WAWFOR

World Aviation Weather Forecast

GRIB2 Data Set Guide

Version 3.7

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Change Record:

Version:	Changes:	Date:	By:
0.0	Original issue	19 June 2017	Haase-Straub /WV2P
0.1	Add information on turbulence	11.07.2017	Metzinger/WV21
0.2	Small changes related to turbulence	12.07.2017	Barleben/WV2
0.3	Add information on icing	18.07.2017	Metzinger/WV21
1.0	Add information on icing and turbulence to Appendix A	11.10.2017	Metzinger/WV21
1.1	Small changes of description of icing	20.10.2017	Kalinka/FE22
2.0	Describe the filenames	23.11.2107	Metzinger/WV21
2.1	Correction of EDP height levels	15.01.2018	Metzinger/WV21
2.2	Correction of EDP height levels	15.02.2018	Metzinger/WV21
2.3	Add description of WAWFOR ICON6_Nest, remove WAWFOR-ICON13 European section	06.08.2018	Wortmann/WV21
2.4	Add WAWFOR ICON13 European section as third data set of WAWFOR	21.09.2018	Wortmann/WV21
2.5	Add time step 00-04vv to WAWFOR ADWICE data set	05.06.2019	Metzinger/WV21 Wortmann/WV21
2.6	Adapt calculation of tropopause height and troposphere temperature	11.07.2019	Metzinger/WV21
2.7	Add 4 pressure level to package WAWFOR 3d and 4 parameter to package WAWFOR 1d, implementation in operational use with model run 29.10.2019 06 UTC	29.10.2019	Wortmann/WV21
2.8	Change of time steps from vv+36 to vv+48 in package 5	19.02.2020	Wortmann/WV21
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3.0	Remove description of data set WAWFOR ICON Global EU	25.06.2020	Metzinger/WV24
3.1	Detailed description of vertical interpolation, small correction Appendix B (package 2: level indicator of cb top)	09.08.2021	Wortmann/WV24
3.2	Correction of using precise pressure levels in the calculation of flight levels to avoid the use of approximations that are currently in use (according to ICAO guideline), valid for package 1 (wawfor	17.05.2022	Wortmann/WV24

	3d), package 4 (adwice) and package 5 (turbulence) Correction double output of RAIN_CON and correction level type parameter „cb horizontal extent“ in package „wawfor_cb“		
3.3	Adaption of icing to new vertical pressure levels. Introduction of low-level heights in AMSL differentiation in between “no icing” (=0) and “missing data / below ground”) in Icing data and correction of technical details addition chapter 1.2 “correction of technical details	12/18.08.2022	Wortmann/WV24 Kalinka/FE22
3.4	correction of FL specification: 5000PA correspond to FL675	11.10.2022	Metzinger/WV24
3.5	Remark to unit of precipitation	19.12.2022	Metzinger/WV24
3.6	Add time steps vv+78h in WAWFOR ICON-EU Add convection parameter in package CB in WAWFOR ICON-EU	10.01.2024	Wortmann/WV24 Metzinger/WV24 Wetter/WV22
3.7	Correction of naming of Geopotential Height instead of Geopotential	12.06.2024	Wortmann/WV24 Metzinger/WV24

1. Introduction to WAWFOR DWD Forecasts in GRIB2 format

1.1 Purpose of this document

The purpose of this document is to enable the programmer of the aviation service provider without explicit extensive knowledge of meteorology to handle WAWFOR data.

There are two WAWFOR data sets:

1. **WAWFOR ICON Global**: This data set has a global expansion and is based on the global model ICON13 (0.25° x 0.25° (~25km x 25km)).

2. **WAWFOR ICON-EU**: This data set is an European section from 23.5° W to 62.5° E / 29.5° N to 70.5° N, but based on the model ICON6_Nest with an higher spatial resolution (0.0625° x 0.0625° (~6.5km x 6.5km)).

For more information, also see chapter 2.4 “WAWFOR fields”.

1.2 Decoding of GRIB2 files[1]

A GRIB2 file has to be decoded. The received messages (the files in the data sets) also need decoding for further processing. For decoding a GRIB2 file, the Software ecCodes provided by the ECMWF:
https://software.ecmwf.int/wiki/display/ECC/ecCodes+Home
can be used. This is a DWD recommendation.

For correct handling of GRIB2 data local GRIB tables are needed. The current version of GRIB2 tables are provided on the DWD open data webservice:
https://opendata.dwd.de/weather/lib/grib/

1.3 Access to WAWFOR data set

There are three ways to access the WAWFOR data set:

- Download data via SFTP server (GRIB2 File)
- Push transfer of data from DWD to customer (GRIB2 File)
- GeowebService (WMS request, WCS request)

[1] This chapter contains only a brief description. A complete definition of the GRIB2 format is given in the WMO Specification, see [1], [3] and [4].

1.5 GRIB2 file size

The file size of the global WAWFOR packages based on ICON13 and the European WAWFOR packages based on ICON6_Nest for all available prediction steps are approximately (**only GeowebService*):

	Global (ICON13)	Europe (ICON6_Nest)
Package 1: volume data	31G/*34G**	43G/*48G**
Package 2: cb, weather and precipitation	550M	950M
Package 3: single level	1.4G	2.3G
Package 4: icing	3.7G/*4.2G**	3.0/*3.5G**
Package 5: turbulence	2.9G	3.4G
Package static-data	3.5M	3.5M
In total	~ 39G/43G	~54G/*59G**

2. WAWFOR data set – technical issues

2.1 WAWFOR packages

WAWFOR represents a data set that explicitly addresses the needs of aviation customers. It contains elements directly taken from the DWD ICON13 NWP model and the ICON6_Nest like temperature or 10m-wind, elements derived from the ICON13 and ICON6_Nest model such as horizontal extent of cumulonimbus clouds as well as elements, such as icing and turbulence, applying advanced processes.

