction (excluding lake fraction but including glacier fraction)	GlobCover2009
FR_LUC	Landuse class fraction	
HSURF	Orography height at cell centres	GLOBE
LAI_MX	Leaf area index in the vegetation phase	GlobCover 2009
NDVI_MAX	Normalized differential vegetation index	SeaWiFS
NDVI_MRAT	proportion of monthly mean NDVI to yearly maximum (monthly fields)	SeaWiFS
PLCOV_MX	Plant covering degree in the vegetation phase	GlobCover 2009
ROOTDP	Root depth	GlobCover 2009
RSMIN	Minimum stomatal resistance	GlobCover 2009
SOILTYP	Soil type	HWSD
${\rm SSO_STDH}$	Standard deviation of sub-grid scale orographic height	GLOBE
SSO_THETA	Principal axis-angle of sub-grid scale orography	GLOBE
SSO_GAMMA	Horizontal anisotropy of sub-grid scale orography	GLOBE
${\rm SSO_SIGMA}$	Average slope of sub-grid scale orography	GLOBE
T_2M_CL	Climatological 2m temperature (serves as lower boundary condition for soil model)	CRU
Z0 (*)	Surface roughness length (over land), containing a contribution from subgrid-scale orography	GlobCover 2009

Note that fields marked with (*) are not required in operational model runs. I.e. the surface roughness ZO is only needed, if the additional contribution from sub-grid scale orography is taken into account (i.e. for itype_zO=1). In operational runs, land-use specific roughness lengths are taken from a GlobCoverbased lookup table. FOR_D and FOR_E will become obsolete, as soon as the surface tile approach (which is currently under development) is activated. However, due to technical reasons, all the above fields must be provided as input, irrespective of the options chosen.

Remarks on post-processing

Some of the external parameter fields produced by ExtPar are modified by ICON. The following fields are affected: HSURF, FR_LAND, FR_LAKE, Z0. Thus, for consistency reasons, the modified fields should be used for post-processing tasks rather than the original external parameter fields.

Chapter 4

Analysis fields

The 3-hourly first guess output of ICON contains the following fields:

Table 4.1: Available 3h first guess output fields

Type	GRIB shortName
Atmosphere	VN, U, V, W, DEN, THETA_V, T, QV, QC, QI, QR, QS, TKE, P
Surface (general)	T_G, T_SO(0), QV_S, T_2M, TD_2M, U_10M, V_10M, PS, Z0
Land specific	W_SNOW, T_SNOW, RHO_SNOW, H_SNOW, FRESHSNW, W_I, T_SO(1:nlev_soil), W_SO, W_SO_ICE
Lake/sea ice specific	T_MNW_LK, T_WML_LK, H_ML_LK, T_BOT_LK, C_T_LK, T_B1_LK, H_B1_LK, T_ICE, H_ICE, FR_ICE
Time invariant	FR.LAND, HHL, CLON, CLAT, ELON, ELAT, VLON, VLAT

Atmospheric analysis fields are computed every 3 hours (00, 03, 06,... 21 UTC) by the 3DVar data assimilation system. Sea surface temperature T_SO(0) and sea ice cover FR_ICE are provided once per day (00 UTC) by the SST-Analysis. A snow analysis is conducted every 3 hours. It povides updated information on the snow height H_SNOW and snow age FRESHSNW. In addition a soil moisture analysis (SMA) is conducted once per day (00 UTC). It basically modifies the soil moisture content W_SO, in order to improve the 2 m temperature forecast.

For the 3-hourly assimilation cycle and forecast runs, ICON must be provided with 2 input files: One containing the First Guess (FG) and the other containing analysis (AN) fields, only. Variables for which no analysis is available are always read from the first guess file (e.g. TKE). Other variables may be read either from the first guess or the analysis file, depending on the starting time. E.g. for T_SO(0) the first guess is read at 03, 06, 09, 12, 15, 18, 21 UTC, however, the analysis is read at 00 UTC. In Table 4.2 the available and employed first guess and analysis fields are listed as a function of starting time.

Table 4.2: The leftmost column shows variables that are mandatory for the assimilation cycle and forecast runs. Column 2 indicates, whether or not an analysis is performed for these variables. Columns 3 to 10 show the origin of these variables (analysis or first guess), depending on the starting time.

ShortName	Analysis	00	03	06	09	12	15	18	21
Atmosphere									
VN	_	FG							
$\mathrm{THETA}_{-}\mathrm{V}$	_	FG							
DEN	_	FG							
W	_	FG							
TKE	_	FG							
QC, QI, QR, QS	_	FG							
QV	3DVar	AN							
${ m T}$	3DVar	AN							
P	3DVar	AN							
U, V	3DVar	AN							
Surface									
Z0	_	FG							
$T_{-}G$	_	FG							
$\mathrm{QV}_{ ext{-}}\mathrm{S}$	_	FG							
$T_SO(0)$ (SST only)	Ana_SST	AN	FG						
$T_SO(0:nlevsoil)$	_	FG							
W_SO_ICE	_	FG							
$W_{-}SO$	SMA	AN	FG						
W_I	_	FG							
W_SNOW^1	Ana_SNOW	AN							
$T_{-}SNOW$	_	FG							
${ m RHO_SNOW^1}$	Ana_SNOW	AN							
H_SNOW	Ana_SNOW	AN							
FRESHSNW	Ana_SNOW	AN							
Sea ice/Lake									
$T_{-}ICE$	_	FG							
H_ICE	_	FG							
FR_ICE	Ana_SST	AN	FG						
T_MNW_LK	_	FG							
$T_{-}WML_{-}LK$	_	FG							

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Table 4.2: The leftmost column shows variables that are mandatory for the assimilation cycle and forecast runs. Column 2 indicates, whether or not an analysis is performed for these variables. Columns 3 to 10 show the origin of these variables (analysis or first guess), depending on the starting time.

ShortName	Analysis	00	03	06	09	12	15	18	21
H_ML_LK	_	FG							
T_BOT_LK	_	FG							
$C_{-}T_{-}LK$	_	FG							
T_B1_LK	_	FG							
H_B1_LK	_	FG							

4.1 Incremental analysis update

Analysis fields provided by the data assimilation system are usually not perfectly balanced, leading to e.g. the generation of spurious gravity waves. Thus, atmospheric models generally require some initialization procedure in order to minimize spin-up effects and to prevent the accumulation of noise. In ICON, a method known as Incremental Analysis Update (IAU) (Bloom et al., 1996, Polavarapu et al., 2004) is applied. The basic idea is quite simple: Rather than adding the analysis increments $\Delta \mathbf{x}^A = \mathbf{x}^A - \mathbf{x}^{FG}$ (i.e. the difference between the analysis \mathbf{x}^A and the model first guess \mathbf{x}^{FG}) in one go, they are incorporated into the model in small drips over many timesteps (see Figure 4.1).



Figure 4.1: Incremental Analysis Update. Analysis increments are added to the background state (FG) in small drips over some time interval rather than in one go. Currently, increments for U, V, P, T, QV are treated in this way.

¹Note that ρ_snow is read from the analysis, however it does not contain any new/independent information compared to the model first guess, except for an initialization of newly generated snow points and a limitation over glacier points. w_snow is read from the analysis, too, however it is re-diagnosed within the ICON-code based on the analyzed snow height h_snow and the former mentioned snow density ρ_snow .

Mathematically speaking, during forward integration the model is forced with appropriately weighted analysis increments:

$$\frac{\mathrm{d}\mathbf{x}}{\mathrm{d}t} = A\mathbf{x} + g(t)\Delta\mathbf{x}^A$$
, with $\int g(t)\,\mathrm{d}t = 1$ (4.1)

x is the discrete model state, A is a matrix representing the (non)-linear dynamics of the system and g(t) is a weighting function, which is non-zero over some time-interval Δt .

This drip by drip incorporation acts as a low pass filter in frequency domain on the analysis increments such that small scale unbalanced modes are effectively filtered (see Bloom et al. (1996)). The filter characteristic depends on the weighting function g(t). It should be noted that IAU only filters the increments and not the backgound state, such that regions where analysis increments are zero remain unaffected. This method is currently applied to the prognostic atmospheric fields π , ρ , v_n , q_v , based on analysis increments provided for u, v, p, t and q_v . π denotes the Exner pressure.

The method sounds incredibly simple, however there are a few technical aspects to be taken care of when implementing this into an operational system: Figure 4.2 shows how the IAU-method is implemented in ICON for a 3h assimilation run starting at midnight. Analysis increments are applied over a 3h hour time window, centered at the actual model start time. As indicated by the blue line, constant weights are used:

$$g(t) = \frac{\Delta t}{T}$$
, for $-T/2 < t < T/2$ (4.2)

T is the window width and Δt is the fast physics time step. The key point in terms of technical implementation is that the model must be started 90 minutes prior to the actual starting time of the assimilation run. The model is started from the 22:30 UTC first guess. The analysis increments for U, V, P, T, QV, whose validity time is 00:00 UTC are added over 3 hours until at 1:30 the free forecast starts. Then, two first guess data sets are written into the database. One at 1:30 UTC, which will be used for starting the next 3h assimilation run, and a second one at 3:00 UTC, which is required as input for the assimilation system itself. Thus in general, using the IAU method requires some care in terms of reading and writing the right fields at the right times.



Figure 4.2: Time line for an ICON assimilation run starting at 00:00 UTC.

Chapter 5

Global output fields: Forecast runs

ICON output fields are exclusively available in GRIB2 format (**GRI**dded **B**inary Edition **2**), with the exception of meteogram data (NetCDF). GRIB is a bit-oriented data storage format which was developed by WMO to facilitate the exchange of large volumes of gridded data between weather prediction centres. For decoding and encoding GRIB2 messages, the DWD in general and ICON in particular makes use of the ECMWF GRIB API. The current operational version at DWD is 1.12.3.

In GRIB2, a product (i.e. a variable/field) is identified by a set of three parameters

- Discipline (see GRIB2 code table 0.0)
- ParameterCategory (see GRIB2 code table 4.1)
- ParameterNumber (see GRIB2 code table 4.2),

augmented by a large number of additional metadata in order to uniquely describe the nature of the data. Noteworthy examples of additional metadata are

- typeOfFirstfixedSurface and typeOfSecondFixedSurface (see GRIB2 code table 4.5)
- typeOfStatisticalProcessing, former known as stepType (instant, accum, avg, max, min, diff, rms, sd, cov, ...): describes the statistical process used to calculate the field

just to name a few.

A documentation of the official WMO GRIB2 code tables can be found here:

http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/LatestVERSION/WMO306_vI2_GRIB2_CodeFlag_en.pdf

In the following, typeOfFirstFixedSurface and typeOfSecondFixedSurface will be abbreviated by Lev-Typ 1/2.

5.1 Deprecated output fields

With the launch of ICON, the following former GME output fields are no longer available:

• BAS_CON [-]: Level index of convective cloud base. Instead, HBAS_CON [m] should be used.

