# ICON Database Reference Manual

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Offenbach am Main, Germany

This document is based on Revision 20332 of the ICON code,
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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. |
| 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 `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` |

# Contents

# Chapter 1

# Introduction

The **ICO**sahedral **N**onhydrostatic model ICON is the new global numerical weather prediction model at DWD. It will become operational at 2015-01-20, replacing the current 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.

From 2014-01-20 on, ICON analysis and forecast fields will serve as initial and boundary data for

- the regional model COSMO-EU
- RLMs (**R**elocated **L**ocal **M**odel) 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.

If you encounter bugs or inconsistencies, or if you have suggestions for improving this document, please contact one of the following colleagues:


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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 2.1c, 2.1d).

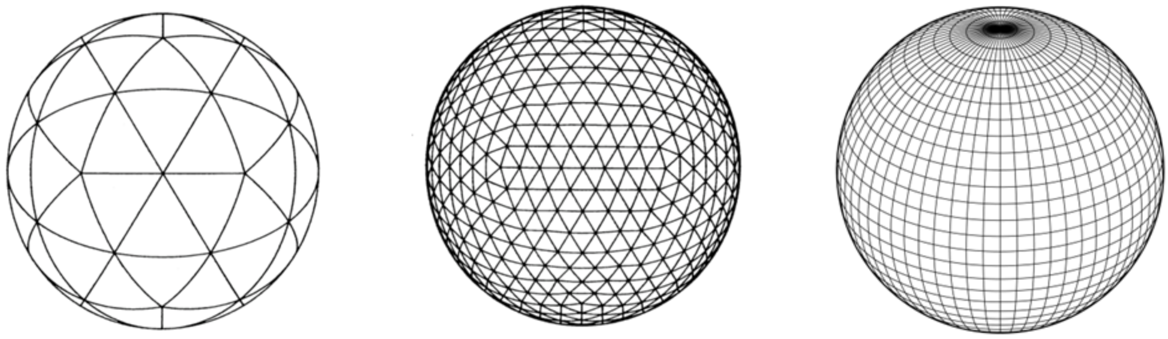
(a) (b)

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


(c) (d)

**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 (**R**n) followed by $k$ bisection steps (**B**k), resulting in a **R**n**B**k grid. Figures 2.3a and 2.3b show **R**2**B**00 and **R**2**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.



(a) (b) (c)

**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 "**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

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

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).

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

| **Grid** | **number of cells** ($n_c$) | **avg. resolution** [km] | $\mathbf{\Delta A_{max}}$ [$\mathbf{km^2}$] | $\mathbf{\Delta A_{min}}$ [$\mathbf{km^2}$] |
|---|---|---|---|---|
| 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 be based on the R3B07 grid, thus, having a horizontal resolution of about 13 km!**