Each WAWFOR data set consists of 5 packages plus a package containing static data, each of these being available for global expansion as well as for a European section:

- **Package 1:** Volume data for flight planning, like wind, temperature, humidity, geopotential height and cloud cover.

- **Package 2:** Single-level fields like precipitation, weather interpretation (WW) and Cumulonimbus (Cb). Additionally, WAWFOR ICON-EU contains Height of top of dry convection, Lifting ratio VST (gliding) (hourly), Potential flight distance PFD (gliding) (hourly sum) and Potential flight distance PFD (gliding) (daily sum vv+22h, 48h,70h).

- **Package 3:** Single-level fields like Tropopause height and Tropopause temperature, maximum wind and corresponding height, 2m-temperature and 2m-dewpoint, surface temperature, QNH, QFF, 10m-wind and 10m-maximum wind, total cloud cover.

- **Package 4:** Icing based on the system ADWICE (**A**dvanced **D**iagnosis and **W**arning system for aircraft **IC**ing **E**nvironments) (Kalinka, F. et al, 2017)[2]

- **Package 5:** Turbulence (by definition EDP data are "only" applicable for a medium weight aircraft at cruising altitude (!))

Additionally, a package containing static data is being supplied with each model run.

- **Static-data package**: Containing geometric height of surface and land-sea distribution.

For a detailed listing of WAWFOR data packages 1 to 5, plus the static-data package, and corresponding elements see Appendix A.

WAWFOR data sets are available for each ICON13 and ICON6_Nest NWP model run (00UTC, 06UTC, 12UTC, 18UTC). WAWFOR Global is running up to 48h, WAWFOR ICON6_Nest is running up to 78h, both at a temporal resolution of one hour. The package turbulence is running up to 36h based on ICON13 and 48h based on ICON6_Nest at a temporal resolution of one hour. The package icing is actually available from forecast step 00 up to 48h also at a temporal resolution of one hour.

2.2 WAWFOR file names and files numbers

For each prediction step there is a separate file containing all elements of the corresponding package. Thus, one model run comprises 49 files (WAWFOR Global) respectively 79 files (WAWFOR ICON6_Nest). Package 2 comprises 48 files (WAWFOR Global) respectively 78 files (WAWFOR ICON6_Nest., as it does not provide data for prediction step zero, and the static-data package is available only at prediction step zero. Note, that for prediction step zero, maximum wind (10m) in Package 3 is not available. Package 5 – turbulence – comprises 37 or rather 49 files and package 4 – icing – actually 49 files.

The respective model run is marked within the respective filename as follows:

- WAWFOR global data set based on ICON13:

[2] Kalinka, F., Roloff, K., Tendel, J., Hauf, T. (2017): The In-flight icing warning system ADWICE for European airspace – Current structure, recent improvements and verification results. Meteorologische Zeitschrift Vol. 26 No. 4 (2017), p. 441 – 455

e.g. *P_3d_T_000_201807311200.grb2* stands for P_*package*_T_0*vv*_ *YYYYMMDDHHMM*.grb2

- WAWFOR European data set based on ICON6_Nest:
  e.g. *Pieu_cb_T_048_201807310000.grb2* stands for
  Pieu_*package*_T_0*vv*_ *YYYYMMDDHHMM*.grb2

with

- package: 3d, 1d, cb, cat, ice, static
- *vv*: forecast step from hour 00 to 48 (WAWFOR Global) respectively 78 (WAWFOR ICON6_Nest) and
- *YYYYMMDDHHMM: year, month, day, hour, minute*

This is valid as well for SFTP server as for push transfer to customer. For the global and European WAWFOR data set, every individual package is being stored in a separate directory named as following:

https://data.dwd.de/aviation/WAWFOR/...

- …/data_set_1d/…
  - …/IconGlobal
  - …/IconEU
- …/data_set_3d/…
  - …/IconGlobal
  - …/IconEU
- …/data_set_cb/…
  - …/IconGlobal
  - …/IconEU
- …/data_set_ice/…
  - …/IconGlobal
  - …/IconEU
- …/data_set_cat/…
  - …/IconGlobal
  - …/IconEU
- …/data_set_static/…
  - …/IconGlobal
  - …/IconEU

2.3 WAWFOR fields

All global WAWFOR fields (ICON13) are given on the same horizontal grid points, the spatial resolution being 0.25° x 0.25° (~25km x 25km).

The rectangular grid for the global expansion (based on ICON13) extends from -180°W to 180°E, the WAWFOR scanning mode is from SW to NE.

All European WAWFOR fields (ICON6_Nest) are given on the same horizontal grid points, the spatial resolution being 0.0625° x 0.0625° (~6.5km x 6.5km). The rectangular grid for the European expansion extends from 23.5° W to 62.5° E / 29.5° N to 70.5° N, the WAWFOR scanning mode is from SW to NE.

The property “bit depths” of all WAWFOR data sets is set to 12 bit, with the exception of maximum accuracy of 16 bit for RELHUM, QNH, QFF and HSURF. Also the accuracy of the elements of Package 5 is set to accuracy of 16 bit (bitsPerValue).