- TOP_CON [-]: Level index of convective cloud top. Instead, HTOP_CON [m] should be used.
- W_G1, W_G2 [mm H2O]: Soil water content in upper layer (0 to 10 cm) and middle layer (10 to 100 cm), respectively. If needed, these fields can be derived from W_SO.
- FIS [m² s⁻¹]: Surface Geopotential. Instead, HSURF [m] should be used (see Section 5.2).
- O3 [kg/kg], TO3 [Dobson]: Ozone mixing ratio and corresponding total ozone concentration. No longer available; no substitution

5.2 New output fields

Table 5.1 contains a list of new output fields that became available with the launch of ICON (compared to GME). A more thorough description of these fields is provided in Section 5.3.

Table 5.1: Newly available output fields

ShortName	Unit	Description					
		Atmosphere					
DEN	${\rm kgm^{-3}}$	density of moist air (3D field)					
TKE	$\rm m^2s^{-2}$	Turbulent kinetic energy (3D field)					
DTKE_CON	$\mathrm{m}^2\mathrm{s}^{-3}$	Buoyancy-production of TKE due to sub grid scale convection (3D field) $$					
\mathbf{W}	$\rm ms^{-1}$	vertical velocity in height coordinates $w = \frac{\mathrm{d}z}{\mathrm{d}t}$ (3D field)					
P	Pa	pressure (3D field)					
Surface							
CAPE_CON	$ m Jkg^{-1}$	Convective available potential energy (2D field)					
${f QV}_{-}{f 2M}$	$\rm kgkg^{-1}$	Specific humidity at 2m above ground (2D field)					
RELHUM_2M	%	Relative humidity at 2m above ground (2D field)					
SOBS_RAD	${ m Wm^{-2}}$	Net short-wave radiation flux at surface (instantaneous)					
$\mathbf{THBS_RAD}$	${ m Wm^{-2}}$	Net long-wave radiation flux at surface (instantaneous)					
		Lake					
C_T_LK	1	Shape factor with respect to the temperature profile in the thermocline (2D field)					
$H_{-}ML_{-}LK$	m	Mixed-layer depth (2D field)					
$T_{-}BOT_{-}LK$	K	Temperature at the water-bottom sediment interface (2D field)					
$\mathbf{T}_{-}\mathbf{M}\mathbf{N}\mathbf{W}_{-}\mathbf{L}\mathbf{K}$	K	Mean temperature of the water column (2D field)					
$\mathbf{T}_{-}\mathbf{WML}_{-}\mathbf{LK}$	K	Mixed-layer temperature (2D field)					
		Geometry					

Continued on next page

Table 5.1: continued

HSURF	m	Geometric Height of the earths surface above sea level (2D field)
HHL	m	Geometric Height of model half levels above sea level (3D field)
CLON,CLAT	\deg	Geographical longitude/latitude of native grid triangle cell center
ELON,ELAT	deg	Geographical longitude/latitude of native grid triangle edge midpoint $$
VLON,VLAT	deg	Geographical longitude/latitude of native grid triangle vertex

5.3 Available output fields

ICON forecasts are performed multiple times a day with varying forecast times. An overview of the various forecasts, including its forecast time and output intervals is provided in Figure 5.1.



Figure 5.1: Time span covered by the various ICON forecasts. A forecast run is launched every three hours. Output fields are available hourly up to $VV = 78\,\mathrm{h}$ and 3-hourly for larger forecast times. The vertical rules () and () indicate the time until when output is generally available on the native grid () and/or on the lat-lon grid ().

Main forecasts are performed 4 times a day at 0, 6, 12, 18 UTC, covering a forecast time span of 180 h for the 0 und 12 UTC runs and 120 h for the 6 und 18 UTC runs. Prior to 2015-02-25 the 6 and 18 UTC runs were restricted to 78 h. In preparation for the replacement of COSMO-EU by a high resolution ICON nest, additional short-range forecasts are performed at 3, 9, 15 and 21 UTC. The ICON nest will provide boundary data for the high resolution COSMO-DE runs, once COSMO-EU has been switched off. The forecast time covered by these runs is limited to 30 h. See Chapter 6 for more details on the ICON nest and the available output fields.

All time-dependent output fields are available hourly up to $VV = 78 \,\mathrm{h}$ and 3-hourly for larger forecast times². Please note that for ICON fields the time unit is minutes rather than hours, and thus differs from GME (hours).

Output is available on two distinct horizontal grids:

- The native triangular grid with an average resolution of 13 km, and
- a regular latitude-longitude grid with a resolution of $\Delta \lambda = \Delta \Phi = 0.25^{\circ}$.

On the native grid most output fields are defined on triangle cell (circum-)centers, except for VN, which is defined on cell edges. On the lat-lon grid, all fields are defined on cell centers. A single 2D GRIB2 field on the native and regular lat-lon grid contains 2949120 and 1036800 grid points, respectively.

For details regarding the available fields, please see the tables below. Note that the vertical rules in the leftmost column indicate whether the field is available on the native grid (\blacksquare), on the lat-lon grid(\blacksquare), or on both grids(\blacksquare).

For details regarding the algorithm for interpolation onto the lat-lon grid, see Section 8.2.

5.3.1 Time-constant (external parameter) fields

Table 5.2 provides an overview of the available time invariant fields. They are available from the database category CAT_NAME= $model_const_an_suite$. As mentioned in Section 3.2, HSURF, FR_LAND, FR_LAKE and ZO are modified by ICON. Thus, the latter should not be taken from the $const_an$ database categorie, unless you definitely know what you are doing. For convenience, the modified invariant fields (and some more) are stored in the forecast database categories for step s[h] = 0 (CAT_NAME= $model_suite$). Table 5.3 provides a list of all fields which are exclusively written for s[h] = 0.

See Section 9.1 for more details on the database categories and Section 9.2 for sample retrievals.

ShortName Discipline Category Number Description Unit Date/Time (YYYY-MM-DDThh) D=0001-01-01T00 HSURF Geometric height of the earths 0 3 6 1/101inst $_{\mathrm{m}}$ surface above msl

Table 5.2: Time-constant fields (CAT_NAME=\$model_const_an_\$suite)

Continued on next page

²An exception here are the lat-lon output fields U_10M and V_10M, which are available hourly throughout the forecast. This is because U_10M and V_10M are needed as input by the wave models.

Table 5.2: continued

CLAT	Geographical latitude of native grid triangle cell center	0	191	1	1/-	inst	Deg. N
CLON	Geographical longitude of native grid triangle cell center	0	191	2	1/-	inst	Deg. E
FOR_E	Fraction of evergreen forest (possible range $[0,1]$)	2	0	29	1/-	inst	1
FOR_D	Fraction of deciduous forest (possible range $[0,1]$)	2	0	30	1/-	inst	1
FR_LAND	Land fraction (possible range $[0,1]$)	2	0	0	1/-	inst	1
FR_LAKE	Fresh water lake fraction (possible range $[0,1]$)	1	2	2	1/-	inst	1
FR_LUC	Land use class fraction (possible range $[0,1]$)	2	0	36	1/-	inst	1
DEPTH_LK	Lake depth	1	2	0	1/162	inst	m
ROOTDP	Root depth of vegetation	2	0	32	1/-	inst	m
RSMIN	Minimum stomatal resistance	2	0	16	1/-	inst	${ m sm^{-1}}$
EMIS_RAD	Longwave surface emissivity	2	3	199	1/-	inst	1
SOILTYP	Soil type of land fraction (9 types $[1, \ldots, 9]$)	2	3	196	1/-	inst	1
SSO_STDH	Standard deviation of sub-grid scale orography	0	3	20	1/-	inst	m
SSO_GAMMA	Anisotropy of sub-gridscale orography	0	3	24	1/-	inst	1
SSO_THETA	Angle of sub-gridscale orography	0	3	21	1/-	inst	rad
SSO_SIGMA	Slope of sub-gridscale orography	0	3	22	1/-	inst	1
LAI_MX	Leaf area index in the vegetation phase	2	0	28	1/-	max	1
NDVI_MAX	Normalized differential vegetation index	2	0	31	1/-	max	1
PLCOV_MX	Plant covering degree in the vegetation phase	2	0	4	1/-	max	1
T_2M_CL	Climatological 2 m temperature (used as lower bc. for soil model)	0	0	0	103/-	inst	K

Continued on next page

Table 5.2: continued

Z0	Surface roughness length (over land)	2	0	1	1/-	inst	m
Ι	Date/Time (YYYY-MM-DDThh)) D =1	111-0)1-11T	711		
AER_SS12	Sea salt aerosol climatology (monthly fields)	0	20	102	1/-	avg	1
AER_DUST12	Total soil dust aerosol climatology (monthly fields)	0	20	102	1/-	avg	1
AER_ORG12	Organic aerosol climatology (monthly fields)	0	20	102	1/-	avg	1
AER_SO412	Total sulfate aerosol climatology (monthly fields)	0	20	102	1/-	avg	1
AER_BC12	Black carbon aerosol climatology (monthly fields)	0	20	102	1/-	avg	1
ALB_DIF12	Shortwave $(0.3-5.0\mu\mathrm{m})$ albedo for diffuse radiation (monthly fields)	0	19	18	1/-	avg	1
ALBUV12	UV-visible $(0.3-0.7\mu\mathrm{m})$ albedo for diffuse radiation (monthly fields)	0	19	222	1/-	avg	1
ALB_NI12	Near infrared $(0.7-5.0\mu\mathrm{m})$ albedo for diffuse radiation (monthly fields)	0	19	223	1/-	avg	1
NDVI_MRAT	ratio of monthly mean NDVI (normalized differential vegetation index) to annual max	0	0	192	1/-	avg	1

Table 5.3: Variables exclusively available for VV=0 from the forecast databases (CAT_NAME=\$model_\$run_fc_\$suite, s[h]=0)

ShortName	${\bf Description}$	Discipline	Category	Number	$\mathrm{Lev}\text{-}\mathrm{Typ}\ 1/2$	${ m stepType}$	Unit
Z CLAT	Geographical latitude of native grid triangle cell center	0	191	1	1/-	inst	Deg. N
Z CLON	Geographical longitude of native grid triangle cell center	0	191	2	1/-	inst	Deg. E
Ø DEPTH_LK	Lake depth	1	2	0	1/162	inst	m

 $Continued\ on\ next\ page$

Table 5.3: continued

ELAT	Geographical latitude of native grid triangle edge midpoint	0	191	1	1/-	inst	Deg. N
ELON	Geographical longitude of native grid triangle edge midpoint	0	191	2	1/-	inst	Deg. E
FR_LAKE	Fresh water lake fraction (possible range $[0,1]$)	1	2	2	1/-	inst	1
FR_LAND	Land fraction (possible range $[0,1]$)	2	0	0	1/-	inst	1
HHL	Geometric height of model half levels above msl	0	3	6	150/101	inst	m
HSURF	Geometric height of the earths surface above msl	0	3	6	1/101	inst	m
LAI	Leaf area index	2	0	28	1/-	inst	1
NDVIRATIO	ratio of current NDVI (normalized differential vegetation index) to annual max	2	0	192	1/-	inst	1
PLCOV	Plant cover	2	0	4	1/-	inst	%
RLAT	Geographical latitude of regular lat-lon grid cell centers	0	191	1	1/-	inst	Deg. N
RLON	Geographical longitude of regular lat-lon grid cell centers	0	191	2	1/-	inst	Deg. E
ROOTDP	Root depth of vegetation	2	0	32	1/-	inst	m
SOILTYP	Soil type of land fraction (9 types $[1, \ldots, 9]$)	2	3	196	1/-	inst	1
VLAT	Geographical latitude of native grid triangle vertex	0	191	1	1/-	inst	Deg. N
VLON	Geographical longitude of native grid triangle vertex	0	191	2	1/-	inst	Deg. E

