



Initial & Boundary Data

D. Rieger, F. Prill (DWD)



Overview



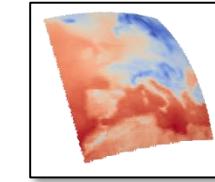
Computational
Grids



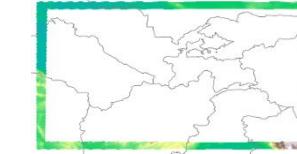
External
Parameters

Zonda

Grid & Extpar
Web Tool



Initial Data



Lateral
Boundary Data

Computational Grids



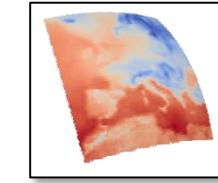
Computational
Grids



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Boundary Data

Spherical Geodesic Grids

Spherical geodesic grids derived from icosahedron.

By $RnBk$ we denote a grid that originates from an icosahedron whose

- edges have been initially divided into n parts,
- followed by k subsequent edge bisections.
- grid optimized by a so-called “spring dynamics step”.

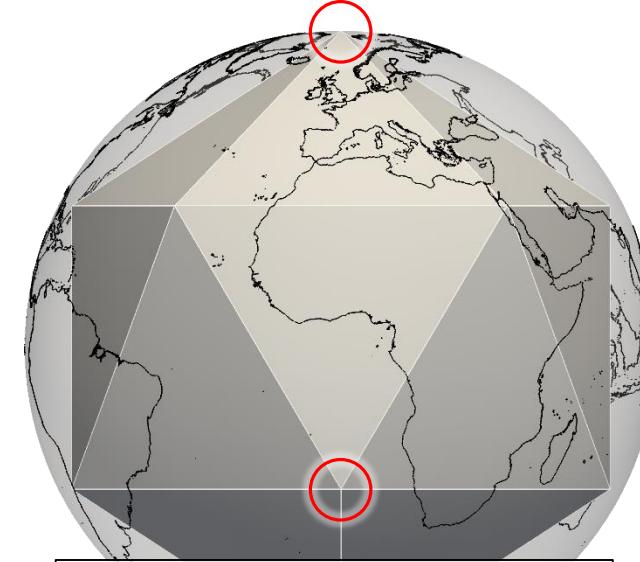
The total number of cells in a global ICON grid is given by

$$n_{cells} = 20 n^2 4^k , \quad \Delta x \approx \frac{5050}{n^{2k}} [\text{km}].$$

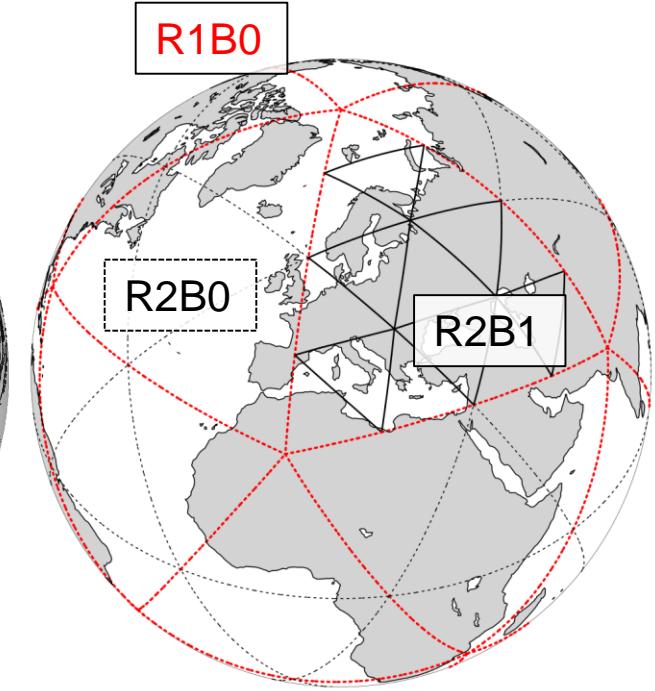
ICON namelist parameter

```
grid_nml::dynamics_grid_filename
```

two vertices coincide with the North and South Poles



12 “pentagon points”:
vertex is adjacent to 5 cells
(elsewhere: 6)



NetCDF Format of Grid Files

The unstructured triangular ICON grid resulting from the grid generation process is represented in NetCDF following the CF metadata convention.