Note, that for interpolation from ICON native (triangular) grid (resolution of 13 km and 90 levels) to WAWFOR resolution two regrid methods have been applied:

- “nearest neighbour” (nnb) for elements of Package 2,3,5 and for the static-data package, as well as surface values T_2M, TD_2M, U_10M, V_10M und VMAX_10M from Package 3.
- “radial basic function” (rbf) for all elements from Packages 1 and 3 (except for fields _2M and _10M)

Package icing is calculated on rectangular grid, thus no horizontal interpolation is needed.

Vertical interpolation is being calculated by natural logarithm of pressure (full level). However, WAWFOR data consider the orography. That means at low levels the WAWFOR pressure and geometric levels intersect with orography. Because the condition ”zero topography height” is seldom met in real applications, WAWFOR 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. At first WAWFOR interpolates the field HHL to full levels and then calculates by natural logarithm of pressure (full level) the desired WAWFOR fields on pressure heights (hPa) and Low level heights (AMSL).

These sub-terrain data, where the WAWFOR pressure and geometric levels intersect with orography, are set to “missing”.

For EDP (package 5) and the icing information (package 4), it is done by taking the value of nearest model layer, considering the predicted pressure. Sub-terrain data are also set to “missing”

Undefined data is set to “missing”, see for example Cb base (HBAS_CON) and Cb top (HTOP_CON).

The unit of data follows conventions of SI units.

For the calculation of WAWFOR data a constant Earth radius of 6.371.229 m, as used in the DWD NWP models ICON13 and ICON6_Nest, is applied. This does not correspond to the ICAO suggested Earth radius of 6.356.766 m. However, the effect of this difference on WAWFOR fields is negligible.

For a listing per element/package see table “WAWFOR Parameters – production details” in Appendix C.

3. WAWFOR data sets – content-related issues

The WAWFOR data sets were verified with the aid of visualization software METVIEW and NinJo.

3.1 Particular fields – production details

Elements that were calculated from the NWP models ICON13 and ICON6_Nest (furthermore mentioned as ICON), that were treated in any noteworthy way or where there is anything noteworthy, are explained explicitly below:

Package 1

- Geopotential height of pressure levels in gpm, corresponding to geopotential divided by a g0=9.80665. This element is not available on height levels.

Package 2

- Precipitation rates smaller than zero were set to zero. As precipitation taken from ICON are accumulated quantities, rounding may errors occur, resulting in small negative values. This means that no precipitation happened during the last hour.
- HTOP_DC: Height of the top of dry convection above MSL. It is the upper limit of dry thermals rising from near the surface. At grid points without dry convection the value is zero, or the surface height at points below MSL.
- LIFT_RATIO: Hourly average lifting ratio above MSL of a standard class glider aircraft as a result of dry convection.
- POT_FLT_DIST: The potential flight distance (PFD) represents the optimum flight distance achievable for a standard class glider aircraft. The PFD is available both as hourly sum and as an integral for the complete duration of the daily dry convection. Each daily sum is provided at 22 UTC

of the respective day. Please note: for the model runs 06,12 and 18 UTC the daily sum is taken from the 00UTC run to get a whole day for the computation.

- WW: The ICON quantity already relates to the past hour only.
- HBAS_CON and HTOP_CON: For these quantities to be consistent with Cumulonimbus (Cb) horizontal extent, a mask of Cumulonimbus (Cb) horizontal extent, which includes the check of total precipitation to be larger than 0.015 mm/h, is applied to filter out drizzle. Outside this mask, these quantities are not defined. Also, HBAS_CON is not to be smaller than HSURF.
- Cumulonimbus (Cb) horizontal extent (CBHEXT) is calculated from the total precipitation rate of the former hour. Based on the weather interpretation (WW), segments of the total precipitation rate are assigned to threshold levels. Values of Cb horizontal extent range from 0% to 100%. To make sure, that there are defined values of HBAS_CON and HTOP_CON only where CBHEXT is larger than zero, a mask of CBHEXT is applied to these quantities to guarantee consistency. For the detailed definition of Cb horizontal extent see Appendix D.

Package 3

- Tropopause height and Tropopause temperature are calculated following the definition from Chris Tyson from Met Office (personal communication), the WAFC Tropopause data are based on, too:

> "The Tropopause height is the lowest level where lapse rate over 2 adjacent model layers of atmosphere is less than 0.002 K/m (i.e. less than 2 deg C/km). This level must be between 500hPa and 50hPa, and the temperature at that point must be <243K.
>
> The criteria extend upon the WMO definition to prevent erroneous identification of Tropopause heights at 'medium' levels (occasionally experienced due to elevated inversions that can meet the basic WMO criteria over some hot and high desert areas in summer)."

To take the ICAO standard atmosphere into account a correction of the troposphere height ($TR - Height$) is done following this formula[3]:

[3] See https://www.weather.gov/epz/wxcalc_pressurealtitude and http://www.wolkenschnueffler.de/40464.html

For polytrope atmosphere < 11km

$$TR - Height = \frac{Tisa}{y}\left[1 - \left(\frac{ptr}{Pisa}\right)^{\frac{Rd*y}{g0}}\right]$$

And for isotrope atmosphere between 11km and 20km:

$$TR - Height = 11000\left[\frac{Rd * Ttr}{g0}\right] * \ln\left(\frac{ptr}{pisat}\right)$$

With

- $Tisa$ ICAO standard temperature [K] in NN: 288.15K
- y ICAO standard atmosphere (ISA) temperature lapse rate: 0.0065K
- ptr pressure troposphere (hPa)
- $pisa$ Standard sea-level atmospheric pressure (1013.25 hPa) ISA
- Rd gas constant dry air (Jkg⁼1K*1)
- $g0$ gravitational accerleration:9.8065m/s²
  - Ttr ICAO standard temperature [K] troposphere: 216.615K
  - $pisat$ pressure ICAO standard [hPa] in troposphere height: 226.32hPa

Maximum wind corresponds to the maximum of the absolute value of the wind vector |v| in a given column below pressure level 75hPa.