5.3.2 Multi-level fields on native hybrid vertical levels

Table 5.4: Hybrid multi-level forecast (VV > 0) and initialised analysis (VV = 0) products

ShortName	$ {\bf Description}$	Discipline	Category	Number	Lev-Typ 1/2	$\operatorname{stepType}$	Unit
7 CLC	Cloud cover	0	6	22	150/150	inst	%
Z DEN	Density of moist air	0	3	10	150/150	inst	${\rm kgm^{-3}}$
DTKE_CON	Buoyancy-production of TKE due to sub grid scale convection	0	19	219	150/-	inst	$\mathrm{m}^2\mathrm{s}^{-3}$
P	Pressure	0	3	0	150/150	inst	Pa
V QC	Cloud mixing ratio ²	0	1	22	150/150	inst	$\rm kgkg^{-1}$
Ø□ QI	Cloud ice mixing ratio ²	0	1	82	150/150	inst	$\rm kgkg^{-1}$
Q R	Rain mixing ratio ²	0	1	24	150/150	inst	$\rm kgkg^{-1}$
Q S	Snow mixing ratio ²	0	1	25	150/150	inst	$\rm kgkg^{-1}$
Ø QV	Specific humidity	0	1	0	150/150	inst	$\rm kgkg^{-1}$
V ∃ T	Temperature	0	0	0	150/150	inst	K
¼ TKE	Turbulent kinetic energy	0	19	11	150/-	inst	$\mathrm{m}^2\mathrm{s}^{-2}$
Z ■ U	Zonal wind	0	2	2	150/150	inst	${ m ms^{-1}}$
Z ■ V	Meridional wind	0	2	3	150/150	inst	$\rm ms^{-1}$
Ø■ W	Vertical wind	0	2	9	150/-	inst	${ m ms^{-1}}$

5.3.3 Multi-level fields interpolated to pressure levels

For regular grid output the following pressure levels are available:

 $1000,\ 975,\ 950,\ 925,\ 900,\ 875,\ 850,\ 825,\ 800,\ 775,\\ 750,\ 725,\ 700,\ 600,\ 500,\ 400,\ 300,\ 250,\ 200,\ 150,\ 100,\\ 70,\ 50,\ 30,\ 20,\ 10,\ 7,\ 5,\ 3,\ 2,\ 1,\ 0.3,\ 0.1\ \mathrm{hPa}.$

 $^{^2}$ for the time being, erroneously encoded as mixing ratios instead of specific quantities

Newly available pressure levels (as compared to GME) are highlighted in red. The output fields are listed in Table 5.5. I.e. note that all 17 WMO standard pressure levels are included.

Table 5.5: Regular grid output: Multi-level forecast (VV>0) and initialised analysis (VV=0) products interpolated to pressure levels 1000, 975, 950, 925, 900, 875, 850, 825, 800, 775, 750, 725, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10, 7, 5, 3, 2, 1, 0.3, 0.1 hPa.

ShortName	Description	Discipline	Category	Number	Lev-Typ $1/2$	${\rm stepType}$	Unit
FI	Geopotential	0	3	4	100/-	inst	$\mathrm{m}^2\mathrm{s}^{-2}$
OMEGA	Vertical velocity in pressure coordinates ($\omega = \mathrm{d}p/\mathrm{d}t$)	0	2	8	100/-	inst	$\mathrm{Pa}\mathrm{s}^{-1}$
RELHUM	Relative humidity (with respect to water)	0	1	1	100/-	inst	%
\blacksquare T	Temperature	0	0	0	100/-	inst	K
U	Zonal wind	0	2	2	100/-	inst	$\rm ms^{-1}$
■ V	Meridional wind	0	2	3	100/-	inst	${ m ms^{-1}}$

Table 5.6: Native (triangular) grid output: Multi-level forecast (VV > 0) and initialised analysis (VV = 0) products interpolated to pressure levels 1000, 950, 850, 700, 500, 300 hPa.

	${\bf ShortName}$		Discipline	Category	Number	m Lev-Typ~1/2	$\operatorname{stepType}$	Unit
	FI	Geopotential	0	3	4	100/-	inst	$\mathrm{m}^2\mathrm{s}^{-2}$
	RELHUM	Relative humidity (with respect to water)	0	1	1	100/-	inst	%
	T	Temperature	0	0	0	100/-	inst	K
Z	U	Zonal wind	0	2	2	100/-	inst	${ m ms^{-1}}$
	V	Meridional wind	0	2	3	100/-	inst	$\rm ms^{-1}$

On the native (triangular) grid, output is generated for levels

1000, 950, 850, 700, 500, 300 hPa.

The output fields are listed in Table 5.6.

5.3.4 Multi-level fields interpolated to height levels

Table 5.7: Regular grid output: Multi-level forecast (VV>0) and initialised analysis (VV=0) products interpolated to height levels 10000, 5000, 3000, 2000, 1500, 1000, 500, 100 m (above mean sea level).

ShortName	Description	Discipline	Category	Number	Lev-Typ $1/2$	${\rm stepType}$	Unit
U	Zonal wind	0	2	2	102 / -	inst	${ m ms^{-1}}$
■ V	Meridional wind	0	2	3	102/-	inst	$\rm ms^{-1}$
■ W	Vertical wind	0	2	9	102/-	inst	$\rm ms^{-1}$
\blacksquare T	Temperature	0	0	0	102 / -	inst	K
P	Pressure	0	3	0	102/-	inst	Pa

5.3.5 Single-level fields

Table 5.8: Single-level forecast (VV > 0) and initialised analysis (VV = 0) products

ShortName	Description	Discipline	Category	Number	Lev-Typ 1/2	stepType	Unit
				—		0 2	
Z ALB_RAD	Shortwave broadband albedo for diffuse radiation	0	19	1	1/-	inst	%
ALHFL_S	Latent heat net flux at surface (average since model start)	0	0	10	1/-	avg	${ m Wm^{-2}}$
APAB_S	Photosynthetically active radiation flux at surface (average since model start)	0	4	10	1/-	avg	${ m Wm^{-2}}$
ASHFL_S	Sensible heat net flux at surface (average since model start)	0	0	11	1/-	avg	${ m Wm^{-2}}$
ASOB_S	Net short-wave radiation flux at surface (average since model start)	0	4	9	1/-	avg	${ m Wm^{-2}}$
¼ ASOB_T	Net short-wave radiation flux at TOA (average since model start)	0	4	9	8/-	avg	${ m Wm^{-2}}$
ASWDIFD_S	Surface down solar diffuse radiation (average since model start)	0	4	199	1/-	avg	${ m Wm^{-2}}$
ASWDIFU_S	Surface up solar diffuse radiation (average since model start)	0	4	8	1/-	avg	${ m Wm^{-2}}$
ASWDIR_S	Surface down solar direct radiation (average since model start)	0	4	198	1/-	avg	$ m Wm^{-2}$
¼ ATHB_S	Net long-wave radiation flux at surface (average since model start)	0	5	5	1/-	avg	${ m Wm^{-2}}$
¼ ATHB_T	Net long-wave radiation flux at TOA (average since model start)	0	5	5	8/-	avg	${ m Wm^{-2}}$
¼ AUMFL_S	U-momentum flux at surface $\overline{u'w'}^{1/2}$ (average since model start)	0	2	17	1/-	avg	m
AVMFL_S	V-momentum flux at surface $\overline{v'w'}^{1/2}$ (average since model start)	0	2	18	1/-	avg	m
Z CAPE_CON	Convective available potential energy	0	7	6	1/-	inst	$\rm Jkg^{-1}$
¼ CLCH	High level clouds	0	6	22	100/100	inst	%

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Table 5.8: continued

ZE CLCM	Mid level clouds	0	6	22	100/100	inst	%
CLCL	Low level clouds	0	6	22	100/1	inst	%
Z CLCT	Total cloud cover	0	6	1	1/-	inst	%
■ CLCT_MOD	Modified total cloud cover for media	0	6	199	1/-	inst	1
■ CLDEPTH	Modified cloud depth for media	0	6	198	1/-	inst	1
FRESHSNW	Fresh snow factor (weighting function for albedo indicating freshness of snow)	0	1	203	1/-	inst	1
FR_ICE	Sea/lake ice cover (possible range: $[0,1]$)	10	2	0	1/-	inst	1
HBAS_CON	Height of convective cloud base above msl	0	6	26	2/101	inst	m
HICE	Sea/Lake ice thickness (Max: 3 m)	10	2	1	1/-	inst	m
H_SNOW	Snow depth	0	1	11	1/-	inst	m
HTOP_CON	Height of convective cloud top above msl	0	6	27	3/101	inst	m
HTOP_DC	Height of top of dry convection above msl	0	6	196	3/101	inst	m
HZEROCL	Height of 0 degree Celsius isotherm above msl	0	3	6	4/101	inst	m
PS	Surface pressure (not reduced)	0	3	0	1/-	inst	Pa
■ QV_2M	Specific humidity at 2m above ground	0	1	0	103/-	inst	$\rm kgkg^{-1}$
Ø QV_S	Surface specific humidity	0	1	0	1/-	inst	$\rm kgkg^{-1}$
RAIN_CON ⁴	Convective rain (accumulated since model start)	0	1	76	1/-	accu	${\rm kgm^{-2}}$
RAIN_GSP ⁴	Large scale rain (accumulated since model start)	0	1	77	1/-	accu	${\rm kgm^{-2}}$
RELHUM_2M	Relative humidity at 2m above ground	0	1	1	103/-	inst	%
RHO_SNOW	Snow density	0	1	61	1/-	inst	${\rm kgm^{-3}}$