The most important data entries are

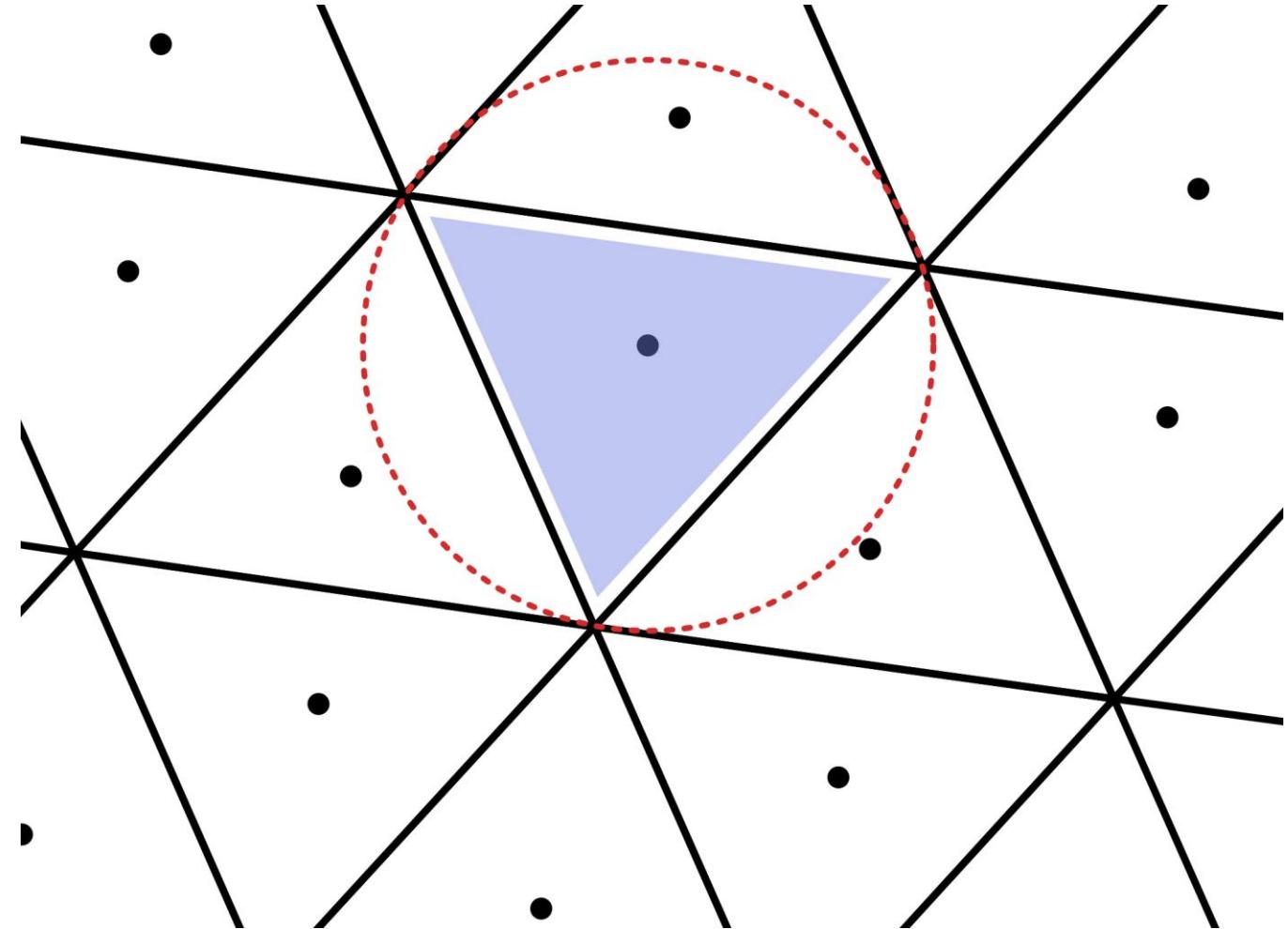
- edges have been initially divided into **n** parts,
- **cell**, **vertex**, **edge** (INTEGER dimension)
number of triangle cells, vertices and edges
- **clon**, **clat** (double array, dimension: #triangles, given in radians)
longitude/latitude of the midpoints of triangle circumcenters
... **vlon**, **vlat** and **elon**, **elat** are defined accordingly.
- **vertex_of_cell** (INTEGER array, dimensions: [3, #triangles])
indices **vertex_of_cell(:, i)** denote the triangle vertices that belong to the triangle **i**.
- **edge_of_cell** (INTEGER array, dimensions: [3, #triangles])
indices **edge_of_cell(:, i)** denote the triangle edges that belong to the triangle **i**.
- **neighbor_cell_index** (INTEGER array, dimensions: [3, #triangles])
indices **neighbor_cell_index(:, i)** denote the neighbor triangles for triangle **i**.