- QNH is being calculated (via the fieldextra operator) based on surface pressure PS (pressure reduced at sea level, based on standard atmosphere [Pa]), and geometric ground altitude HSURF:

  QNH = PS * (T0 / (T0-alpha*HSURF))**n

  with T0 = 288.15K, alpha = 0.0065K/m, n = 5.256.

- QFF corresponds to MLSP (mean sea level pressure)

Package 4

- PID_CODE: Icing Degree Code (0=no icing, 1=light, 2=moderate, 3=severe, miss=below ground / no data). The icing intensity is predicted in the aviation well known intensities: Light, Moderate and Severe. Identification of the icing intensities are based on empirical relations between physical cloud parameters and the icing intensity.

- Composit Graphic: For the icing degree code it is possible to build a composit graphic. The objective of this composit graphic is to get a 3-dimensional overview on possible icing risk in one picture. It consists of the following six parameters:
    1. PIDC_BASE_HFT: Icing Base (hft)
    2. PIDC_MAX_BASE_HFT: Icing Max Base (hft)
    3. PIDC_MAX_TOP_HFT: Icing Max Top (hft)
    4. PIDC_TOP_HFT: Icing Top (hft)
    5. PIDC_MAX_CODE: Icing Max Code (0=no icing, 1=light, 2=moderate, 3=severe, miss=below ground / no data) - Icing Degree Composit;
    6. PIDC_VERT_CODE: Icing Vertical Code (1=continuous,2=discontinuous) (entire atmosphere)

    PIDC_MAX_CODE describes the maximum expected icing intensity in the entire airspace with altitudes in between base of maximum icing intensity (PIDC_MAX_BASE_HFT) and top of it (PIDC_MAX_TOP_HFT). Altitudes of icing in lower intensities, if any, are described by PIDC_BASE_HFT for lower limit and PIDC_TOP_HFT for upper limit. Note that altitudes from MSL up to (and including) 5000ft are described as levels AMSL. Altitudes above 5000ft are described by their corresponding pressure-level (see Appendix A).
    PIDC_VERT_CODE describes, whether icing between PIDC_BASE_HFT and PIDC_TOP_HFT is continuous (=1) or not (=2).

    However, there are two weaknesses. It is not possible to determine the icing intensity above or below severe icing (no distinction between light and moderate icing) and second, there is no information about in which altitudes icing is discontinuous, if so.

- PISC_SIG_CODE: Icing Significant Code (0=no icing, 1=general, 2=convective, 3=stratiform, 4=freezing, miss=below ground / no data). This icing product contains information about the likely icing scenario.

Package 5

- EDP Eddy Dissipation Parameter (m**2/3 s**-1): forecast of **E**ddy **D**issipation **R**ate (EDR), i.e. the transfer rate of **T**urbulence **K**inetic **E**nergy (TKE) into heat with three additional source terms for the temporal change of TKE, reflecting the relevant sources for aircraft turbulence (Clear Air-, Mountain Wave-, Convective Induced Turbulence)
- EDP_MAX_UUIR Eddy Dissipitation Rate, Total Maximum in upper UIR (<FL450)

- EDP_MAX_LUIR: Eddy Dissipitation Rate, Total Maximum in lower UIR (<FL350)
- EDP_MAX_UFIR: Eddy Dissipitation Rate Total Maximum in upper FIR (<FL255)
- EDP_MAX_LFIR: Eddy Dissipation Rate Total Maximum in lower FIR (<FL180)

(remark: The turbulence is given as the maximum EDP-value of a vertical layer)

Package 6

- FR_LAND and HSURF: Note that land-sea distribution and geometric ground altitude do not fit together in detail. Smoothing of orography (HSURF) in ICON13 and ICON6_Nest results in an artificial lifting of the sea level.

4. Known differences between global and European WAWFOR and WAFC London/Washington WAFS GRIB2 data sets (and FABEC data sets)

4.1 Scanning mode

The WAWFOR scanning mode is from South Pole to North Pole, from SW to NO. This corresponds to the WAFC London scanning mode (and to the FABEC scanning mode).

4.2 Spatial resolution

The WAWFOR spatial resolutions of 0.25° x 0.25° (data set based on ICON13) and 0.0625° x 0.0625° (data set based on ICON6_Nest) differ from the WAFS spatial resolution of 1.25° x 1.25°.

4.3 Elements determined differently

In Package 2 the quantity Cumulonimbus (Cb) horizontal extent represents the degree of cloud coverage caused by Cumulonimbus (Cb), as described in ICAO Annex 3 to be the areal percentage of the convective part.

In Package 3 the determination of the height of maximum wind and corresponding wind components starts at pressure level 75hPa, searching for the wind maximum going downwards. For WAFS data the height level of MAXWIND is based on the maximum wind in layer 700hPa to 100hPa (~FL98 to FL530).