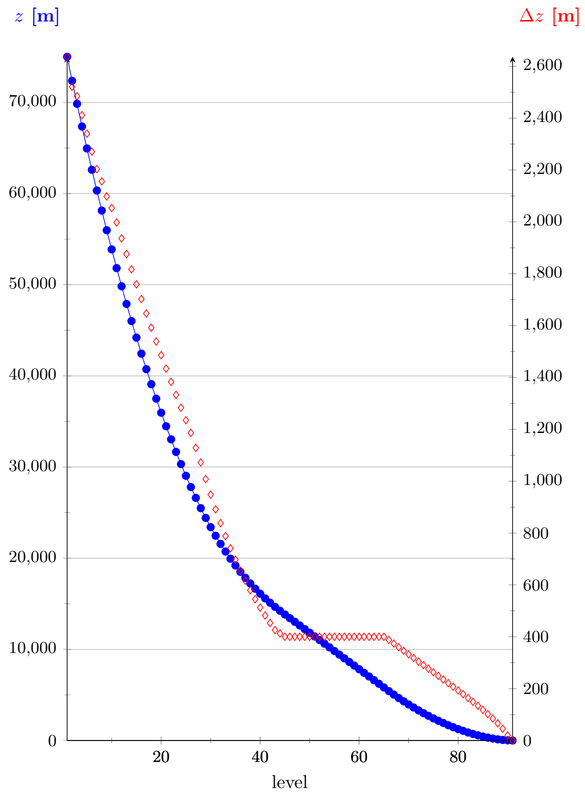
### 2.1.1 Local grid refinement

## 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 $z = 16$ km. Model levels above are flat. The required smooth large-scale contribution of the model topography is generated by digital filtering with a $\nabla^2$-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.**




| *level* | [*m*] | [*Pa*] |
|---:|---:|---:|
| 1 | 75 000 | 2.1 |
| 5 | 64 946 | 10.0 |
| 10 | 53 878 | 46.3 |
| 15 | 44 198 | 158.8 |
| 20 | 35 958 | 487.2 |
| 25 | 29 039 | 1 355.0 |
| 30 | 23 409 | 3 211.8 |
| 35 | 19 202 | 6 209.4 |
| 40 | 16 108 | 10 113.6 |
| 45 | 13 822 | 14 504.3 |
| 50 | 11 822 | 19 882.1 |
| 55 | 9 822 | 27 166.6 |
| 60 | 7 822 | 36 528.6 |
| 65 | 5 822 | 48 347.1 |
| 70 | 3 954 | 62 009.2 |
| 75 | 2 432 | 75 325.6 |
| 80 | 1 255 | 87 126.2 |
| 85 | 436 | 96 190.0 |
| 90 | 20 | 101 085.0 |

**Figure 2.4:** *Vertical (half) levels of the ICON model (planned operational setup). The table of selected pressure values (for zero height) is based on the 1976 US standard atmosphere.*

# 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 the 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<br>(Global Aerosol Climatology Project) | $4x5°$ |
| GLDB Global lake database | 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 $90° > \phi > -56°$ (with $\phi$ denoting latitude) and switch to the coarser, however globally available dataset *GLCC* for $-56° > \psi > -90°$.

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 $(0.3 - 5.0\,\mu\text{m})$ albedo for diffuse radiation (monthly fields) | MODIS |

*Continued on next page*

Table 3.2: *continued*

| | | |
|---|---|---|
| ALB_UV12 | UV-visible ($0.3 - 0.7\,\mu$m) albedo for diffuse radiation (monthly fields) | MODIS |
| ALB_NI12 | UV-visible ($0.7 - 5.0\,\mu$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 |
| 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 |
| 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) | GlobCover 2009 |

