ICON Database
Reference Manual

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History of versions

Version	Date	Author(s)	Changes
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.

Contents

Chapter 1

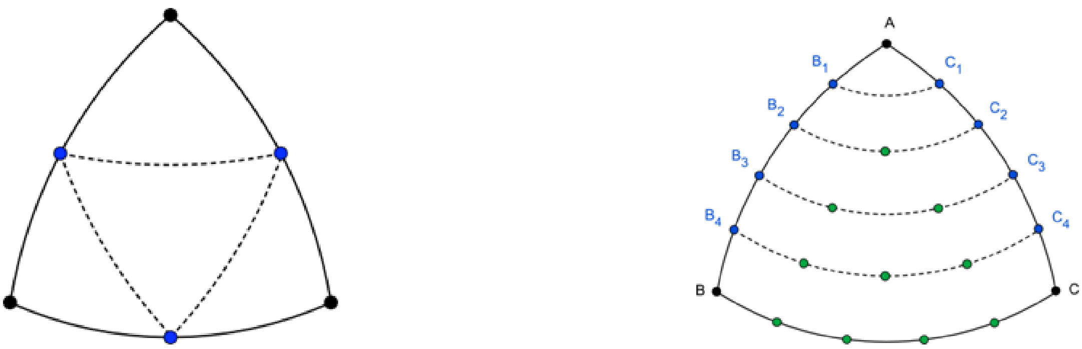
Grid geometry

1.1 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 1.1a) which is projected onto a sphere. The spherical icosahedron (Figure 1.1b) 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 1.2a, 1.2b).

(a) (b)

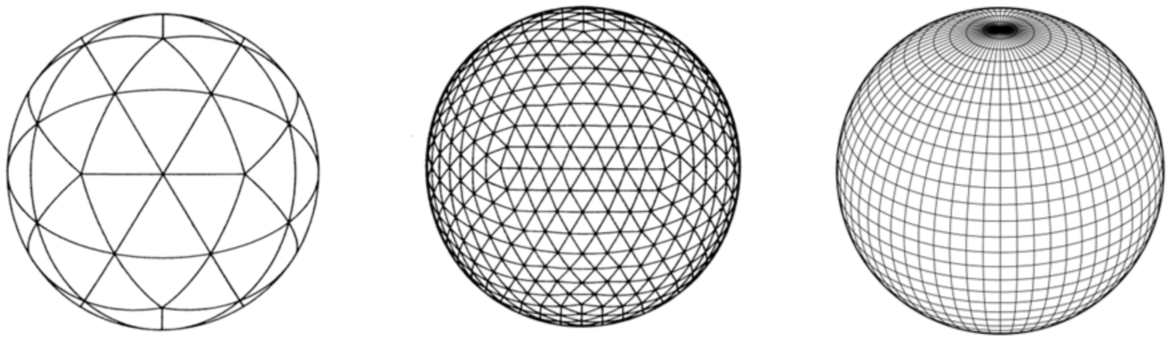
Figure 1.1: *Icosahedron before (a) and after (b) projection onto a sphere*



(a) (b)

Figure 1.2: *(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 (**R**n) followed by k bisection steps (**B**k), resulting in a **R**n**B**k grid. Figures 1.3a and 1.3b show **R2B**00 and **R2B**02 ICON grids. Such grids avoid polar singularities of latitude-longitude grids (Figure 1.3c) and allow a high uniformity in resolution over the whole sphere.



(a) (b) (c)

Figure 1.3: *(a) R2B00 grid. (b) R2B02 grid. (c) traditional latitude-longitude grids with polar singularities*

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

$$
\begin{aligned}
n_c &= 20\,n^2\,4^k \\
n_e &= 30\,n^2\,4^k \\
n_v &= 10\,n^2\,4^k + 2
\end{aligned}
$$

In Table 1.1, some characteristics of frequently used ICON grids are given. The table contains information about the total number of triangles (n_c), the average distance between triangle cell centers (also referred to as the average resolution), 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.

Table 1.1: *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]**	$\mathbf{\Delta A_{max}}$ **[km^2]**	$\mathbf{\Delta A_{min}}$ **[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