 $Continued\ on\ next\ page$

Table 5.8: continued

RSTOM	I Stomatal resistar	ace	2	0	195	1/-	inst	${ m sm^{-1}}$
Z RUNOF	F_G Soil water runoff since model start	•	2	0	5	106/-	accu	${\rm kgm^{-2}}$
RUNOF	Surface water run since model start	noff (accumulated)	2	0	5	106/-	accu	${\rm kgm^{-2}}$
SNOW_	CON ⁴ Convective snown equivalent (accur model start)		0	1	55	1/-	accu	${\rm kgm^{-2}}$
SNOW_	GSP ⁴ Large snowfall w (accumulated sin	_	0	1	56	1/-	accu	${\rm kg}{\rm m}^{-2}$
■ SOBS_R	AD Net short-wave resurface (instanta)		0	4	9	1/-	inst	${ m Wm^{-2}}$
Z T_2M	Temperature at 2	2m above ground	0	0	0	103/-	inst	K
∥ ∃ TCH	Turbulent transfer heat and moistur		0	0	19	1/-	inst	1
TCM	Turbulent transfer momentum (surf		0	2	29	1/-	inst	1
TD_2M	Dew point temperabove ground	erature at 2m	0	0	6	103/-	inst	K
$T_{-}G$	Ground temperate at sfc-atm interfa	ture (temperature	0	0	0	1/-	inst	K
THBS_F	RAD Net long-wave ra surface (instanta		0	5	5	1/-	inst	${ m Wm^{-2}}$
T_ICE	Sea/Lake ice tem ice-atm interface		10	2	8	1/-	inst	K
TMAX_	2M Maximum tempe above ground	rature at 2m	0	0	0	103/-	max	K
TMIN_2	Minimum temper above ground	rature at 2m	0	0	0	103/-	min	K
TOT_PI	REC ⁴ Total precipitation since model start	*	0	1	52	1/-	accu	$\rm kgm^{-2}$
TQC	Column integrate (grid scale)	ed cloud water	0	1	69	1/-	inst	$\rm kgm^{-2}$
TQC_DI	Total column int water (including contribution)	_	0	1	215	1/-	inst	${\rm kgm^{-2}}$
TQI	Column integrate scale)	ed cloud ice (grid	0	1	70	1/-	inst	$\rm kgm^{-2}$

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Table 5.8: continued

TQI_DIA	Total column integrated cloud ice (including sub-grid-scale contribution)	0	1	216	1/-	inst	${\rm kgm^{-2}}$
TQR	Column integrated rain (grid scale)	0	1	45	1/-	inst	${\rm kgm^{-2}}$
TQS	Column integrated snow (grid scale)	0	1	46	1/-	inst	${\rm kgm^{-2}}$
TQV	Column integrated water vapour (grid scale)	0	1	64	1/-	inst	${\rm kgm^{-2}}$
T₋S	Temperature of the soil surface (equivalent to T_SO(0))	2	3	18	1/-	inst	K
T_SNOW	Temperature of the snow surface	0	0	18	1/-	inst	K
¼ U_10M	Zonal wind at 10m above ground	0	2	2	103/-	inst	${ m ms^{-1}}$
V -10M	Meridional wind at 10m above ground	0	2	3	103/-	inst	$\rm ms^{-1}$
VMAX_10M	Maximum wind at $10\mathrm{m}$ above ground	0	2	22	103/-	max	${ m ms^{-1}}$
LW N	Plant canopy surface water	2	0	13	1/-	inst	$\rm kgm^{-2}$
W_SNOW	Snow depth water equivalent	0	1	60	1/-	inst	${\rm kgm^{-2}}$
¼ WW	Weather interpretation (WMO)	0	19	25	1/-	inst	1
Z ZO	Surface roughness (above land and water)	2	0	1	1/-	inst	m

5.3.6 Surface fields interpolated to msl

 $[\]overline{\ ^4 \text{Note that the unit which is displayed, when inspecting the GRIB2 message with $grib_dump$ is kg m$^{-2}$ s$^{-1}$ rather than kg m$^{-2}$. Mathematically this is wrong, however, it is in accordance with the GRIB2 standard. To get the mathematically correct unit for accumulated fields (<math>typeOfStatisticalProcessing=1$), the unit displayed by $grib_dump$ must be multiplied by s.

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Table 5.9: Forecast (VV > 0) and initialised analysis (VV = 0) products interpolated to msl

ShortName	Description	Discipline	Category	Number	m Lev-Typ~1/2	$\operatorname{stepType}$	Unit
PMSL	Surface pressure reduced to msl	0	3	1	101/-	inst	Pa

5.3.7 Soil-specific multi-level fields

Table 5.10: Multi-level forecast (VV > 0) and initialised analysis (VV = 0) products of the soil model

ShortName	Description	Discipline	Category	Number	m Lev-Typ~1/2	$\operatorname{stepType}$	Unit
T_SO	Soil temperature	2	3	18	106/-	inst	K
₩ SO	Soil moisture integrated over individual soil layers (ice + liquid)	2	3	20	106/106	inst	${\rm kgm^{-2}}$
W_SO_ICE	Soil ice content integrated over individual soil layers	2	3	22	106/106	inst	${\rm kgm^{-2}}$

Soil temperature is defined at the soil depths given in Table 5.11 (column 2). Levels 1 to 8 define the full levels of the soil model. A zero gradient condition is assumed between levels 0 and 1, meaning that temperatures at the surface-atmosphere interface are set equal to the temperature at the first full level depth. (0.5 cm). Temperatures are prognosed for layers 1 to 7. At the lowermost layer (mid-level height 1458 cm) the temperature is fixed to the climatological average 2 m-temperature.

Soil moisture W_SO is prognosed for layers 1 to 6. In the two lowermost layers W_SO is filled with W_SO(6) (zero gradient condition).

level no.	depth [cm]	layer no.	upper/lower bounds [cm]
0	0.0		
1	0.5	1	0.0 - 1.0
2	2.0	2	1.0 - 3.0
3	6.0	3	3.0 - 9.0
4	18.0	4	9.0 - 27.0
5	54.0	5	27.0 - 81.0
6	162.0	6	81.0 - 243.0
7	486.0	7	243.0 - 729.0
8	1458.0	8	729.0 - 2187.0

 ${\bf Table~5.11:~Soil~model:~vertical~distribution~of~levels~and~layers}$

5.3.8 Lake-specific single-level fields

Table 5.12: Single-level forecast (VV > 0) and initialised analysis (VV = 0) products of the lake model model

ShortName	Description	Discipline	Category	Number	Lev-Typ 1/2	$\operatorname{stepType}$	Unit
C_T_LK	Shape factor with respect to the temperature profile in the thermocline	1	2	10	162/166	inst	1
H_ML_LK	Mixed-layer depth	1	2	0	1/166	inst	m
T_BOT_LK	Temperature at the water-bottom sediment interface	1	2	1	$162/\!-$	inst	K
T_MNW_LK	Mean temperature of the water column	1	2	1	1/162	inst	K
T_WML_LK	Mixed-layer temperature	1	2	1	1/166	inst	K

Chapter 6

EU Nest output fields: Forecast runs

6.1 Available output fields

This section contains a list of output fields that are available with the launch of the ICON-EU nest. See Fig. 2.6a on page 8 for details regarding the nest location and extent. Forecasts on the EU-nest are performed multiple times a day with varying forecast times. Forecasts reaching out to 120 h are performed at 0, 6, 12, and 18 UTC. Additional short-range forecasts reaching out to 30 h are performed at 3, 9, 15 and 21 UTC. Its main purpose is to provide boundary data for the high resolution COSMO-DE runs. A schematic overview of the various forecasts, including its forecast time and output intervals is provided in Figure 6.1.

Output is available on two distinct horizontal grids:

- a native triangular grid with an average resolution of 6.5 km, and
- a regular latitude-longitude grid with a resolution of $\Delta \lambda = \Delta \Phi = 0.0625^{\circ}$.

Note that output on the native (triangular) grid is limited to 48 h, whereas output on the regular grid is generally available til forecast end. See also Figure 6.1.

Again, in the subsequent tables the availability of specific field on the native grid (\checkmark), on the lat-lon grid(\checkmark), or on both grids (\checkmark) is marked in the leftmost column.

6.1.1 Time-constant (external parameter) fields for the EU nest



Figure 6.1: Time span covered by the various EU nest forecasts. A forecast run is launched every three hours. Output fields are available hourly up to $VV = 78 \,\mathrm{h}$ and 3-hourly for larger forecast times. The vertical rules indicate the time until when output is generally available on the native grid () and/or on the lat-lon grid (). I.e. output on the native grid is limited to $VV = 48 \,\mathrm{h}$.

Table 6.1: Variables exclusively available for VV=0 from the forecast databases (CAT_NAME=\$model_\$run_fc_\$suite, s[h]=0)

${\bf ShortName}$	Description	Discipline	Category	Number	$\mathrm{Lev}\text{-}\mathrm{Typ}\ 1/2$	${\rm stepType}$	Unit
Z CLAT	Geographical latitude of native grid triangle cell center	0	191	1	1/-	inst	Deg. N
Z CLON	Geographical longitude of native grid triangle cell center	0	191	2	1/-	inst	Deg. E
■ DEPTH_LK	Lake depth	1	2	0	1/162	inst	m

Continued on next page

Table 6.1: continued

ELAT	Geographical latitude of native grid triangle edge midpoint	0	191	1	1/-	inst	Deg. N
ELON	Geographical longitude of native grid triangle edge midpoint	0	191	2	1/-	inst	Deg. E
FR_LAKE	Fresh water lake fraction (possible range $[0,1]$)	1	2	2	1/-	inst	1
FR_LAND	Land fraction (possible range $[0,1]$)	2	0	0	1/-	inst	1
HHL	Geometric height of model half levels above msl	0	3	6	150/101	inst	m
HSURF	Geometric height of the earths surface above msl	0	3	6	1/101	inst	m
LAI	Leaf area index	2	0	28	1/-	inst	1
PLCOV	Plant cover	2	0	4	$1/\!-$	inst	%
RLAT	Geographical latitude of regular lat-lon grid cell centers	0	191	1	1/-	inst	Deg. N
RLON	Geographical longitude of regular lat-lon grid cell centers	0	191	2	1/-	inst	Deg. E
ROOTDP	Root depth of vegetation	2	0	32	1/-	inst	m
SOILTYP	Soil type of land fraction (9 types $[1, \ldots, 9]$)	2	3	196	1/-	inst	1
VLAT	Geographical latitude of native grid triangle vertex	0	191	1	1/-	inst	Deg. N
VLON	Geographical longitude of native grid triangle vertex	0	191	2	1/-	inst	Deg. E

6.1.2 Multi-level fields on native hybrid vertical levels for the EU nest

Table 6.2: Hybrid multi-level forecast (VV > 0) and initialised analysis (VV = 0) products

ShortName	Description	Discipline	Category	Number	Lev-Typ $1/2$	$\operatorname{stepType}$	Unit
■ CLC	Cloud cover	0	6	22	150/150	inst	%
DTKE_CON	Buoyancy-production of TKE due to sub grid scale convection	0	19	219	150/-	inst	$\mathrm{m}^2\mathrm{s}^{-3}$
∕ ₽	Pressure	0	3	0	150/150	inst	Pa

 $Continued\ on\ next\ page$

Table 6.2: continued

<mark>∕</mark> QC	Cloud mixing ratio ²	0	1	22	150/150	inst	$kg kg^{-1}$
Ø QI	Cloud ice mixing ratio ²	0	1	82	150/150	inst	$\rm kgkg^{-1}$
Q R	Rain mixing ratio ²	0	1	24	150/150	inst	$\rm kgkg^{-1}$
Q S	Snow mixing ratio ²	0	1	25	150/150	inst	$\rm kgkg^{-1}$
Ø∃ QV	Specific humidity	0	1	0	150/150	inst	$\rm kgkg^{-1}$
¼ ∃ T	Temperature	0	0	0	150/150	inst	K
■ TKE	Turbulent kinetic energy	0	19	11	150/-	inst	$\mathrm{m}^2\mathrm{s}^{-2}$
Ø ₽ U	Zonal wind	0	2	2	150/150	inst	${ m ms^{-1}}$
V V	Meridional wind	0	2	3	150/150	inst	$\rm ms^{-1}$
Ø∃ W	Vertical wind	0	2	9	150/-	inst	$\rm ms^{-1}$

6.1.3 Multi-level fields interpolated to pressure levels

For regular grid output the following pressure levels are available:

```
1000, 975, 950, 925, 900, 875, 850, 825, 800, 775, 750, 725, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50 hPa.
```

Newly available pressure levels (as compared to COSMO-EU) are highlighted in red. The output fields are listed in Table 6.3.