Note that fields marked with (*) are not required in operational model runs. I.e. the surface roughness `Z0` is only needed, if the additional contribution from sub-grid scale orography is taken into account (i.e. for `itype_z0=1`). In operational runs, land-use specific roughness lengths are taken from a GlobCover-based 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. 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 analysis cycle, ICON must be provided with 2 input files, containing First Guess (FG) and analysis (AN) fields, respectively. Variables for which no analysis is available are always read from the first guess file (e.g. TKE). Other variables may be either read 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 analyis 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 | FG | FG | FG | FG | FG | FG | FG |
| THETA_V | – | FG | FG | FG | FG | FG | FG | FG | FG |
| DEN | – | FG | FG | FG | FG | FG | FG | FG | FG |
| W | – | FG | FG | FG | FG | FG | FG | FG | FG |
| TKE | – | FG | FG | FG | FG | FG | FG | FG | FG |
| QC, QI, QR, QS | – | FG | FG | FG | FG | FG | FG | FG | FG |
| QV | 3DVar | AN | AN | AN | AN | AN | AN | AN | AN |
| T | 3DVar | AN | AN | AN | AN | AN | AN | AN | AN |
| P | 3DVar | AN | AN | AN | AN | AN | AN | AN | AN |
| U, V | 3DVar | AN | AN | AN | AN | AN | AN | AN | AN |
| **Surface** | | | | | | | | | |
| Z0 | – | FG | FG | FG | FG | FG | FG | FG | FG |
| T_G | – | FG | FG | FG | FG | FG | FG | FG | FG |
| QV_S | – | FG | FG | FG | FG | FG | FG | FG | FG |
| T_SO(0) | Ana_SST | AN | FG | FG | FG | FG | FG | FG | FG |
| T_SO(1:nlevsoil) | – | FG | FG | FG | FG | FG | FG | FG | FG |
| W_SO_ICE | – | FG | FG | FG | FG | FG | FG | FG | FG |
| W_SO | SMA | AN | FG | FG | FG | FG | FG | FG | FG |
| W_I | – | FG | FG | FG | FG | FG | FG | FG | FG |
| W_SNOW[1] | Ana_SNOW | AN | AN | AN | AN | AN | AN | AN | AN |
| T_SNOW | Ana_SNOW | AN | AN | AN | AN | AN | AN | AN | AN |
| RHO_SNOW[1] | Ana_SNOW | AN | AN | AN | AN | AN | AN | AN | AN |
| H_SNOW | Ana_SNOW | AN | AN | AN | AN | AN | AN | AN | AN |
| FRESHSNW | Ana_SNOW | AN | AN | AN | AN | AN | AN | AN | AN |
| **Sea ice/Lake** | | | | | | | | | |
| T_ICE | Ana_SST | AN | FG | FG | FG | FG | FG | FG | FG |
| H_ICE | Ana_SST | AN | FG | FG | FG | FG | FG | FG | FG |
| FR_ICE | Ana_SST | AN | FG | FG | FG | FG | FG | FG | FG |
| T_MNW_LK | – | FG | FG | FG | FG | FG | FG | FG | FG |
| T_WML_LK | – | FG | FG | FG | FG | FG | FG | FG | 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 | FG | FG | FG | FG | FG | FG | FG |
| T_BOT_LK | – | FG | FG | FG | FG | FG | FG | FG | FG |
| C_T_LK | – | FG | FG | FG | FG | FG | FG | FG | FG |
| T_B1_LK | – | FG | FG | FG | FG | FG | FG | FG | FG |
| H_B1_LK | – | FG | FG | FG | FG | FG | FG | FG | 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 **I**ncremental **A**nalysis **U**pdate (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).

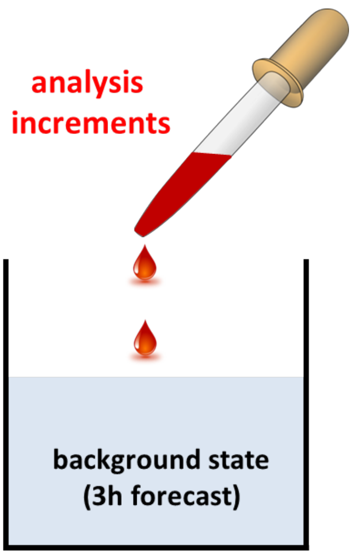


**Figure 4.1:** ***I****ncremental* ***A****nalysis* ***U****pdate. Analysis increments are added to the background state (FG) in small drips over some time interval rather than in one go. Currently, increments for* `U`, `V`, `P`, `T`, `QV` *are treated in this way.*

[1]Note 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:

$$\frac{d\mathbf{x}}{dt} = A\mathbf{x} + g(t)\Delta\mathbf{x}^A \qquad , \text{with} \quad \int g(t)\,dt = 1 \tag{4.1}$$

$\mathbf{x}$ 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 $\Delta t$.

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 $\pi$, $\rho$, $v_n$, $q_v$, based on analysis increments provided for $u$, $v$, $p$, $t$ and $q_v$.

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 3 h 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:

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

$T$ is the window width and $\Delta t$ 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.