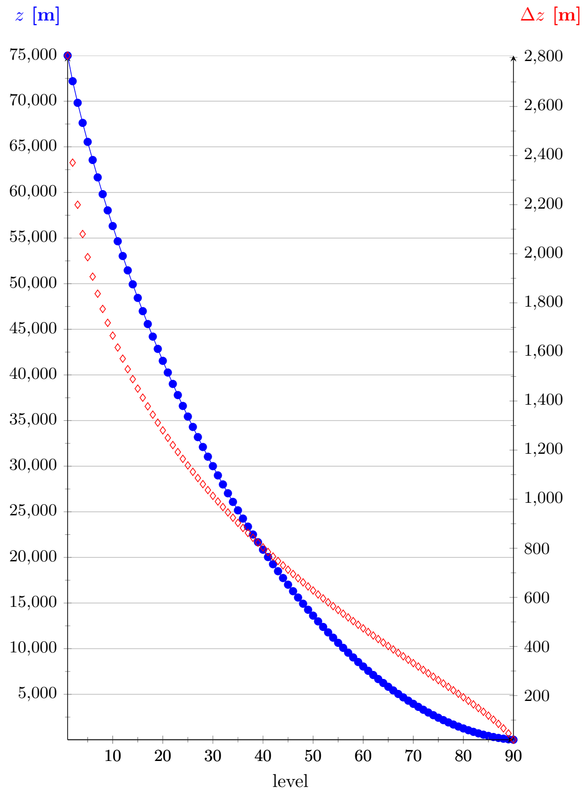
The first operational version of ICON will most likely be based on the R3B07 grid, thus, having a horizontal resolution of about 13 km!

1.1.1 Local grid refinement

1.2 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, Koller & Schär [1]. The required smooth large-scale contribution of the model topography is generated by digital filtering with a ∇^2-diffusion operator. Figure 1.4 shows the (half) levels of the current (preliminary) ICON setup with 90 vertical levels.



level	$[m]$	$[Pa]$
1	75 000	2.1
6	63 555	12.3
11	54 651	41.8
16	46 991	111.0
21	40 262	267.8
26	34 298	618.7
31	28 988	1 365.4
36	24 255	2 816.9
41	20 040	5 439.7
46	16 298	9 814.6
51	12 991	16 532.5
56	10 091	26 070.0
61	7 573	37 851.2
66	5 421	51 045.6
71	3 622	64 737.1
76	2 168	77 845.2
81	1 062	89 198.3
86	318	97 558.8
90	20	101 085.0

Figure 1.4: *Vertical levels of the ICON model (preliminary setup). The table of selected pressure values (for zero height) is based on the 1976 US standard atmosphere.*

Chapter 2

Available output fields in GRIB2-format

In GRIB2, a variable is uniquely defined by the following set of metadata:

- *Discipline* (see GRIB2 code table 4.2)
- *ParameterCategory* (see GRIB2 code table 4.2)
- *ParameterNumber* (see GRIB2 code table 4.2)
- *typeOfFirstfixedSurface* and *typeOfSecondFixedSurface* (see GRIB2 code table 4.5)
- *stepType* (instant, accum, avg, max, min, diff, rms, sd, cov, . . .)

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 *LevTyp 1/2*.

2.1 Deprecated output fields

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

- **OMEGA** [Pa/s]: Vertical velocity in pressure coordinates $\omega = \frac{\mathrm{d}p}{\mathrm{d}t}$. Since ICON is a nonhydrostatic model, the vertical velocity **W** [m/s] is provided, instead (see Section 2.2).
- **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.
- **T_S** [K]: Temperature at the soil-atmosphere-, or soil-snow-interface. Note that T_S = T_SO(0), thus T_S is redundant.
- **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** [$\mathrm{m}^2\,\mathrm{s}^{-1}$]: Surface Geopotential. Instead, **HSURF** [m] should be used (see Section 2.2).
- **O3** [kg/kg], **TO3** [Dobson]: Ozone mixing ratio and corresponding total ozone concentration. No longer available; no substitution

2.2 New output fields

Table 2.1 contains a list of new output fields that will become available with the launch of ICON (compared to GME). A more thorough description of these fields is provided in Section 2.3.

Table 2.1: *Newly available output fields*

ShortName	Unit	Description
W	m/s	vertical velocity in height coordinates $w = \frac{\mathrm{d}z}{\mathrm{d}t}$ (3D field)
DEN	kg/m^3	density of moist air (3D field)
TKE	m^2/s^2	Turbulent kinetic energy (3D field)
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 mid-point
VLON,VLAT	deg	Geographical longitude/latitude of native grid triangle vertex

2.3 Available output fields listed in tabular form

2.3.1 Time-constant (external parameter) fields

Table 2.2: *Time-constant fields (Date D=000000)*

ShortName	Description	Discipline	Category	Number	Lev-Typ 1/2	stepType	Unit
HSURF	Geometric height of the earths surface above msl	0	3	6	1/101	inst	m
HHL	Geometric height of model half levels above msl	0	3	6	105/101	inst	m
RLAT	Geographical latitude	0	191	1	1/–	inst	Deg. N
RLON	Geographical longitude	0	191	2	1/–	inst	Deg. E
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
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
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
FR_LAND	Land fraction (possible range $[0, 1]$)	2	0	0	1/–	inst	1
ROOTDP	Root depth of vegetation	2	0	32	1/–	inst	m
EMIS_RAD	Longwave surface emissivity	2	3	199	1/–	inst	1
RSMIN	Minimum stomatal resistance	2	0	16	1/–	inst	$\mathrm{s\,m^{-1}}$
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
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
NDVI_MRAT	ratio of monthly mean NDVI (normalized differential vegetation index) to annual max	0	0	192	1/–	avg	1