5. References

For documentation of the ICON model see:

https://www.dwd.de/DE/fachnutzer/forschung_lehre/numerische_wettervorhersage/numerische_wettervorhersage_node.html

For the Official International Documentation for GRIB2 see the WMO documentations:

[1] WMO, “Manual on codes,” [Online]. Available:
Manual on Codes, Volume I.1 – International Codes (wmo.int)

[2] WMO, “Guide to GRIB2,” [Online]. Available: https://github.com/noaaport/nbsp/blob/master/dev-notes/grib/GRIB2_062006.pdf.

[3] WMO, “Tables extracted from the Manual on Codes (Latest version),” [Online]. Available: https://library.wmo.int/?lvl=notice_display&id=10684#.Yuo20D3P2Uk.

[4] WMO, “template GRIB2,” [Online]. Available: https://wmoomm.sharepoint.com/:b:/s/wmocpdb/EUmnLNAM9WdMr1S7GRMl_G8BFqp-B1Qie-k-vMwmrG22GQ?e=cEd2Vk

6. WAWFOR Metadata

For WAWFOR Parameters and corresponding metadata see Appendix B.

1 Appendix A: Listing of elements of global and European WAWFOR packages

Package No	Package 1	Package 2	Package 3	Package 4	Package 5	Package 6
Package Name	**Volume data**	**Cb, precipitation and weather**	**ICON single levels**	**ADWICE / Icing**	**Turbulence / EDP**	**Static data, orography, land-sea**
File Name	**wawfor_3d_glo /-eu**	**wawfor_cb_glo /-eu**	**wawfor_1d_glo / _eu**	**wawfor_ice_glo /_eu**	**wawfor_cat_glo /_eu**	**wawfor_static _glo /_eu**
NWP Model	ICON13 & ICON6_Nest					
Modell Runs	4x (Every 6h, model run 00 UTC, 06 UTC, 12 UTC and 18 UTC)					
Forecast time	00h to +48h (glo) 00h to +78h (eu)	01h to +48h (glo) 01h to +78h (eu)	00h to +48h (glo) 00h to +78h (eu)	00h to +48h	000h to +36 (glo) 00h to +48h (eu)	0h to +48h
Time steps	1h					
Horizontal data coverage	Rectangular lat-lon grid: ICON13: global 0° W to 360° E ICON6_Nest: Europe 23.5° W to 62.5° E / 29.5° N to 70.5° N					
Horizontal resolution	ICON13: 0,25° x 0,25° ~ 25km x 25km ICON6_Nest: 0.0625° x 0.0625° ~ 6.5km x 6.5km					
Vertical resolution	57 (*66**) pressure levels & 13 low level heights	Cumulonimbus base level, Level of cloud tops, Mean sea level, Convection	depends on variables	32 (*41**) pressure levels & 13 low level heights	36 pressure levels	Surface

Package Name	Volume data	Cb, precipitation and weather	ICON single levels	ADWICE / Icing	Turbulence / EDP	Static data, orography, land-sea
Pressure levels (PA) ***only GeowebService***	*99510 (FL005)*, 97720 (FL010)*, 95950 (FL015)*, 94210 (FL020)*, 92500 (FL025)*, 90810 (FL030)*, 89150 (FL035)*, 87510 (FL040)*, 85900 (FL045)**, 84310 (FL050), 81200 (FL060), 78190 (FL070), 75260 (FL080), 72430 (FL090), 69680 (FL100), 67020 (FL110), 64440 (FL120), 61940 (FL130), 59520 (FL140), 57180 (FL150), 54920 (FL160), 52720 (FL170), 50600 (FL180), 48550 (FL190), 46560 (FL200), 44650 (FL210), 42790 (FL220), 41000 (FL230), 39270 (FL240), 37600 (FL250), 35990 (FL260), 34430 (FL270), 32930 (FL280), 31490 (FL290), 30090 (FL300), 28740 (FL310), 27450 (FL320), 26200 (FL330), 25000 (FL340), 23840 (FL350), 22730 (FL360), 21660 (FL370), 20650 (FL380), 19680 (FL390), 18750 (FL400), 17870 (FL410), 17040 (FL420), 16240 (FL430), 15470 (FL440), 14750 (FL450), 14060 (FL460), 13400 (FL470), 12770 (FL480), 12170 (FL490), 11600 (FL500), 11050 (FL510), 10530 (FL520), 10040 (FL530), 9570 (FL540), 9120 (FL550), 8700 (FL560), 8280 (FL570), 7900 (FL580), 7520 (FL590), 7170 (FL600), 5000 (FL675)	n.a.	n.a.	99510 (FL005)*, 97710 (FL010)*, 95950 (FL015)*, 94210 (FL020)*, 92500 (FL025)*, 90810 (FL030)*, 89150 (FL035)*, 87510 (FL040)*, 85900 (FL045)*, 84310 (FL050), 81200 (FL060), 78190 (FL070), 75260 (FL080), 72430 (FL090), 69680 (FL100), 67020 (FL110), 64440 (FL120), 61940 (FL130), 59520 (FL140), 57180 (FL150), 54920 (FL160), 52720 (FL170), 50600 (FL180), 48550 (FL190), 46560 (FL200), 44650 (FL210), 42790 (FL220), 41000 (FL230), 39270 (FL240), 37600 (FL250), 35990 (FL260), 34430 (FL270), 32930 (FL280), 31490 (FL290), 30090 (FL300), 28740 (FL310), 27450 (FL320), 26200 (FL330), 25000 (FL340), 23840 (FL350), 22730 (FL360)	69680 (FL100), 67020 (FL110), 64440 (FL120), 61940 (FL130), 59520 (FL140), 57180 (FL150), 54920 (FL160), 52720 (FL170), 50600 (FL180), 48550 (FL190), 46560 (FL200), 44650 (FL210), 42790 (FL220), 41000 (FL230), 39270 (FL240), 37600 (FL250), 35990 (FL260), 34430 (FL270), 32930 (FL280), 314920 (FL290), 30090 (FL300), 28740 (FL310), 27450 (FL320), 26200 (FL330), 25000 (FL340), 23840 (FL350), 22730 (FL360), 21660 (FL370), 20650 (FL380), 19680 (FL390), 18750 (FL400), 17870 (FL410), 17040 (FL420), 16240 (FL430), 15470 (FL440), 14750 (FL450)	n.a.