On the native (triangular) grid no output is generated for pressure levels.

 $^{^{2}}$ for the time being, erroneously encoded as mixing ratios instead of specific quantities

Table 6.3: Regular grid output on the ICON EU Nest: Multi-level forecast (VV>0) and initialised analysis (VV=0) products interpolated to pressure levels 1000, 975, 950, 925, 900, 875, 850, 825, 800, 775, 750, 725, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50 hPa.

ShortName	Description	Discipline	Category	Number	Lev-Typ $1/2$	${\rm stepType}$	Unit
∃ FI	Geopotential	0	3	4	100/-	inst	$\mathrm{m}^2\mathrm{s}^{-2}$
OMEGA	Vertical velocity in pressure coordinates $(\omega = \mathrm{d}p/\mathrm{d}t)$	0	2	8	100/-	inst	$\mathrm{Pa}\mathrm{s}^{-1}$
■ RELHUM	Relative humidity (with respect to water)	0	1	1	100/-	inst	%
\blacksquare T	Temperature	0	0	0	100/-	inst	K
U	Zonal wind	0	2	2	100/-	inst	$\rm ms^{-1}$
V	Meridional wind	0	2	3	100 / -	inst	$\rm ms^{-1}$

6.1.4 Multi-level fields interpolated to height levels

Table 6.4: Regular grid output on the ICON EU Nest: Multi-level forecast (VV > 0) and initialised analysis (VV = 0) products interpolated to height levels 10000, 5000, 3000, 2000, 1500, 1000, 500, 100 m (above mean sea level).

ShortName	Description	Discipline	Category	Number	m Lev-Typ~1/2	$\operatorname{stepType}$	Unit
U	Zonal wind	0	2	2	102/-	inst	${ m ms^{-1}}$
■ V	Meridional wind	0	2	3	102/-	inst	$\rm ms^{-1}$
\blacksquare W	Vertical wind	0	2	9	102 / -	inst	$\rm ms^{-1}$
\blacksquare T	Temperature	0	0	0	102/-	inst	K
₽	Pressure	0	3	0	102/-	inst	Pa

6.1.5 Single-level fields

Table 6.5: Single-level forecast (VV > 0) and initialised analysis (VV = 0) products on the ICON EU Nest

ShortName	Description	Discipline	Category	Number	Lev-Typ 1/2	stepType	Unit
ALB_RAD	Shortwave broadband albedo for diffuse radiation	0	19	1	1/-	inst	%
ALHFL_S	Latent heat net flux at surface (average since model start)	0	0	10	1/-	avg	${ m Wm^{-2}}$
■ APAB_S	Photosynthetically active radiation flux at surface (average since model start)	0	4	10	1/-	avg	${ m Wm^{-2}}$
ASHFL_S	Sensible heat net flux at surface (average since model start)	0	0	11	1/-	avg	${ m Wm^{-2}}$
ASOB_S	Net short-wave radiation flux at surface (average since model start)	0	4	9	1/-	avg	${ m Wm^{-2}}$
ASOB_T	Net short-wave radiation flux at TOA (average since model start)	0	4	9	8/-	avg	${ m Wm^{-2}}$
ASWDIFD_S	Surface down solar diffuse radiation (average since model start)	0	4	199	1/-	avg	${ m Wm^{-2}}$
ASWDIFU_S	Surface up solar diffuse radiation (average since model start)	0	4	8	1/-	avg	${ m Wm^{-2}}$
ASWDIR_S	Surface down solar direct radiation (average since model start)	0	4	198	1/-	avg	${ m Wm^{-2}}$
ATHB_S	Net long-wave radiation flux at surface (average since model start)	0	5	5	1/-	avg	${ m Wm^{-2}}$
ATHB_T	Net long-wave radiation flux at TOA (average since model start)	0	5	5	8/-	avg	${ m Wm^{-2}}$
AUMFL_S	U-momentum flux at surface $\overline{u'w'}^{1/2}$ (average since model start)	0	2	17	1/-	avg	m
AVMFL_S	V-momentum flux at surface $\overline{v'w'}^{1/2}$ (average since model start)	0	2	18	1/-	avg	m
CAPE_CON	Convective available potential energy	0	7	6	1/-	inst	$\rm Jkg^{-1}$
■ CLCH	High level clouds	0	6	22	100/100	inst	%
■ CLCM	Mid level clouds	0	6	22	100/100	inst	%
■ CLCL	Low level clouds	0	6	22	100/1	inst	%

Continued on next page

Table 6.5: continued

	CLCT	Total cloud cover	0	6	1	1/-	inst	%
	CLCT_MOD	Modified total cloud cover for media	0	6	199	1/-	inst	1
	CLDEPTH	Modified cloud depth for media	0	6	198	1/-	inst	1
Z	FRESHSNW	Fresh snow factor (weighting function for albedo indicating freshness of snow)	0	1	203	1/-	inst	1
	HBAS_CON	Height of convective cloud base above msl	0	6	26	2/101	inst	m
	H_ICE	Sea/Lake ice thickness (Max: $3\mathrm{m}$)	10	2	1	1/-	inst	m
	H_SNOW	Snow depth	0	1	11	1/-	inst	m
	HTOP_CON	Height of convective cloud top above msl	0	6	27	3/101	inst	m
	HTOP_DC	Height of top of dry convection above msl	0	6	196	3/101	inst	m
	HZEROCL	Height of 0 degree Celsius isotherm above msl	0	3	6	4/101	inst	m
	PS	Surface pressure (not reduced)	0	3	0	1/-	inst	Pa
	$\mathrm{QV}_{-}\!\mathrm{S}$	Surface specific humidity	0	1	0	1/-	inst	$\rm kgkg^{-1}$
	RAIN_CON	Convective rain (accumulated since model start)	0	1	76	1/-	accu	${\rm kgm^{-2}}$
	RAIN_GSP	Large scale rain (accumulated since model start)	0	1	77	1/-	accu	${\rm kgm^{-2}}$
	RELHUM_2M	Relative humidity at 2m above ground	0	1	1	103/-	inst	%
	RHO_SNOW	Snow density	0	1	61	1/-	inst	${\rm kgm^{-3}}$
	RUNOFF_G	Soil water runoff (accumulated since model start)	2	0	5	106/-	accu	${\rm kgm^{-2}}$
	RUNOFF_S	Surface water runoff (accumulated since model start)	2	0	5	106/-	accu	${\rm kgm^{-2}}$
	SNOW_CON	Convective snowfall water equivalent (accumulated since model start)	0	1	55	1/-	accu	$\rm kgm^{-2}$
	SNOW_GSP	Large snowfall water equivalent (accumulated since model start)	0	1	56	1/-	accu	${\rm kgm^{-2}}$
	$\rm SNOWLMT^5$	Height of snowfall limit above MSL	0	1	204	4/101	inst	m
	$T_{-}2M$	Temperature at 2m above ground	0	0	0	103/-	inst	K

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Table 6.5: continued

■ TCH	Turbulent transfer coefficient for heat and moisture (surface)	0	0	19	1/-	inst	1
■ TCM	Turbulent transfer coefficient for momentum (surface)	0	2	29	1/-	inst	1
■ TD ₋₂ M	Dew point temperature at 2m above ground	0	0	6	103/-	inst	K
T_G	Ground temperature (temperature at sfc-atm interface)	0	0	0	1/-	inst	K
TICE	Sea/Lake ice temperature (at ice-atm interface)	10	2	8	1/-	inst	K
■ TMAX_2M	Maximum temperature at 2m above ground	0	0	0	103/-	max	K
■ TMIN_2M	Minimum temperature at 2m above ground	0	0	0	103/-	min	K
TOT_PREC	Total precipitation (accumulated since model start)	0	1	52	1/-	accu	${\rm kgm^{-2}}$
■ TQC	Column integrated cloud water (grid scale)	0	1	69	1/-	inst	${\rm kgm^{-2}}$
■ TQI	Column integrated cloud ice (grid scale)	0	1	70	1/-	inst	${\rm kgm^{-2}}$
■ TQR	Column integrated rain (grid scale)	0	1	45	1/-	inst	${\rm kgm^{-2}}$
■ TQS	Column integrated snow (grid scale)	0	1	46	1/-	inst	${\rm kgm^{-2}}$
■ TQV	Column integrated water vapour (grid scale)	0	1	64	1/-	inst	${\rm kgm^{-2}}$
■ T ₋ S	Temperature of the soil surface (equivalent to T_SO(0))	2	3	18	1/-	inst	K
T_SNOW	Temperature of the snow surface	0	0	18	1/-	inst	K
■ U_10M	Zonal wind at 10m above ground	0	2	2	$103/\!-$	inst	${\rm ms^{-1}}$
■ V_10M	Meridional wind at 10m above ground	0	2	3	103/-	inst	$\rm ms^{-1}$
■ VMAX_10M	Maximum wind at $10\mathrm{m}$ above ground	0	2	22	103/-	max	$\rm ms^{-1}$
LW L	Plant canopy surface water	2	0	13	1/-	inst	${\rm kgm^{-2}}$
₩_SNOW	Snow depth water equivalent	0	1	60	1/-	inst	${\rm kgm^{-2}}$
■ WW	Weather interpretation (WMO)	0	19	25	1/-	inst	1

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Table 6.5: continued

Z 0	Surface roughness (above land and	2	0	1	1/-	inst	m
	water)						

6.1.6 Surface fields interpolated to msl

Table 6.6: Forecast (VV > 0) and initialised analysis (VV = 0) products interpolated to msl

ShortName		Discipline	Category	Number	Lev-Typ 1/2	$\operatorname{stepType}$	Unit
PMSL	Surface pressure reduced to msl	0	3	1	101/-	inst	Pa

 $^{^5\}mathrm{Planned},$ but not yet available

6.1.7 Soil-specific multi-level fields

Table 6.7: Multi-level forecast (VV > 0) and initialised analysis (VV = 0) products of the soil model

${\bf ShortName}$	Description	Discipline	Category	Number	Lev-Typ 1/2	$\operatorname{stepType}$	Unit
T_SO	Soil temperature	2	3	18	106/-	inst	K
¼ W₋SO	Soil moisture integrated over individual soil layers (ice + liquid)	2	3	20	106/106	inst	${\rm kgm^{-2}}$
■ W_SO_ICE	Soil ice content integrated over individual soil layers	2	3	22	106/106	inst	${\rm kgm^{-2}}$

Soil temperature is defined at the soil depths given in Table 6.8 (column 2). Levels 1 to 8 define the full levels of the soil model. A zero gradient condition is assumed between levels 0 and 1, meaning that temperatures at the surface-atmosphere interface are set equal to the temperature at the first full level depth. (0.5 cm). Temperatures are prognosed for layers 1 to 7. At the lowermost layer (mid-level height 1458 cm) the temperature is fixed to the climatological average 2 m-temperature.