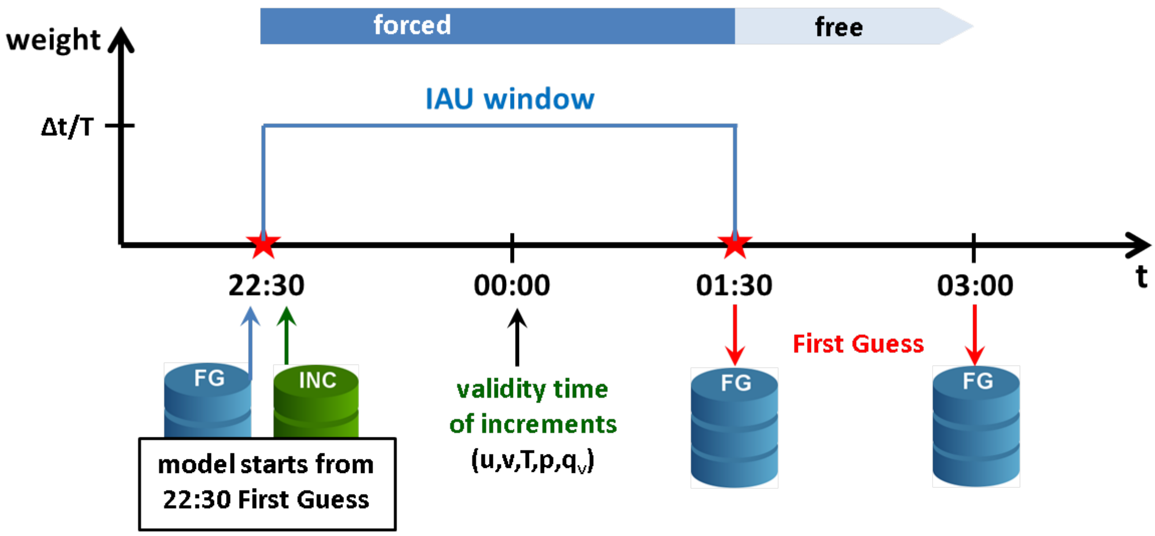


**Figure 4.2:** *Time line for an ICON assimilation run starting at 00:00 UTC.*

# Chapter 5

# 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*.

## 5.1 Deprecated output fields

With the launch of ICON, the following former GME output fields will no longer be 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.
- **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** [$m^2\,s^{-1}$]: 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 will become 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 |
|---|---|---|
| **W** | m/s | vertical velocity in height coordinates $w = \frac{\mathrm{d}z}{\mathrm{d}t}$ (3D field) |
| **DEN** | $\mathrm{kg/m^3}$ | density of moist air (3D field) |
| **TKE** | $\mathrm{m^2/s^2}$ | Turbulent kinetic energy (3D field) |
| **DTKE_CON** | $\mathrm{m^2/s^3}$ | Buoyancy-production of TKE due to sub grid scale convection (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 |

## 5.3 Available output fields

ICON 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 $\Delta\lambda = \Delta\Phi = 0.25°$. On the native grid most output fields are defined on triangle cell 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 ( ), on the lat-lon grid( ), or on both grids( ).

### 5.3.1 Time-constant (external parameter) fields

**Table 5.2:** *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 | 150/101 | 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 |