Geometry and Topology Data

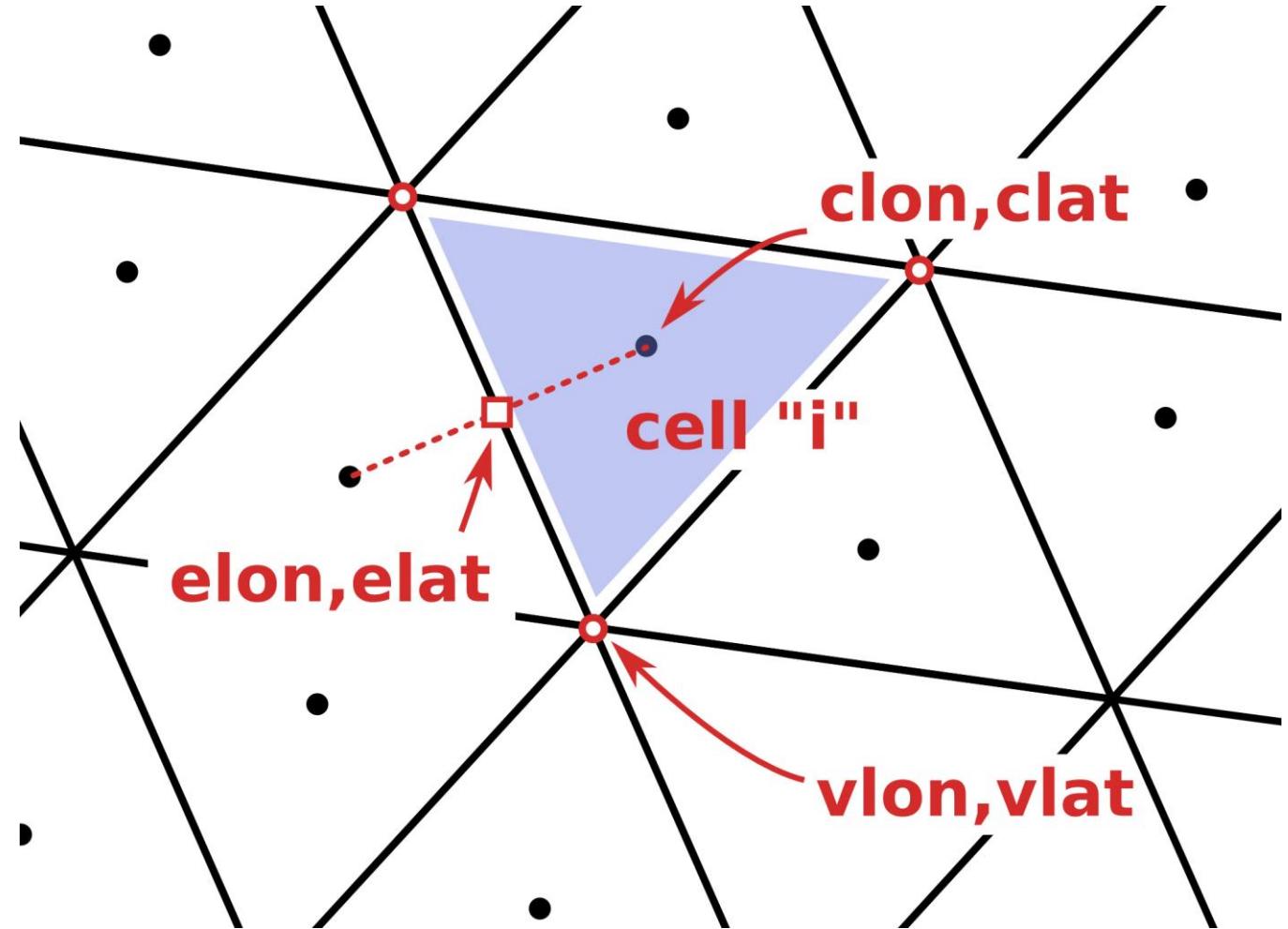
C-staggering

mass placed at triangle
circumcenters



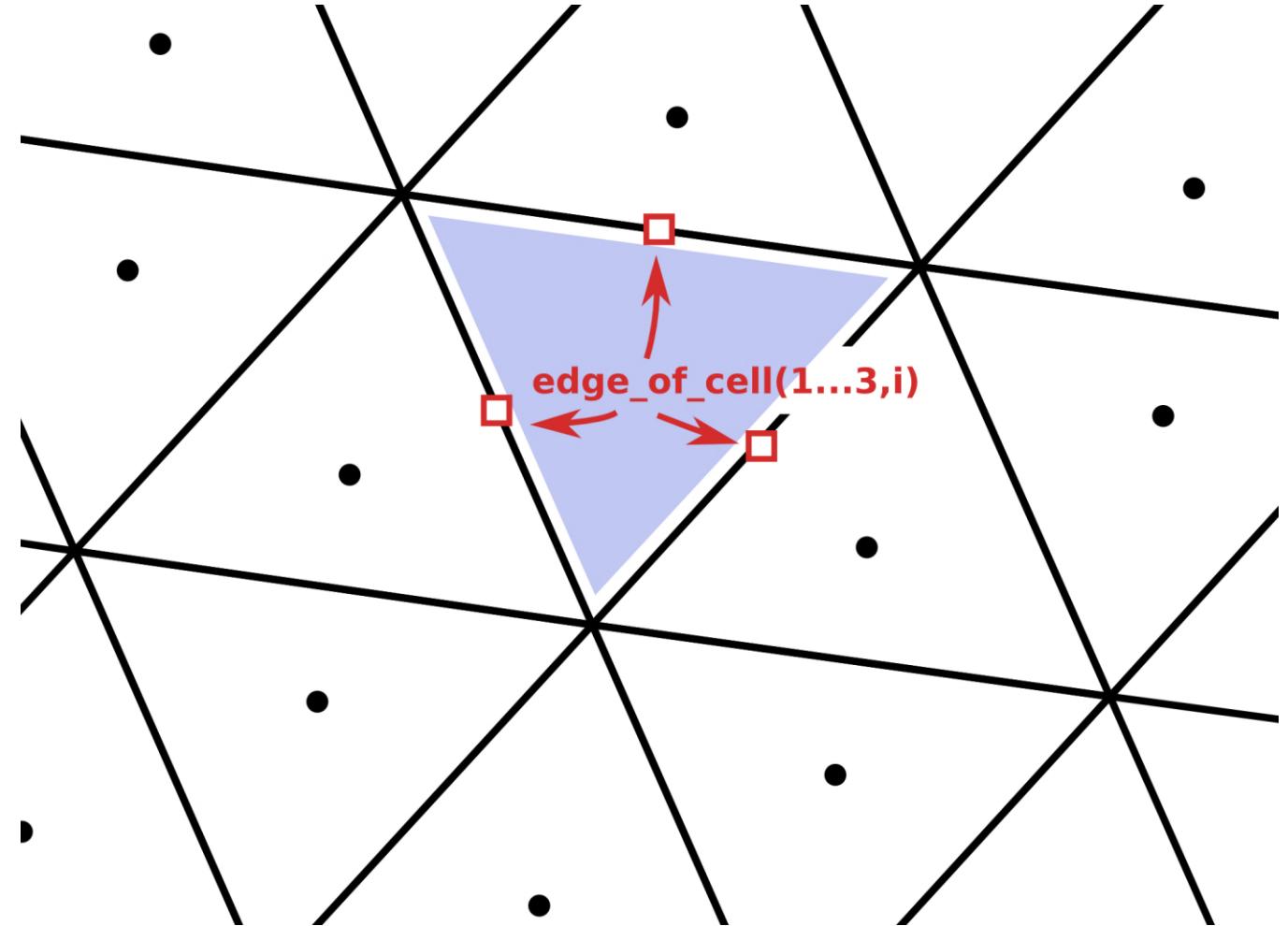
Geometry and Topology Data

The arc connecting two neighboring mass points (dual edge) is orthogonal to the shared triangle edge.
The bisection points are used as velocity points.