Soil moisture W_SO is prognosed for layers 1 to 6. In the two lowermost layers W_SO is filled with W_SO(6) (zero gradient condition).

Table 6.8: Soil model: vertical distribution of levels and layers

level no.	depth [cm]	layer no.	upper/lower bounds [cm]
0	0.0		
1	0.5	1	0.0 - 1.0
2	2.0	2	1.0 - 3.0
3	6.0	3	3.0 - 9.0
4	18.0	4	9.0 - 27.0
5	54.0	5	27.0 - 81.0
6	162.0	6	81.0 - 243.0
7	486.0	7	243.0 - 729.0
8	1458.0	8	729.0 - 2187.0

6.1.8 Lake-specific single-level fields

Table 6.9: Initialised analysis (VV = 0) products of the lake model model on the ICON EU nest.

ShortName	Description	Discipline	Category	Number	Lev-Typ 1/2	$\operatorname{stepType}$	Unit
C_T_LK	Shape factor with respect to the temperature profile in the thermocline	1	2	10	162/166	inst	1
¼ H_ML_LK	Mixed-layer depth	1	2	0	1/166	inst	m
T_BOT_LK	Temperature at the water-bottom sediment interface	1	2	1	162/-	inst	K
T_MNW_LK	Mean temperature of the water column	1	2	1	1/162	inst	K
7 T₋WML_LK	Mixed-layer temperature	1	2	1	1/166	inst	K

Table 6.10: Single-level forecast (VV > 0) products of the lake model model on the ICON EU nest.

ShortName	Description	Discipline	Category	Number	Lev-Typ 1/2	$\operatorname{stepType}$	Unit
■ C_T_LK	Shape factor with respect to the temperature profile in the thermocline	1	2	10	162/166	inst	1
H_ML_LK	Mixed-layer depth	1	2	0	1/166	inst	m
T_BOT_LK	Temperature at the water-bottom sediment interface	1	2	1	162/-	inst	K
T_MNW_LK	Mean temperature of the water column	1	2	1	1/162	inst	K
T_WML_LK	Mixed-layer temperature	1	2	1	1/166	inst	K

Chapter 7

Extended description of available output fields

In order to facilitate the selection and interpretation of fields and to guard against possible misinterpretation or mis-usage, the following section provides a more thorough description of the available output fields.

7.1 Cloud products

CLCT_MOD Modified total cloud cover $(0 \le CLCT_MOD \le 1)$. Used for visualization purpose (i.e.

gray-scale figures) in the media. It is derived from CLC, neglecting cirrus clouds if there are only high clouds present at a given grid point. The reason for this treatment is that the general public does not regard transparent cirrus clouds as

'real' clouds.

CLDEPTH Modified cloud depth (0 < CLDEPTH < 1). Used for visualization purpose (i.e. gray-

scale figures) in the media. A cloud reaching a vertical extent of 700 hPa or more,

has CLDEPTH = 1.

HBAS_CON Height of the convective cloud base in m above msl. HBAS_CON is initialized with

 $-500\,\mathrm{m}$ at points where no convection is diagnosed.

 $\mathbf{HTOP_CON} \qquad \text{Same, but for cloud top.}$

7.2 Atmospheric products

HZEROCL Height of the 0° C isotherm above MSL. At points where the temperature is below

 0° C within the entire atmospheric column, HZEROCL is undefined and set to -999.

SNOWLMT Height of snow fall limit above MSL. It is defined as the height where the wet

bulb temperature T_w first exceeds 1.3°C (scanning mode from top to bottom). If this threshold is never reached within the entire atmospheric column, SNOWLMT is

undefined (GRIB2 bitmap).

7.3 Near surface products

TMIN_2M Minimum temperature at 2 m above ground. Minima are collected over 3-hourly

intervals on the global grid and over 1-hourly intervals for the EU-nest. For forecast times larger than $vv=78\,\mathrm{h}$ the interval is prolonged to 3 hours for the EU-nest as

well.

TMAX_2M Same, but for maximum 2 m temperature.

VMAX_10M Maximum wind gust at 10 m above ground. It is diagnosed from the turbulence state in the atmospheric boundary layer, including a potential enhancement by the

SSO parameterization over mountainous terrain. In the presence of deep convection, it contains an additional contribution due to convective gusts.

Maxima are collected over 3-hourly intervals on the global grid and over hourly intervals for the EU-nest. For forecast times larger than $vv = 78 \,\mathrm{h}$ the interval is prolonged to 3 hours for the EU-nest as well.

7.3.1 General comment on statistically processed fields

In GRIB2, the overall time interval over which a statistical process (like averaging, computation of maximum/minimum) has taken place is encoded as follows:

The beginning of the overall time interval is defined by referenceTime + forecastTime, whereas the end of the overall time interval is given by referenceTime + forecastTime + lengthOfTimeRange. See Section 8.1 for more details on statistically processed fields.

7.4 Surface products

ASWDIFD_S Downward solar diffuse radiation flux at the surface, averaged over forecast time.

See Section 8.1 for more information on time averaging.

ASWDIR_S Downward solar direct radiation flux at the surface. See Section 8.1 for more infor-

mation on time averaging.

ALB_RAD Ratio of upwelling to downwelling diffuse radiative flux for wavelength interval $[0.3 \,\mu\text{m}, 5.0 \,\mu\text{m}]$. Values over snow-free land points are based on a monthly mean

MODIS climatology. MODIS values have been limited to a minimum value of 2%.

From ASWDIFD_S and ASWDIR_S the time averaged global radiation at the surface GLOB can easily be computed as follows:

$${\tt GLOB} = {\tt ASWDIFD_S} + {\tt ASWDIR_S}$$

An estimate of GLOB can also be derived from the net solar radiation flux at the surface ASOB_S and the albedo ALB_RAD:

$$\texttt{GLOB} = \frac{\texttt{ASOB_S}}{1 - 0.01\,\texttt{ALB_RAD}}$$

However be aware that this is only approximately true, because ALB_RAD is an instantaneous field, and it only constitutes the albedo for the diffuse component of the incoming solar radiation ("white sky" albedo). However, ASOB_S contains both diffuse and direct components. As a consequence, the reflection of the incoming direct radiation, which is dependent on the solar zenith angle (and described by the so called "black sky" albedo), is not correctly taken into account.

7.5. Soil products 47

FR_ICE Sea and lake ice cover. Currently, the only possible values are 0 (no ice cover) and 1

(ice covered grid point). For lake points, FR_ICE is synchronized with H_ICE meaning that FR_ICE is set to 1 (0), where the lake model indicates $H_ICE > 0$ ($H_ICE = 0$).

H_ICE Ice thickness over sea and frozen fresh water lakes. The maximum allowable ice

thickness is limited to $3\,\mathrm{m}.$ New sea-ice points generated by the analysis are initial-

ized with $\text{H_ICE} = 0.5\,\text{m}$.

T_ICE Ice temperature over sea-ice and frozen lake points. Melting ice has a temperature

of $273.15\,\mathrm{K}$. Ice-free points over land, sea, and lakes are set to T_SO(0).

T_G Temperature at the atmosphere-surface interface. It is the temperature that is crucial for the computation of surface fluxes. T_G is equal to T_SO(0) over open water and snow-free land. At other grid points one has

• $T_G = T_SNOW + (1 - f_snow) * (T_SO(0) - T_SNOW)$ over (partially) snow covered

grid points. f_snow is the grid point fraction that is snow covered.

 \bullet T_G = T_ICE over frozen sea and fresh water lakes

TOT_PREC Total precipitation accumulated since model start.

TOT_PREC = RAIN_GSP + SNOW_GSP + RAIN_CON + SNOW_CON

W_I Water content of interception layer, i.e. the amount of precipitation intercepted by vegetation canopies. The maximum capacity of the interception reservoir is currently

limited to $6.0E-3\,\mathrm{kg}\,\mathrm{m}^{-2}$ due to numerical reasons and thus almost negligible. Over

water points, $W_{-}I$ is set to 0.

Surface roughness length. Constant over land, where it depends only on the type of land cover. I.e. it does not contain any contribution from subgrid-scale orography. Over water, the roughness length usually varies with time. It is computed by the so called Charnock-formula, which parameterizes the impact of waves on the roughness length. Note that this field differs significantly from the external parameter field Z0

(see Table 3.2 or 5.2).

7.5 Soil products

 $\mathbf{Z0}$

RUNOFF_G Water runoff from soil layers. Sum over forecast.

RUNOFF_S Surface water runoff from interception and snow reservoir and from limited infiltra-

tion rate. Sum over forecast.

 $\mathbf{T}_\mathbf{SO}$ Temperature of the soil and earth surface (uppermost level). The soil full level

depths at which the the soil temperature is defined are given in Table 5.11. The temperature at the uppermost level T_SO(0) is not prognostic. It is rather set equal to the temperature at the first prognostic level T_SO(1). The temperature at the lowermost level T_SO(8) is set to the climatological 2 m temperature T_2M_CL. At sea-points, T_SO(0:7) is filled with the sea-surface temperature. Note that T_SO(0) does not necessarily represent the temperature at the interface soil-atmosphere. I.e. over snow/ice covered surfaces, T_SO(0) represents the temperature below snow/ice.

7.6 Vertical Integrals

TQX Column integrated water species X, derived from the 3D grid-scale prognostic quantities QX, with $X \in \{V, C, I, R, S\}$. TQX is based on the assumption that there would be no sub-grid-scale variability. That assumption is particularly problematic for precipitation generation, moist turbulence and radiation.

$\mathbf{TQX_DIA}$

Total column integrated water species X, with $X \in \{C, I\}$. Takes into account the sub-grid-scale variability that includes simple treatments of turbulent motion and convective detrainment. These cloud variables attempt to represent all model included physical processes. They are also consistent with the cloud cover variables CLC, CLCT, CLCH, CLCM and CLCL.

Chapter 8

Remarks on statistical processing and horizontal interpolation

8.1 Statistically processed output fields

8.1.1 Time-averaged fields

The quantities

ALHFL_S ASHFL_S AUMFL_S AVMFL_S	HFL_S	A
APAB_S ASOB_S ASOB_T ATHB_S	AB_S	\mathbf{A}
ATHB_T ASWDIR_S ASWDIFS_S ASWDIFU_	HB_T	\mathbf{A}'

constitute time averages over the respective forecast time. The averaging process is performed from forecast start $(t_0 = 0 \text{ s})$ till forecast end. Thus, time averaged fields which are written to the database at $t = t_i$ contain averages for the elapsed time interval $[t_0, t_i]$.