### 5.3.2 Multi-level fields on native hybrid vertical levels

**Table 5.3:** *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 | $\mathrm{m\,s^{-1}}$ |
| V | Meridional wind | 0 | 2 | 3 | 150/150 | inst | $\mathrm{m\,s^{-1}}$ |
| W | Vertical wind | 0 | 2 | 9 | 150/– | inst | $\mathrm{m\,s^{-1}}$ |
| T | Temperature | 0 | 0 | 0 | 150/150 | inst | K |
| DEN | Density of moist air | 0 | 3 | 10 | 150/150 | inst | $\mathrm{kg\,m^{-3}}$ |
| QV | Specific humidity | 0 | 1 | 0 | 150/150 | inst | $\mathrm{kg\,kg^{-1}}$ |
| QC | Cloud mixing ratio[2] | 0 | 1 | 22 | 150/150 | inst | $\mathrm{kg\,kg^{-1}}$ |
| QI | Cloud ice mixing ratio[2] | 0 | 1 | 82 | 150/150 | inst | $\mathrm{kg\,kg^{-1}}$ |
| QR | Rain mixing ratio[2] | 0 | 1 | 24 | 150/150 | inst | $\mathrm{kg\,kg^{-1}}$ |
| QS | Snow mixing ratio[2] | 0 | 1 | 25 | 150/150 | inst | $\mathrm{kg\,kg^{-1}}$ |
| CLC | Cloud cover | 0 | 6 | 22 | 150/150 | inst | % |
| TKE | Turbulent kinetic energy | 0 | 19 | 11 | 150/– | inst | $\mathrm{m^2\,s^{-2}}$ |
| DTKE_CON | Buoyancy-production of TKE due to sub grid scale convection | 0 | 19 | 219 | 150/– | inst | $\mathrm{m^2\,s^{-3}}$ |

### 5.3.3 Multi-level fields interpolated to pressure levels

The following pressure levels are available: 1000, 950, 925, 900, 850, 800, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10, 7, 5, 3, 2, 1, 0.3, 0.1 hPa. Newly available pressure levels (as compared to GME) are highlighted in red. I.e. note that all 17 WMO standard pressure levels are included.

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

**Table 5.4:** *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 | $m^2\,s^{-2}$ |
| OMEGA | Vertical velocity in pressure coordinates ($\omega = dp/dt$) | 0 | 2 | 8 | 100/– | inst | $Pa\,s^{-1}$ |
| RELHUM | Relative humidity (with respect to water) | 0 | 1 | 1 | 100/– | inst | % |
| T | Temperature | 0 | 0 | 0 | 100/– | inst | K |
| 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 | $m\,s^{-1}$ |

### 5.3.4 Single-level fields

Table 5.5: 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 | 0 | 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 | $W\,m^{-2}$ |

*Continued on next page*

Table 5.5: *continued*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ATHB_S | Net long-wave radiation flux at surface (average since model start) | 0 | 5 | 5 | 1/– | avg | $W\,m^{-2}$ |
| APAB_S | Photosynthetically active radiation flux at surface (average since model start) | 0 | 4 | 10 | 1/– | avg | $W\,m^{-2}$ |
| 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 | $W\,m^{-2}$ |
| ASWDIR_S | Surface down solar direct radiation (average since model start) | 0 | 4 | 198 | 1/– | avg | $W\,m^{-2}$ |
| ASWDIFD_S | Surface down solar diffuse radiation (average since model start) | 0 | 4 | 199 | 1/– | avg | $W\,m^{-2}$ |
| ASWDIFU_S | Surface up solar diffuse radiation (average since model start) | 0 | 4 | 8 | 1/– | avg | $W\,m^{-2}$ |
| ALB_RAD | Surface albedo for visible range, diffuse | 0 | 19 | 1 | 1/– | inst | % |
| RAIN_GSP[4] | Large scale rain (accumulated since model start) | 0 | 1 | 77 | 1/– | accu | $kg\,m^{-2}$ |
| SNOW_GSP[4] | Large snowfall water equivalent (accumulated since model start) | 0 | 1 | 56 | 1/– | accu | $kg\,m^{-2}$ |
| RAIN_CON[4] | Convective rain (accumulated since model start) | 0 | 1 | 76 | 1/– | accu | $kg\,m^{-2}$ |
| SNOW_CON[4] | Convective snowfall water equivalent (accumulated since model start) | 0 | 1 | 55 | 1/– | accu | $kg\,m^{-2}$ |
| TOT_PREC[4] | Total precipitation (accumulated since model start) | 0 | 1 | 52 | 1/– | accu | $kg\,m^{-2}$ |
| RUNOFF_S | Surface water runoff (accumulated since model start) | 2 | 0 | 5 | 106/– | accu | $kg\,m^{-2}$ |
| RUNOFF_G | Soil water runoff (accumulated since model start) | 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 |