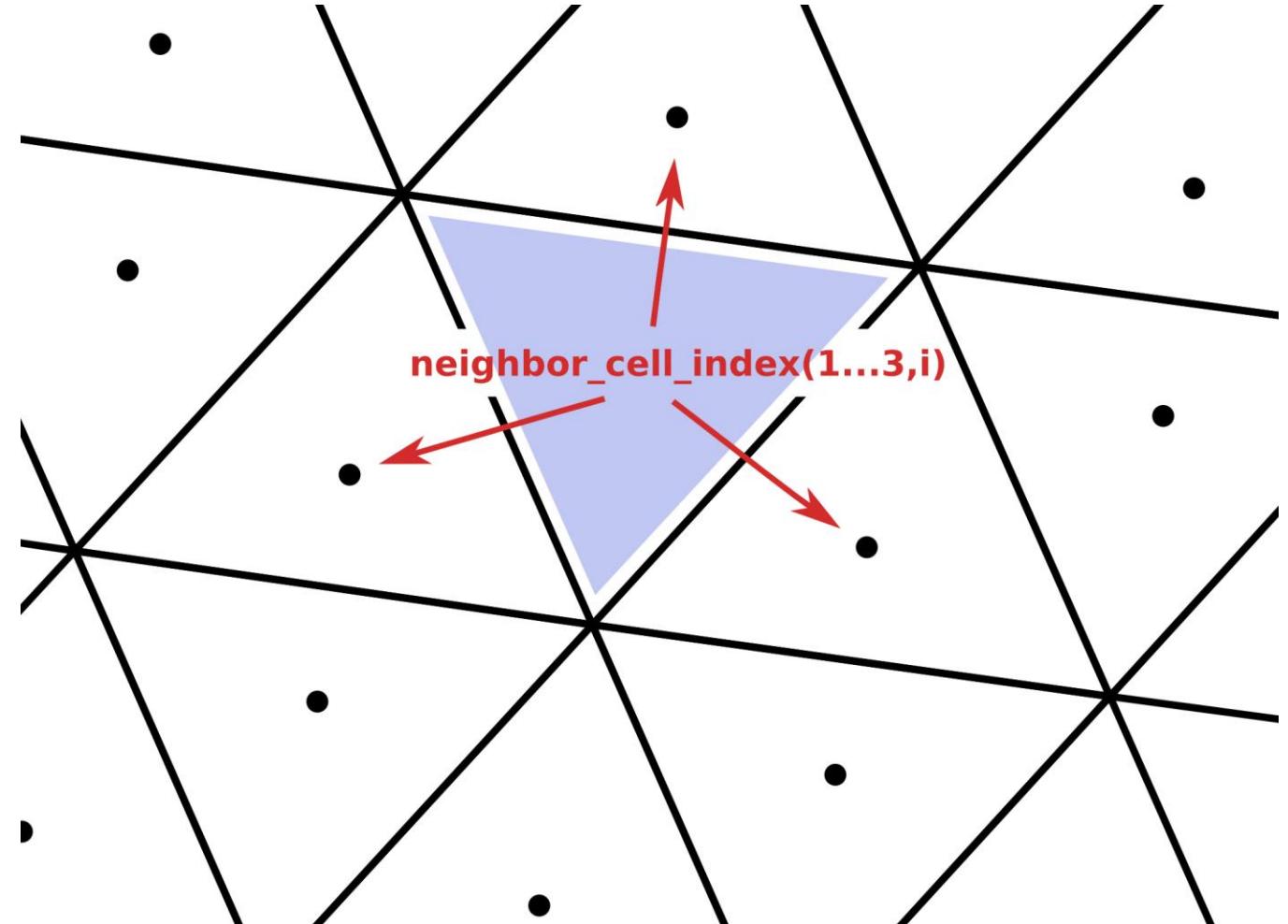
Geometry and Topology Data

Topologically, each triangular cell is defined by three edge indices, and each edge is given by its two vertex indices.
The cells' three edges are assumed to be oriented counter-clockwise.



Geometry and Topology Data

Other (redundant)
topological and
geometrical information is
available.



Nested Grid Hierarchies

ICON has the capability for running

- **global** simulations on a single global grid
- global simulations with “**nests(= refined domains)**
- regional simulations (**ICON-LAM**)

Due to the contained parent-child index data, a refined sub-grid can only be used with its original parent grid!