Let Ψ denote the instantaneous value of one of the above fields. The time average $\overline{\Psi}$ at time t stored in the database is given as

$$\overline{\Psi}(t) = \frac{1}{t} \int_0^t \Psi \, \mathrm{d}t$$
 , for $t > 0$.

For t = 0, the average $\overline{\Psi}$ is equal to 0. If time averages are required for other time intervals $[t_1, t_2]$, with $t_1 > 0$, these can be computed as follows:

$$\begin{split} \overline{\Psi}(t_2 - t_1) &= \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \Psi \, \mathrm{d}t \\ &= \frac{1}{t_2 - t_1} \left[\int_{0}^{t_2} \Psi \, \mathrm{d}t - \int_{0}^{t_1} \Psi \, \mathrm{d}t \right] \\ &= \frac{1}{t_2 - t_1} \left[t_2 \overline{\Psi}(t_2) - t_1 \overline{\Psi}(t_1) \right] \end{split}$$

For this equation to work, it is of course necessary that the fields $\overline{\Psi}(t_1)$ and $\overline{\Psi}(t_2)$ are available from the database.

The averaging process is fully reflected by the field's GRIB2 metainfo. In order to check whether a field contains the desired time average, it is advisable to check the content of the GRIB2 keys listed in Table 8.1. I.e. productDefinitionTemplateNumber=8 indicates that the field in question is statistically processed. The statistical process itself is specified by the key typeOfStatisticalProcessing. The averaging interval (relative to the start of the forecast) is given by

[forecastTime, forecastTime+lengthOfTimeRange].

Since the averaging process starts at t = 0, the key forecastTime is set to 0.

Table 8.1: List of GRIB2 keys which provide information about the averaging process

Octet(s)	Key	Value	Meaning
8-9	${\tt productDefinitionTemplateNumber}$	8	Average, accumulation, extreme values or other statistically processed values at a horizontal level or in a horizontal layer in a continuous or non-continuous time interval
19-22	forecastTime	0	Starting time of the averaging process relative to the reference time.
47	typeOfStatisticalProcessing	0	Average
50-53	lengthOfTimeRange	variable	Time range over which statistical processing is done

8.1.2 Accumulated fields

The quantities

RAIN_GSP SNOW_GSP RAIN_CON SN	NOW_CON
TOT_PREC RUNOFF_S RUNOFF_G	

are accumulated over the respective forecast time. The accumulation process is performed from forecast start $(t_0 = 0 \text{ s})$ till forecast end. Thus, fields which are written to the database at $t = t_i$ are accumulated for the elapsed time interval $[t_0, t_i]$.

Let Ψ denote the instantaneous value of one of the above fields. The accumulation $\hat{\Psi}$ at time t stored in the database is given as

$$\hat{\Psi}(t) = \int_0^t \Psi \, \mathrm{d}t$$
 , for $t > 0$.

For t = 0, the accumulation $\hat{\Psi}$ is equal to 0. If accumulations are required for other time intervals $[t_1, t_2]$, with $t_1 > 0$, these can be computed as follows:

$$\hat{\Psi}(t_2 - t_1) = \int_{t_1}^{t_2} \Psi \, dt$$

$$= \int_{0}^{t_2} \Psi \, dt - \int_{0}^{t_1} \Psi \, dt$$

$$= \hat{\Psi}(t_2) - \hat{\Psi}(t_1)$$

For this equation to work, it is of course necessary that the fields $\hat{\Psi}(t_1)$ and $\hat{\Psi}(t_2)$ are available from the database.

The accumulation process is fully reflected by the field's GRIB2 metainfo. In order to check whether a field contains the desired accumulation, it is advisable to check the content of the GRIB2 keys listed in

Table 8.2. I.e. productDefinitionTemplateNumber=8 indicates that the field in question is statistically processed. The statistical process itself is specified by the key typeOfStatisticalProcessing. The accumulation interval (relative to the start of the forecast) is given by

[forecastTime, forecastTime+lengthOfTimeRange].

Since the accumulation process starts at t=0, the key forecastTime is set to 0.

Table 8.2: List of GRIB2 keys which provide information about the accumulation process

Octet(s)	Key	Value	Meaning
8-9	${\tt productDefinitionTemplateNumber}$	8	Average, accumulation, extreme values or other statistically processed values at a horizontal level or in a horizontal layer in a continuous or non-continuous time interval
19-22	forecastTime	0	Starting time of the accumulation process relative to the reference time.
47	typeOfStatisticalProcessing	1	Accumulation
50-53	lengthOfTimeRange	variable	Time range over which statistical processing is done

8.1.3 Extreme value fields

The quantities

VMAX_10M TMAX_2M TMIN_2M

represent extreme values, which are collected over certain time intervals χ , starting from the beginning of the forecast. The interval χ differs for the different model domains and is set to

- $\chi = 3 \,\mathrm{h}$ on the global domain
- $\chi=1\,\mathrm{h}$ on the nested EU domain until $vv=78\,\mathrm{h}$ and $\chi=3\,\mathrm{h}$ afterwards.

After χ hours of forecast the fields are re-initialized with 0 for the first time and the next χ -hourly collection phase is started. This procedure is repeated till the end of the forecast.

Let Ψ denote the instantaneous value of one of the above fields. The maximumu value Ψ_{max} at time t stored in the database is given as

$$\Psi_{max}(t) = \max(\Psi(t), \Psi_{max}(t))$$
, for $t_i < t < t_i + \chi$

Here, t_i indicates the time when Ψ_{max} was (re)-initialized the last time. For t=0, the extreme value Ψ_{max} is equal to the instantaneous value Ψ .

Please note: Even though a 3 hour time window is used, the database contains hourly, 2-hourly and 3-hourly extreme value fields. This is because the extreme value fields are written to the database hourly, irrespective of the start/end of the 3-hourly time windows. Example: Extreme value fields which are written into the database after a forecast time of 5 hours, contain extreme values collected over the last 2 hours. On the other hand, extreme value fields written into the database after 6 hours contain values collected over the last 3 hours. Thus, when dealing with those fields it is very important to check the GRIB2 keys listed in Table 8.3.

productDefinitionTemplateNumber=8 indicates that the field in question is statistically processed. The statistical process itself is specified by the key typeOfStatisticalProcessing. The time interval (relative to the start of the forecast) over which the extreme value collection was performed is given by [forecastTime,forecastTime+lengthOfTimeRange]. Since the collection process is restarted every χ hours, the key forecastTime can differ from 0.

Octet(s)	Key	Value	Meaning
8-9	${\tt productDefinitionTemplateNumber}$	8	Average, accumulation, extreme values or other statistically processed values at a horizontal level or in a horizontal layer in a continuous or non-continuous time interval
19-22	forecastTime	variable	Starting time of the statistical process relative to the reference time.
47	typeOfStatisticalProcessing	2,3	Maximum/Minimum
50-53	lengthOfTimeRange	variable	Time range over which statistical processing is done

8.2 Technical Details of the Horizontal Interpolation

Most of the output data on regular grids is processed using an RBF-based interpolation method. The algorithm approximates the input field with a linear combination of radial basis functions (RBF) located at the data sites, see, for example, Ruppert (2007). RBF interpolation typically produces over- and undershoots at position where the input field exhibits steep gradients. Therefore, the internal interpolation algorithm performs a cut-off by default. Note that RBF-based interpolation is *not conservative*.

A small number of output fields is treated differently, with a nearest-neighbor interpolation:

RAIN_CON	$RAIN_GSP$	$SNOW_CON$
$SNOW_GSP$	SOILTYP	TOT_PREC
W_SO_ICE	WW	SNOWLMT

The nearest neighbor algorithm selects the value of the nearest point and does not consider the values of neighboring points at all, yielding a piecewise-constant interpolant.

Chapter 9

ICON data in the SKY data bases of DWD

GRIB data of the numerical weather prediction models are stored in the data base SKY at DWD. Documentation on the SKY system is available in the intranet of DWD at IT/Messnetz/Technik \rightarrow Datenmanagement (technisch) \rightarrow Management der DWD Fachdaten -Dokumentation \rightarrow SKY. Here, some remarks are given on the SKY categories for ICON data, and some examples are given how to retrieve data from the data base.

9.1 SKY categories for ICON

In SKY the data is stored in different categories and data base subsystems. These are identified by the cat=CAT_NAME parameter. The name of a category is made up of 4 parts:

\$model_\$run_\$type_\$suite

run, type, and suite are general for all forecast models of DWD. They can have the following values:

- run: main for main forecast runs, ass for assimilation runs, pre for pre-assimilation runs, const for invariant data.
- type: an for analysis data, fc for forecast data.
- suite:
 - **rout** for operational data in db=roma,
 - **para** or **para1** for pre-operational data in db=parma, The category extension para1 denotes the data with EU nest (starting at 12 UTC, 2015032612).
 - **exp** or **exp1** for data from experiments in db=numex. The category extension exp1 is used for experiments of the NUMEX wizard, a special NUMEX user.
 - Data from experiments is additionally identified by the parameter exp=NUM where NUM is the experiment number.

The categories for ICON start with the string **ico** for ICON data on the native ICON grid, or with **icr** for data on a regular lat-lon grid. Next follows a two-letter string to identify the domain of ICON; **gl** for the global domain, **eu** for the nest over Europe. After the domain follows the mesh width of the model in units of 100 m, and then the number of levels after the letter l. As an example icogl130l90 is on the

native grid from a global model with a mesh width 13 km (grid R3B07) and 90 levels. icrgl400l90 is data on a regular grid from a global model with mesh width 40 km (R2B06) and 90 levels. icreu065l50 is an ICON nest over Europe with a mesh width of 6.5 km and 50 levels and interpolated to a regular lat-lon grid.

Hence, the full category name for data from an operational forecast run of ICON on a regular grid will be icrgl130l90_main_fc_rout. The initial analysis for this run is in category icogl130l90_main_an_rout.

Since 2014-08-12 12 UTC ICON is running pre-operationally at DWD. Hence, forecast data is available in the sky database **db=parma** in categories **icogl130l90_main_fc_para** and **icrgl130l90_main_fc_para**.

Since 2015-01-20 06 UTC the *global* ICON model is running operationally at DWD. Forecast data is available in the sky database **db=roma** in categories **icogl130l90_main_fc_rout** and **icrgl130l90_main_fc_rout**.

9.2 Retrieving ICON data from SKY

Here we shall give several examples how to retrieve ICON data from SKY. The parameter d specifies the reference or initial date, s is the forecast step, p the parameter, and f the name of the GRIB data file.