*Continued on next page*

Table 5.5: *continued*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 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 |
| VMAX_10M | Maximum wind at 10 m above ground | 0 | 2 | 22 | 103/– | max | $\mathrm{m\,s^{-1}}$ |
| Z0 | Surface roughness (above land and water) | 2 | 0 | 1 | 1/– | inst | m |
| CLCT | Total cloud cover | 0 | 6 | 1 | 1/– | inst | % |
| 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 |
| 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 | $\mathrm{kg\,m^{-2}}$ |
| TQC | Total column integrated cloud water | 0 | 1 | 69 | 1/– | inst | $\mathrm{kg\,m^{-2}}$ |
| 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 |
| 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 |
| 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 | $\mathrm{W\,m^{-2}}$ |

*Continued on next page*

Table 5.5: *continued*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ALHFL_S | Latent heat net flux at surface (average since model start) | 0 | 0 | 10 | 1/– | avg | $W m^{-2}$ |
| FR_ICE | Sea/lake 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 | $kg m^{-3}$ |
| 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 |
| WW | Weather interpretation (WMO) | 0 | 19 | 25 | 1/– | inst | 1 |

Table 5.6: 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 | $kg m^{-2}$ |
| W_SO_ICE | Soil ice content integrated over individual soil layers | 2 | 3 | 22 | 106/106 | inst | $kg m^{-2}$ |

Soil temperature is defined at the soil depths given in Table 5.7 (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 layers 1 to 7. At the lowermost layer (mid-level height 1458 cm) the temperature is fixed to the climatological average 2 m-temperature.

[4]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 (*typeOfStatisticalProcessing*=1), the unit displayed by *grib_dump* must be multiplied by s.

**Table 5.7:** *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 |

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).

### 5.3.5 Surface fields interpolated to msl

**Table 5.8:** *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 |

## 5.4 Extended description of available output fields

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

### 5.4.1 Cloud products

**CLCT_MOD** Modified total cloud cover ($0 \leq$ `CLCT_MOD` $\leq 1$). 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 ($0 \leq$ `CLDEPTH` $\leq 1$). 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 $-500$ m at points where no convection is diagnosed.

**HTOP_CON** Same, but for cloud top.

### 5.4.2 Near surface products

**TMIN_2M** Minimum temperature at 2 m above ground, computed over 3-hourly intervals.

**TMAX_2M** Same, but for maximum 2 m temperature.

**VMAX_10M** Maximum wind gust at 10 m above ground, computed over 3-hourly intervals. It is diagnosed from the turbulence state in the atmospheric boundary layer, including a pontential enhancement by the SSO parameterization over mountainous terrain. In the presence of deep convection, it contains an additional contribution due to convective gusts.

#### 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`.

### 5.4.3 Surface products

**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 m. New sea-ice points generated by the analysis are initialized with `H_ICE`$=0.5$ m.

**T_ICE** Ice temperature over sea-ice and frozen lake points. Ice-free points over land, sea and lakes are set to `T_SO(0)`.

**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 $6.0E-3\,\mathrm{kg\,m^{-2}}$ due to numerical reasons and thus almost negligible. Over water points, `W_I` is set to 0.

### 5.4.4 Soil products

**T_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 5.7. 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.

# Chapter 6

# 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` → `Datenmanagement (technisch)` → `Management der DWD Fachdaten -Dokumentation` → `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.

## 6.1 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.
- **type**: **an** for analysis data, **fc** for forecast data, **const** for invariant data.
- **suite**: **rout** for operational data in *db=roma,* **para** for pre-operational data in *db=parma*, **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**.