Package Name	Volume data	Cb, precipitation and weather	ICON single levels	ADWICE / Icing	Turbulence / EDP	Static data, orography, land-sea
Low level heights (AMSL) (geometr. height in m AMSL)	500ft (152m), 1000ft (305m), 1500ft (457m), 2000ft (610m), 2500ft (762m), 3000ft (914m), 4000ft (1219m), 5000ft (1524m), 6000ft (1829m), 7000ft (2134m), 8000ft (2438m), 9000ft (2743m), 10000ft (3048m)	n.a.	n.a.	500ft (152m), 1000ft (305m), 1500ft (457m), 2000ft (610m), 2500ft (762m), 3000ft (914m), 4000ft (1219m), 5000ft (1524m), 6000ft (1829m), 7000ft (2134m), 8000ft (2438m), 9000ft (2743m), 10000ft (3048m)	n.a.	n.a.
	(Geopotential Height only on pressure levels)			composit product on entire atmosphere		

Package Name	Volume data	Cb, precipitation and weather	ICON single levels	ADWICE / Icing	Turbulence / EDP	Static data, orography, land-sea
Data (unit; short Name)	wind components u, v (m/s; U, V)	grid-scale rain (kg/m²/h; RAIN_GSP_D)	tropopause height (m; ICAHT)	icing degree code (0=no icing, 1=light, 2=moderate, 3=severe, miss=below ground / no data; PID_CODE)	eddy dissipation parameter (m⅔/s; EDP)	land-sea distributio n (1 to 0; FR_LAND)
	temperature (K; T)	grid-scale snow (kg/m²/h; SNOW_GSP_D)	tropopause temperature (K; T)	icing degree composit: icing base (hft; PIDC_BASE_HFT)	eddy dissipitation rate, total maximum in upper UIR <FL450) (m⅔/s; EDP_MAX_UUIR)	geometric ground altitude (m; HSURF)
	relative humidity (%; RELHUM)	convective rain (kg/m²/h; RAIN_CON_D)	maximum wind components u,v (m/s; U,V)	icing degree composit: icing max base (hft; PIDC_MAX_BASE_HFT)	eddy dissipitation rate, total maximum in lower UIR (<FL350) m⅔/s; EDP_MAX_LUIR)	
	geopotential height (gpm; GH)	convective snow (kg/m²/h; SNOW_CON_D)	height of maximum wind (m; ICAHT)	icing degree composit: icing max top (hft; PIDC_MAX_TOP_HFT)	eddy dissipitation rate total maximum in upper FIR (<FL255) (m⅔/s; EDP_MAX_UFIR)	
	cloud cover (%; CLC)	weather interpretation WW * (1; WW)	temperature (2m) (K; T_2M)	icing degree composit: icing max top (hft; PIDC_TOP_HFT)	eddy dissipitation rate total maximum in lower FIR (<FL180) (m⅔/s; EDP_MAX_LFIR)	
		Cb base (m; ICAHT)	dewpoint temperature (2m) (K; TD_2M)	icing degree composit: icing max code (0=no icing, 1=light, 2=moderate, 3=severe, miss=below ground / no data; PIDC_MAX_CODE)		
		Cb top (m; ICAHT)	surface temperature (K; T_G)	icing vertical code; entire atmosphere (1=continuous, 2=discontinuous; PIDC_VERT_CODE)		

		Cb horizontal extent (%; CBHEXT)	QNH (hPa; ALTS)	Icing Significant Code (0=no icing, 1=general, 2=convective, 3=stratiform, 4=freezing, miss=below ground / no data; PISC_SIG_CODE)		
		Height of top of dry convection (m; HTOP_DC)	QFF (hPa; PMSL)			
		Lifting ratio VST (gliding) (hourly) (m/s; LIFT_RATIO,)	wind components u, v (10m) (m/s; U_10M, V_10M)			
		Potential flight distance PFD (gliding) (hourly sum) (m; POT_FLT_DIST)	maximum wind (10m), (m/s; VMAX_10M)			
		Potential flight distance PFD (gliding) (daily sum 22 UTC) (m; POT_FLT_DIST)	total cloud cover (%; CLCT)			
			total precipitation (kg/m²; TOT_PREC)[4]			
			high level clouds (%; CLCH; 0-400 hPa)			
			mid level clouds (%; CLCM; 400-800 hPa)			
			low level clouds (%; CLCL; 800 hPa-soil)			

[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.