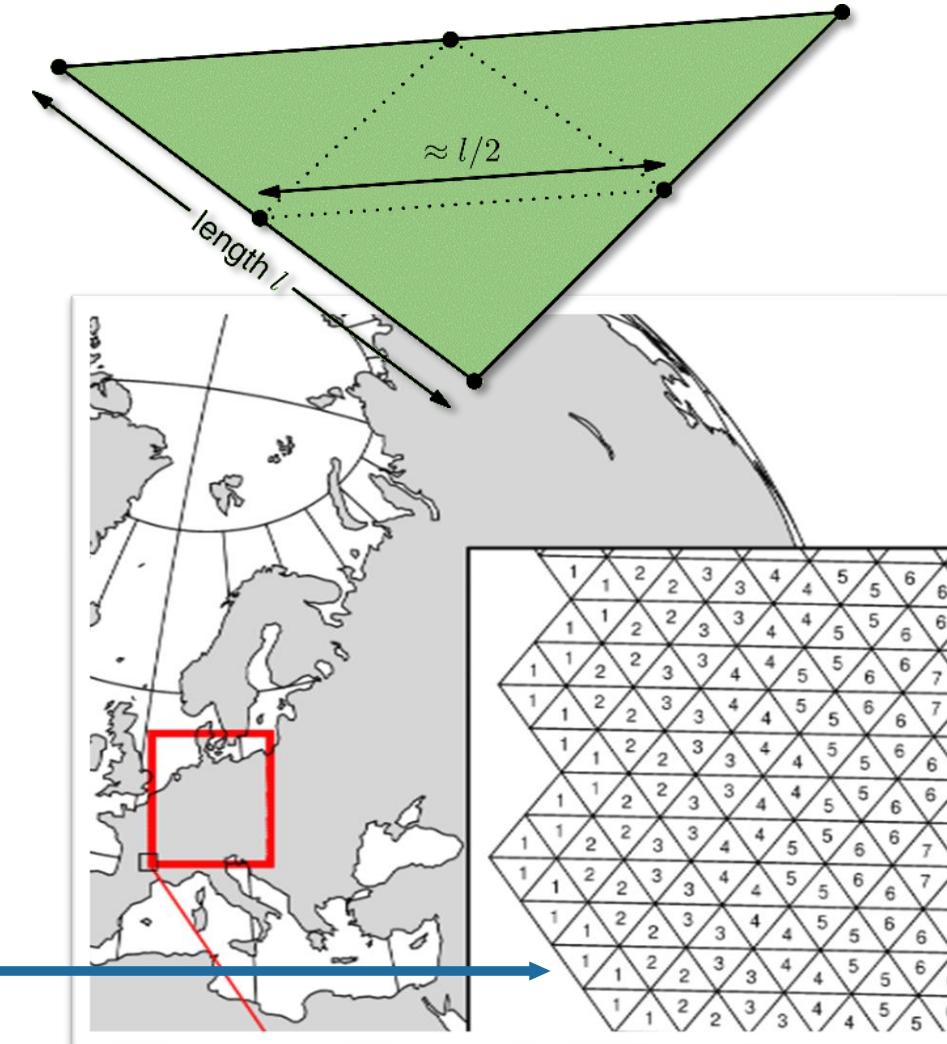
Legacy grids require the setting of

ICON namelist parameter

`grid_nml::dynamics_parent_grid_id`



Index Data for Grid Nesting and ICON-LAM



Refinement: **parent** triangle split into 4 **child** cells.

- only child-to-parent relations are stored:
parent_cell_index(cell)
- even global grids have this information,
used for **coarse radiation grids**.

Regional grids can be used for nests and ICON-LAM.

(exception: local grids where **parent_cell_index** points to a regional radiation grid)

refin_c_ctrl(cell)

Used to identify the nest boundary zone: cell rows are numbered starting from the grid boundary

Public List of ICON Grids

The screenshot shows two separate browser windows. Both windows have the title 'ICON — Grid File Server'.

The top window displays a general overview of the grid files:

- Max-Planck-Institut für Meteorologie logo
- ICON — Grid File Server logo
- This server provides access to ICON grid files. Access is only available by the ICON grid retrieval toolset.

The bottom window shows a detailed list of grid files:

	Attribute	Description
numberGridUsed:	26	operational
Centre	78	
Subcentre	255	
Type	h2_goca	