## 6.2 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=parma cat=icrgl130l90_main_fc_para 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=parma cat=icogl130l90_main_an_para 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=icrgl130l90_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.

```
read db=numex cat=icrgl130l90_main_fc_exp1 exp=907 d=2013100300 s[h]=24 p=U,V lv=P
    lv1=30000 bin f=uvReg300hPa
```

- Retrieve the analysis of U on the native grid:

```
read db=numex cat=icogl130l90_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:

```
read db=numex cat=icogl130l90_main_fc_exp1 exp=907 d=2013100300 s[h]=7/to/9 p=T bin
    f=T_icon_07-09
```

- 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=icrgl400l90_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
```

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

```
read db=numex cat=icrgl400l90_main_fc_exp1 exp=906 d=2013100512 p=T lv1=85000 lv=P
    bin f=t850_iconr
```

# Appendix A

# ICON standard half level heights

ICON standard half level heights $z^h$ are listed in Table A.1. If full level heights $z^f$ 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 $z_i^f$ is given by

$$z_i^f = 0.5\left(z_i^h + z_{i+1}^h\right) \tag{A.1}$$

**Table A.1:** *Standard heights (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 | 75000.000 | 32 | 21569.375 | 63 | 6621.524 |
| 2 | 72363.546 | 33 | 20731.107 | 64 | 6221.524 |
| 3 | 69842.381 | 34 | 19942.837 | 65 | 5821.524 |
| 4 | 67357.797 | 35 | 19201.585 | 66 | 5421.524 |
| 5 | 64946.444 | 36 | 18504.545 | 67 | 5033.731 |
| 6 | 62606.299 | 37 | 17849.081 | 68 | 4659.952 |
| 7 | 60335.466 | 38 | 17232.713 | 69 | 4300.121 |
| 8 | 58132.167 | 39 | 16653.108 | 70 | 3954.183 |
| 9 | 55976.216 | 40 | 16108.074 | 71 | 3622.092 |
| 10 | 53877.930 | 41 | 15595.549 | 72 | 3303.815 |
| 11 | 51824.685 | 42 | 15113.594 | 73 | 2999.329 |
| 12 | 49826.951 | 43 | 14660.386 | 74 | 2708.624 |
| 13 | 47890.748 | 44 | 14234.210 | 75 | 2431.707 |
| 14 | 46014.776 | 45 | 13821.524 | 76 | 2168.596 |
| 15 | 44197.795 | 46 | 13421.524 | 77 | 1919.330 |
| 16 | 42438.627 | 47 | 13021.524 | 78 | 1683.966 |
| 17 | 40736.151 | 48 | 12621.524 | 79 | 1462.584 |
| 18 | 39089.298 | 49 | 12221.524 | 80 | 1255.291 |
| 19 | 37497.048 | 50 | 11821.524 | 81 | 1062.224 |
| 20 | 35958.428 | 51 | 11421.524 | 82 | 883.557 |
| 21 | 34472.507 | 52 | 11021.524 | 83 | 719.514 |
| 22 | 33038.397 | 53 | 10621.524 | 84 | 570.373 |
| 23 | 31655.249 | 54 | 10221.524 | 85 | 436.493 |
| 24 | 30322.249 | 55 | 9821.524 | 86 | 318.336 |
| 25 | 29038.622 | 56 | 9421.524 | 87 | 216.516 |
| 26 | 27803.623 | 57 | 9021.524 | 88 | 131.880 |
| 27 | 26617.350 | 58 | 8621.524 | 89 | 65.677 |
| 28 | 25488.963 | 59 | 8221.524 | 90 | 20.000 |
| 29 | 24416.908 | 60 | 7821.524 | 91 | 0.000 |
| 30 | 23408.796 | 61 | 7421.524 | | |
| 31 | 22460.814 | 62 | 7021.524 | | |

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