2.3.2 Multi-level fields on native hybrid vertical levels

Table 2.3: *Hybrid multi-level forecast ($VV > 0$) and initialised analysis ($VV = 0$) products*

ShortName	Description	Discipline	Category	Number	Lev-Typ 1/2	stepType	Unit
U	Zonal wind	0	2	2	150/150	inst	$m\,s^{-1}$
V	Meridional wind	0	2	3	150/150	inst	$m\,s^{-1}$
W	Vertical wind	0	2	9	150/–	inst	$m\,s^{-1}$
T	Temperature	0	0	0	150/150	inst	K
DEN	Density of moist air	0	3	10	150/150	inst	$kg\,m^{-3}$
QV	Specific humidity	0	1	0	150/150	inst	$kg\,kg^{-1}$
QC	Cloud mixing ratio[2]	0	1	22	150/150	inst	$kg\,kg^{-1}$
QI	Cloud ice mixing ratio[2]	0	1	82	150/150	inst	$kg\,kg^{-1}$
QR	Rain mixing ratio[2]	0	1	24	150/150	inst	$kg\,kg^{-1}$
QS	Snow mixing ratio[2]	0	1	25	150/150	inst	$kg\,kg^{-1}$
CLC	Cloud cover	0	6	22	150/150	inst	%
TKE	Turbulent kinetic energy	0	19	11	150/–	inst	$m^2\,s^{-2}$

2.3.3 Multi-level fields interpolated to pressure levels

The following pressure levels are available: 1000, 950, 925, 900, 850, 700, 500, 400, 300, 250, 200, 150, 100, 50, 10, hPa.

[2]for the time being, erroneously encoded as mixing ratios instead of specific quantities

Table 2.4: *Multi-level forecast ($VV > 0$) and initialised analysis ($VV = 0$) products interpolated to pressure levels*

ShortName	Description	Discipline	Category	Number	Lev-Typ 1/2	stepType	Unit
FI	Geopotential	0	3	4	100/–	inst	$m^2 s^{-2}$
U	Zonal wind	0	2	2	100/–	inst	$m s^{-1}$
V	Meridional wind	0	2	3	100/–	inst	$m s^{-1}$
W	Vertical wind	0	2	9	100/–	inst	$m s^{-1}$
T	Temperature	0	0	0	100/–	inst	K
RELHUM	Relative humidity (with respect to water)	0	1	1	100/–	inst	%

2.3.4 Single-level fields

Table 2.5: Single-level forecast ($VV > 0$) and initialised analysis ($VV = 0$) products

ShortName	Description	Discipline	Category	Number	Lev-Typ 1/2	stepType	Unit
PS	Surface pressure (not reduced)	0	3	1	1/–	inst	Pa
T_SNOW	Temperature of the snow surface	0	0	18	1/–	inst	K
T_G	Ground temperature (temperature at sfc-atm interface)	0	0	0	1/–	inst	K
QV_S	Surface specific humidity	0	1	0	1/–	inst	$kg\,kg^{-1}$
W_SNOW	Snow depth water equivalent	0	1	60	1/–	inst	$kg\,m^{-2}$
W_I	Plant canopy surface water	2	0	13	1/–	inst	$kg\,m^{-2}$
TCM	Turbulent transfer coefficient for momentum (surface)	0	2	29	1/–	inst	1
TCH	Turbulent transfer coefficient for heat and moisture (surface)	0	0	19	1/–	inst	1
ASOB_S	Net short-wave radiation flux at surface (average since model start)	0	4	9	1/–	avg	$W\,m^{-2}$
ATHB_S	Net long-wave radiation flux at surface (average since model start)	0	5	5	1/–	avg	$W\,m^{-2}$