2 Appendix B:

WAWFOR parameters – metadata

Package 1 - - Package volume data					
Product Discipline Section 0	Parameter Category Section 4	Parameter Number Section 4	Level Indicator Section 4	Field Parameter	Unit
0	2	2	100/102	wind component u	m/s
0	2	3	100/102	wind component v	m/s
0	0	0	100/102	temperature	K
0	1	1	100/102	relative humidity	%
0	3	5	100	geopotential height	gpm
0	6	22	100/102	cloud cover	%

Package 2 - - Package Cb, precipitation and weather					
0	1	77	1	gridscale rain	kg/m²/h
0	1	56	1	gridscale snow	kg/m²/h
0	1	76	1	convective rain	kg/m²/h
0	1	55	1	convective snow	kg/m²/h
0	19	25	1	WW *	1
0	3	3	2	Cb base	m
0	3	3	3	Cb top	m
0	6	25	10	Cb horizontal extent	%
0	6	196	3	Height of top of dry convection	m
0	19	241	1	Lifting ratio VST (gliding) (hourly)	m/s
0	19	240	1	Potential flight distance PFD (gliding) (hourly sum) productDefinitionTemplateNumber=0	m
0	19	240	1	Potential flight distance PFD (gliding) (daily sum 22 UCT) productDefinitionTemplateNumber=8	m

Package 3 - - Package ICON single level					
0	3	3	7	Tropopause height	m
0	0	0	7	Tropopause temperature	K
0	2	2	6	maximum wind component u	m/s
0	2	3	6	maximum wind component v	m/s
0	3	3	6	height of maximum wind	m
0	0	0	103	temperature 2m	K
0	0	6	103	dewpoint temperature 2m	K
0	0	0	1	surface temperature	K
0	3	11	101	QNH	hPa
0	3	1	101	QFF	hPa
0	2	2	103	wind component u 10m	m/s
0	2	3	103	wind component v 10m	m/s
0	2	22	103	maximum wind 10m	m/s
0	6	1	1	total cloud coverage	%
0	1	52	1	total precipitation	kg/m^2 [5]
0	6	22	100	high level clouds	%
0	6	22	100	mid level clouds	%
0	6	22	100	low level clouds	%

Package 4 - - Package icing data					
0	19	195	1	Icing Base - Icing Degree Composit	hft
0	19	196	1	Icing Max Base -Icing Degree Composit	hft
0	19	197	1	Icing Max Top - Icing Degree Composit	hft
0	19	198	1	Icing Top - Icing Degree Composit;	hft
0	19	199	10	Icing Vertical Code - Icing Degree Composit(1=continuous,2=discontinuous) (entire atmosphere);	code
0	19	200	10	Icing Max Code (0=no icing, 1=light, 2=moderate, 3=severe, miss=below ground / no data) - Icing Degree Composit;	code
0	19	207	100/102	Icing Degree Code (0=no icing, 1=light, 2=moderate, 3=severe, miss=below ground / no data)	code
0	19	206	10	Icing Significant Code (0=no icing, 1=general, 2=convective, 3=stratiform, 4=freezing, miss=below ground / no data)	code

[5] see page 20

Package 5 - - Package turbulence data					
0	19	216	100	Eddy dissipation rate	m⅔/s
0	19	226	102	Eddy Dissipation Rate Total Col-Max. Upper UIR (<FL450);	m⅔/s
0	19	225	102	Eddy Dissipation Rate Total Col-Max. Lower UIR (<FL350)	m⅔/s
0	19	224	102	Eddy Dissipation Rate Total Col-Max. Upper FIR (< FL255)	m⅔/s
0	19	228	102	Eddy Dissipation Rate Total Col-Max. Lower FIR (< FL180)	m⅔/s

Package 6 - - Package static framework data, terrain orography					
2	0	0	1	land-sea-distribution	1 to 0
0	3	6	1	geometric ground altitude	m

3 Appendix C:

WAWFOR parameters – technical details

Package 1 - - Package volume data							
shortName	bit depth [bit]	interpolation /regridding from ICON	available for vv=0h	only available for vv=0h	undefined data besides sub-terrain data	Field Parameter	Unit
U	12	rbf	yes	no	yes	wind component u	m/s
V	12	rbf	yes	no	yes	wind component v	m/s
T	12	rbf	yes	no	yes	temperature	K
RELHUM	16	rbf	yes	no	yes	relative humidity	%
GH	12	rbf	yes	no	yes	geopotential height	gpm
CLC	12	rbf	yes	no	yes	cloud cover	%

Package 2 - - Package Cb, precipitation and weather							
shortName	bit depth [bit]	interpolation /regridding from ICON	available for vv=0h	only available for vv=0h	undefined data besides sub-terrain data	Field Parameter	Unit
RAIN_GSP_D	12	nnb	no	no	yes	gridscale rain	kg/m²/h
SNOW_GSP_D	12	nnb	no	no	yes	gridscale snow	kg/m²/h
RAIN_CON_D	12	nnb	no	no	yes	convective rain	kg/m²/h
SNOW_CON_D	12	nnb	no	no	yes	convective snow	kg/m²/h
WW	16	nnb	no	no	yes	WW *	1
ICAHT	12	nnb	no	no	yes	Cb base	m
ICAHT	12	nnb	no	no	yes	Cb top	m
CBHEXT	12	nnb	no	no	yes	Cb horizontal extent	%
HTOP_DC	16	nnb	no	no	no	Height of top of dry convection	m
LIFT_RATIO	16	no	no	no	no	Lifting ratio VST (gliding)	m s-1
POT_FLT_DIST	16	no	no	no	no	Potential flight distance PFD (gliding) (m)	m