• Retrieve the 2m temperature and dew point temperature for forecast hours 3 to 78 every 3 hours of today's run at 00 UTC on the global domain from an ICON run on a R3B07 grid with 90 levels to file icon2mdat

```
read db=roma cat=icrgl130190_main_fc_rout d=t00 s[h]=3/to/78/by/3 p=t_2m,td_2m bin f=icon2mdat
```

• Retrieve the analysis of T on the native grid from yesterday 18 UTC:

```
read db=roma cat=icog1130190_main_an_rout d=t18-1d p=T gptype=0 bin f=t_icon_ana
```

• Retrieve the 6, 12, 18, and 24 hour forecast of the 2m temperature from a forecast run on 2012-06-28 at 00 UTC on the global domain from an ICON run on a R3B07 grid with 90 levels:

```
read db=numex cat=icrgl130190_main_fc_exp1 exp=901 d=2012062800 s[h]=6,12,18,24 p= t_2m bin f=t_2m_fc.grb
```

• Retrieve wind components U and V at 300 hPa on the regular grid from a 24 hour forecast on 2013-10-03 at 00 UTC. lv=P specifies the level type as pressure levels. lv1=30000 specifies the level in Pa.

• Retrieve the analysis of U on the native grid:

```
read db=numex cat=icogl130190_main_an_exp1 exp=907 d=2013100300 p=U bin f= u_icon_ana
```

• Retrieve temperature forecasts from 7 to 9 hours on the native grid:

• Retrieve a 6 hour forecast on a regular grid on pressure levels. ICON was run on a 40 km grid (R2B06). Write reference date (d), forecast step (s), level type (lv), value of first level (lv1), decoding date (dedat), and store date (stdat) in information file icr.info.

```
read db=numex cat=icrg1400190_main_fc_exp exp=9323 d=2012010100 step[h]=6 lv=P f=
icr06p bin info=metaData metaArray=d,s,p,lv,lv1,dedat,stdat sort=d,s,p,lv,lv1
infof=icr.info
```

In order to retrieve the same forecast on height levels, the level type must be changed to lv=HMSL.

• Retrieve temperature in 850 hPa from a forecast on 2013-10-05 at 12 UTC:

```
read db=numex cat=icrg1400190_main_fc_exp1 exp=906 d=2013100512 p=T lv1=85000 lv=P
bin f=t850_iconr
```

• Retrieve all available time-invariant (constant) fields on the native grid and store them in the file const_icongl. Write reference date (d), forecast step (s), level type (lv), value of first level (lv1), decoding date (dedat), and store date (stdat) in information file icr.info. It is important to set invar=true.

read db=roma cat=icogl130190_const_an_rout invar=true info=metaData metaArray=d,s,p
,lv,lv1,dedat,stdat bin infof=icr.info f=const_icongl

Appendix A

ICON standard level heights

A.1 Level heights for zero topography height

ICON standard half level heights z^{h0} are listed in Table A.1. Please note that these values correspond to the actual level heights only at grid points with zero topography height, e.g. at ocean grid points.

If full level heights z^{f0} are required, these can be deduced as follows: Let i denote the full level index for which the height is wanted. Then the full level height z_i^{f0} is given by

$$z_i^{f0} = \frac{z_i^{h0} + z_{i+1}^{h0}}{2}.$$

See Table A.2 for a list of all full level heights of the operational setup.

A.2 Non-zero topography heights

The prerequisite "zero topography height" is seldom met in real applications. Instead the user has to compute the model level height for each grid point separately. To this end the invariant fields HSURF and HHL are provided where HHL is the geometric height of model half levels above sea level. The level height above ground can therefore be computed by the following formula:

$$z_i^h(x) = \mathtt{HHL}(x) - \mathtt{HSURF}(x)$$

$$z_i^f(x) = \frac{z_i^h(x) + z_{i+1}^h(x)}{2}$$

Table A.1: Standard heights z_i^{h0} (i.e. for zero topography height) for all 91 vertical half levels.

level index	height $[m]$	level index	height $[m]$	level index	height [m]
1	75 000.000	32	21 569.375	63	6 621.524
2	72 363.546	33	20731.107	64	6 221.524
3	69 842.381	34	19 942.837	65	5 821.524
4	67 357.797	35	19 201.585	66	5 421.524
5	64 946.444	36	18 504.545	67	5 033.731
6	62 606.299	37	17849.081	68	4659.952
7	60 335.466	38	17 232.713	69	4 300.121
8	58 132.167	39	16 653.108	70	3 954.183
9	55 976.216	40	16 108.074	71	3 622.092
10	53 877.930	41	15 595.549	72	3 303.815
11	51 824.685	42	15 113.594	73	2 999.329
12	49 826.951	43	14660.386	74	2708.624
13	47 890.748	44	14 234.210	75	2431.707
14	46 014.776	45	13 821.524	76	2 168.596
15	44 197.795	46	13 421.524	77	1 919.330
16	42 438.627	47	13 021.524	78	1 683.966
17	40 736.151	48	12621.524	79	1 462.584
18	39 089.298	49	12 221.524	80	1 255.291
19	37 497.048	50	11 821.524	81	1 062.224
20	35 958.428	51	11 421.524	82	883.557
21	34 472.507	52	11 021.524	83	719.514
22	33 038.397	53	10 621.524	84	570.373
23	31 655.249	54	10 221.524	85	436.493
24	30 322.249	55	9 821.524	86	318.336
25	29 038.622	56	9421.524	87	216.516
26	27 803.623	57	9021.524	88	131.880
27	26 617.350	58	8 621.524	89	65.677
28	25 488.963	59	8 221.524	90	20.000
29	24 416.908	60	7821.524	91	0.000
30	23 408.796	61	7421.524		
31	22 460.814	62	7 021.524		

Table A.2: Standard heights z_i^{f0} (i.e. for zero topography height) for all 90 vertical full levels.

level index	height $[m]$	level index	height $[m]$	level index	height $[m]$
1	73 681.773	31	22 015.095	61	7221.524
2	71 102.963	32	21 150.241	62	6821.524
3	68 600.089	33	20 336.972	63	6421.524
4	66 152.120	34	19572.211	64	6021.524
5	63 776.371	35	18853.065	65	5621.524
6	61 470.883	36	18 176.813	66	5227.628
7	59 233.817	37	17540.897	67	4846.842
8	57 054.191	38	16 942.910	68	4480.037
9	54 927.073	39	16380.591	69	4127.152
10	52 851.308	40	15 851.812	70	3 788.138
11	50 825.818	41	15354.572	71	3462.954
12	48 858.849	42	14886.990	72	3151.572
13	46952.762	43	14447.298	73	2853.976
14	45106.285	44	14027.867	74	2570.165
15	43 318.211	45	13621.524	75	2300.151
16	41587.389	46	13221.524	76	2043.963
17	39912.725	47	12821.524	77	1801.648
18	38293.173	48	12421.524	78	1573.275
19	36 727.738	49	12021.524	79	1358.938
20	35215.467	50	11621.524	80	1158.757
21	33755.452	51	11221.524	81	972.891
22	32346.823	52	10821.524	82	801.536
23	30 988.749	53	10421.524	83	644.943
24	29680.436	54	10021.524	84	503.433
25	28421.123	55	9621.524	85	377.415
26	27210.487	56	9221.524	86	267.426
27	26053.157	57	8 821.524	87	174.198
28	24952.936	58	8421.524	88	98.779
29	23912.852	59	8021.524	89	42.839
30	22934.805	60	7621.524	90	10.000

Table A.3: Height above ground $z_i^h(x)$ (half levels) for the grid point with maximum topography height in the operational setup R03B07, 13 km spatial resolution.

Example: Height above ground ${\tt HHL}$ - ${\tt HSURF}$

Location with max. surface height

 $\begin{aligned} & \texttt{CLON/CLAT} = 88.180 \ / \ 27.938 \\ & \texttt{HSURF} & = 6425.974 \ \mathrm{m} \end{aligned}$



level idx.	height $[m]$						
1	68 574.026	26	21 377.649	51	5 327.293	76	866.370
2	65 937.573	27	20 191.375	52	5 131.465	77	758.050
3	63 416.409	28	19 062.989	53	4935.623	78	657.498
4	60 931.823	29	17990.934	54	4739.792	79	564.784
5	58 520.471	30	16 982.823	55	4543.948	80	479.555
6	56 180.323	31	16 034.840	56	4 348.128	81	402.027
7	53 909.491	32	15 143.401	57	4152.290	82	331.853
8	51 706.194	33	14 305.133	58	3956.454	83	269.111
9	49 550.241	34	13 516.864	59	3 760.637	84	213.679
10	47 451.955	35	12775.612	60	3564.822	85	165.480
11	45 398.709	36	12078.571	61	3 368.960	86	124.372
12	43400.975	37	11 423.108	62	3 173.123	87	90.304
13	41 464.776	38	10806.739	63	2977.288	88	62.007
14	39 588.803	39	10227.133	64	2781.490	89	40.029
15	37 771.819	40	9682.100	65	2585.635	90	19.913
16	36 012.651	41	9198.296	66	2389.814	91	0.000
17	34 310.178	42	8 722.363	67	2200.963		
18	32 663.323	43	8 275.923	68	2020.269		
19	31 071.073	44	7857.270	69	1847.760		
20	29 532.451	45	7453.121	70	1683.296		
21	28 046.534	46	7062.759	71	1527.009		
22	26 612.424	47	6673.955	72	1 378.876		
23	25 229.274	48	6286.946	73	1238.770		
24	23 896.276	49	5 911.315	74	1 106.582		
25	22 612.647	50	5 594.500	75	982.521		

Table A.4: Height above ground $z_i^f(x)$ (full levels) for the grid point with maximum topography height in the operational setup R03B07, 13 km spatial resolution.

Example: Height above ground, full levels

Location with max. surface height

 ${\tt CLON/CLAT} = 88.180 \; / \; 27.938$

 $\mathtt{HSURF} \qquad = 6425.974 \ \mathrm{m}$



level idx.	height $[m]$						
1	67 255.799	25	21 995.148	49	5 752.908	73	1 172.676
2	64 676.991	26	20 784.512	50	5460.897	74	1044.552
3	62 174.116	27	19627.182	51	5229.379	75	924.446
4	59 726.147	28	18526.961	52	5033.544	76	812.210
5	57 350.397	29	17 486.878	53	4837.708	77	707.774
6	55 044.907	30	16 508.831	54	4641.870	78	611.141
7	52 807.842	31	15589.120	55	4446.038	79	522.169
8	50628.217	32	14724.267	56	4250.209	80	440.791
9	48 501.098	33	13 910.998	57	4054.372	81	366.940
10	46425.332	34	13 146.238	58	3 858.546	82	300.482
11	44 399.842	35	12427.091	59	3662.730	83	241.395
12	42 432.875	36	11 750.839	60	3466.891	84	189.580
13	40526.789	37	11 114.923	61	3271.042	85	144.926
14	38 680.311	38	10516.936	62	3075.206	86	107.338
15	36 892.235	39	9954.617	63	2879.389	87	76.155
16	35 161.414	40	9440.198	64	2683.563	88	51.018
17	33 486.750	41	8 960.329	65	2487.724	89	29.971
18	31 867.198	42	8 499.143	66	2295.388	90	9.956
19	30 301.762	43	8 066.596	67	2 110.616		
20	28 789.492	44	7655.196	68	1934.015		
21	27 329.479	45	7257.940	69	1 765.528		
22	25 920.849	46	6868.357	70	1605.152		
23	24562.775	47	6480.451	71	1 452.942		
24	23 254.461	48	6 099.130	72	1 308.823		

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