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Table 2.5: *continued*

ASOB_T	Net short-wave radiation flux at TOA (average since model start)	0	4	9	8/–	avg	$W\,m^{-2}$
ATHB_T	Net long-wave radiation flux at TOA (average since model start)	0	5	5	8/–	avg	$W\,m^{-2}$
ALB_RAD	Surface albedo for visible range, diffuse	0	19	1	1/–	inst	%
RAIN_GSP	Large scale rain (accumulated since model start)	0	1	77	1/–	accu	$kg\,m^{-2}$
SNOW_GSP	Large snowfall water equivalent (accumulated since model start)	0	1	56	1/–	accu	$kg\,m^{-2}$
RAIN_CON	Convective rain (accumulated since model start)	0	1	76	1/–	accu	$kg\,m^{-2}$
SNOW_CON	Convective snowfall water equivalent (accumulated since model start)	0	1	55	1/–	accu	$kg\,m^{-2}$
TOT_PREC	Total precipitation (accumulated since model start)	0	1	52	1/–	accu	$kg\,m^{-2}$
RUNOFF_S	Surface water runoff (accumulated since model start)[3]	2	0	5	106/–	accu	$kg\,m^{-2}$
RUNOFF_G	Soil water runoff (accumulated since model start)[3]	2	0	5	106/–	accu	$kg\,m^{-2}$
U_10M	Zonal wind at 10m above ground	0	2	2	103/–	inst	$m\,s^{-1}$
V_10M	Meridional wind at 10m above ground	0	2	3	103/–	inst	$m\,s^{-1}$
T_2M	Temperature at 2m above ground	0	0	0	103/–	inst	K
TD_2M	Dew point temperature at 2m above ground	0	0	6	103/–	inst	K
VMAX_10M	Maximum wind at 10 m above ground	0	2	22	103/–	max	$m\,s^{-1}$
Z0	Surface roughness (above land and water)	2	0	1	1/–	inst	m
CLCT	Total cloud cover	0	6	1	1/–	inst	%
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	%
TQV	Total column integrated water vapour	0	1	64	1/–	inst	$kg\,m^{-2}$
TQC	Total column integrated cloud water	0	1	69	1/–	inst	$kg\,m^{-2}$

Continued on next page

Table 2.5: *continued*

TQI	Total column integrated cloud ice	0	1	70	1/–	inst	$\mathrm{kg\,m^{-2}}$
TQR	Total column integrated rain	0	1	45	1/–	inst	$\mathrm{kg\,m^{-2}}$
TQS	Total column integrated snow	0	1	46	1/–	inst	$\mathrm{kg\,m^{-2}}$
HBAS_CON	Height of convective cloud base above msl	0	6	26	2/101	inst	m
HTOP_CON	Height of convective cloud top above msl	0	6	27	3/101	inst	m
HZEROCL	Height of 0 degree Celsius isotherm above msl	0	3	6	4/101	inst	m
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
ASHFL_S	Sensible heat net flux at surface (average since model start)	0	0	11	1/–	avg	$\mathrm{W\,m^{-2}}$
ALHFL_S	Latent heat net flux at surface (average since model start)	0	0	10	1/–	avg	$\mathrm{W\,m^{-2}}$
FR_ICE	Sea ice cover (possible range: $[0, 1]$)	10	2	0	1/–	inst	1
T_ICE	Sea ice temperature (at ice-atm interface)	10	2	8	1/–	inst	K
H_ICE	Sea ice thickness (Max: 3 m)	10	2	1	1/–	inst	m
FRESHSNW	Fresh snow factor (weighting function for albedo indicating freshness of snow)	0	1	203	1/–	inst	1
RHO_SNOW	Snow density	0	1	61	1/–	inst	$\mathrm{kg\,m^{-3}}$
H_SNOW	Snow depth	0	1	11	1/–	inst	m
PLCOV	Plant cover	2	0	4	1/–	inst	%
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

[3]available as soon as shortName.def for GRIB2 has been updated accordingly

Table 2.7: *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

Table 2.6: Multi-level forecast ($VV > 0$) and initialised analysis ($VV = 0$) products of the soil model

ShortName	Description	Discipline	Category	Number	Lev-Typ 1/2	stepType	Unit
T_SO	Soil temperature	2	3	18	106/–	inst	K
W_SO	Soil moisture integrated over individual soil layers (ice + liquid)	2	3	20	106/106	inst	$\mathrm{kg\,m^{-2}}$
W_SO_ICE	Soil ice content integrated over individual soil layers	2	3	22	106/106	inst	$\mathrm{kg\,m^{-2}}$

Soil temperature is defined at the soil depths given in Table 2.7 (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 levels 1 to 7. At the lowermost level (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 time constant.

2.3.5 Surface fields interpolated to msl

Table 2.8: *Forecast ($VV > 0$) and initialised analysis ($VV = 0$) products interpolated to msl*

ShortName	Description	Discipline	Category	Number	Lev-Typ 1/2	stepType	Unit
PMSL	Surface pressure reduced to msl	0	3	1	101/–	inst	Pa

Bibliography

[1] Leuenberger, D., M. Koller, and C. Schär, 2010: A generalization of the sleve vertical coordinate. *Mon. Wea. Rev.*, **138**, 3683–3689.