Package 3 - - Package ICON single level							
shortName	bit depth [bit]	interpolation/regridding from ICON	available for vv=0h	only available for vv=0h	undefined data besides sub-terrain data	Field Parameter	Unit
ICAHT	12	rbf	yes	no	no	Tropopause height	m
T	12	rbf	yes	no	no	Tropopause temperature	K
U	12	rbf	yes	no	no	maximum wind component u	m/s
V	12	rbf	yes	no	no	maximum wind component v	m/s
ICAHT	12	rbf	yes	no	no	height of maximum wind	m
T_2M	12	nnb	yes	no	no	temperature 2m	K
TD_2M	12	nnb	yes	no	no	dewpoint temperature 2m	K
T_G	12	rbf	yes	no	no	surface temperature	K
ALTS	16	rbf	yes	no	no	QNH	hPa
PMSL	16	rbf	yes	no	no	QFF	hPa
U_10M	12	nnb	yes	no	no	wind component u 10m	m/s
V_10M	12	nnb	yes	no	no	wind component v 10m	m/s
VMAX_10M	12	nnb	no	no	no	maximum wind 10m	m/s
CLCT	12	rbf	yes	no	no	total cloud coverage	%
TOT_PREC	12	nnb	Yes	no	no	total precipitation	kg/m^2 [6]
CLCH	12	rbf	yes	no	no	high level clouds	%
CLCM	12	rbf	yes	no	no	mid level clouds	%
CLCL	12	rbf	yes	no	no	low level clouds	%

[6] see page 20

Package 4 - - Package icing data							
shortName	bit depth [bit]	interpolation /regridding from ICON	available for vv=0h	only available for vv=0h	undefined data besides sub-terrain data	Field Parameter	Unit
PID_CODE	12	no	yes	no	yes	Icing Degree Code (Flight Levels) (1=light,2=moderate,3=severe)	
PIDC_BASE_HFT	12	no	yes	no	yes	Icing Base - Degree Composit	hft
PIDC_MAX_BASE_HFT	12	no	yes	no	yes	Icing Max Base - Degree Composit	hft
PIDC_MAX_TOP_HFT	12	no	yes	no	yes	Icing Max Top - Degree Composit	hft
PIDC_TOP_HFT	12	no	yes	no	yes	Icing Top - Degree Composit	hft
PIDC_VERT_CODE	12	no	yes	no	yes	Icing Vertical Code (1=continuous,2=discontinuous)	
PIDC_MAX_CODE	12	no	yes	no	yes	Icing Max Code (1=light,2=moderate,3=severe)	
PISC_SIG_CODE	12	no	yes	no	yes	Icing Signifikant Code (1=general,2=convective,3=stratiform,4=freezing)	

Package 5 - - Package turbulence data							
shortName	bit depth [bit]	interpolation/ regridding from ICON	available for vv=0h	only available for vv=0h	undefined data besides sub-terrain data	Field Parameter	Unit
EDP	16	nnb	yes	no	yes	Eddy dissipation rate	m⅔/s
EDP_MAX_UUIR	16	nnb	yes	no	yes	Eddy Dissipation Rate Total Col-Max. Upper UIR (<FL450);	m⅔/s
EDP_MAX_LUIR	16	nnb	yes	no	yes	Eddy Dissipation Rate Total Col-Max. Lower UIR (<FL350)	m⅔/s
EDP_MAX_UFIR	16	nnb	yes	no	yes	Eddy Dissipation Rate Total Col-Max. Upper FIR (< FL255);	m⅔/s
EDP_MAX_LFIR	16	nnb	yes	no	yes	Eddy Dissipation Rate Total Col-Max. Lower FIR (< FL180);	m⅔/s

Package 6 - Package static framework data, terrain orography							
shortName	bit depth [bit]	interpolation /regridding from ICON	available for vv=0h	only available for vv=0h	undefined data besides sub-terrain data	Field Parameter	Unit
FR_LAND	12	nnb	yes	yes	no	land-sea-distribution	1 to 0
HSURF	16	nnb	yes	yes	no	geometric ground altitude	m

Appendix D:

Definition of quantity Cb horizontal extent available in Package 2

Cb horizontal extent is calculated from the total precipitation rate of the past hour, while segments of the total precipitation rate are assigned to threshold levels, taken from the quantity weather interpretation (WW). Also, convective precipitation is to be larger than sub-scale precipitation.

Range > 0 to 0.25

- Definition: convective precipitation larger than drizzle
- Determination: rk > rl .AND. rg >= 0.015 mm/h

Range 0.25 to 0.5 ISOL (isolated)

- Definition: Rain shower possible, WW weather key 80
- Determination: rk > rl .AND. rg > 0.2 mm/h

Range 0.5 to 0.75 OCNL (occasional)

- Definition: Storm activity, WW weather key 95
- Determination: rk > rl .AND. rg > 0.75mm/h

Range 0.75 to 1.00 FRQ (frequent)

- Definition: Heavy thunderstorm, WW weather key 96
- Determination: rk > rl .AND. rg > 2.00 mm/h

Upper limit 1.00

- For rg>25.0mm, corresponding to one of the three criteria for WW weather key 99.

(„r“ denotes „precipitation“; „k“ „convective“, „l“ „sub scale“ and „g“ denotes „total“.)

Appendix E:

List of abbreviations used in this guide

GRIB2	Gridded Binary code – Edition 2
ICAO	International Civil Aviation Organization
ICAHT	ICAO Standard Atmosphere reference height
MLSP	mean sea level pressure
MSL	mean sea level
nnb	Nearest neighbour
NWP	Numerical Weather Prediction
PFD	potential flight distance
rbf	Radial basic function
WAFC	World Area Forecast Centre
WAFS	World Area Forecast System
WAWFOR	World Aviation Weather Forecast