Description:	Global R03B07 grid, 13 km resolution. Grid rotated by 36 degrees around z-axis.	
File:	gridspubl:edzw/icon_grid_0028_R03B07_G.nc	
Connectivity File:	gridspubl:edzw/icon_grid_0028_R03B07_G-qfinfo.nc	Connectivity data, connecting this global grid with radiation grid 25 and nested grid 27 (Europe).
ExPar:	gridspubl:edzw/icon_expar_0028_R03B07_G_20140731_q2.nc	ExPar data created 2014/07/31 by G. Zenzgat, GRIB2 format, based on globover data.
ExPar:	gridspubl:edzw/icon_expar_0028_R03B07_G_20140731_nc.nc	ExPar data created 2014/07/31 by G. Zenzgat, NetCDF format, based on globover data.
ExPar:	gridspubl:edzw/icon_expar_0028_R03B07_G_20140731_llies_q2.nc	ExPar data for file-based simulation, created 2014/07/31 by G. Zenzgat, GRIB2 format, based on globover data.
ExPar:	gridspubl:edzw/icon_expar_0028_R03B07_G_20140731_llies_nc.nc	ExPar data for file-based simulation, created 2014/07/31 by G. Zenzgat, NetCDF format, based on globover data.
ExPar:	gridspubl:edzw/icon_expar_0028_R03B07_G_20141127_d2.nc	ExPar data created 2014/11/27 by J. Helmer, GRIB2 (g2) format, based on globover data. Contains a couple of bug fixes, i.e. a fix of the Antarctic peninsula landuse classes. DEPRECATED!!

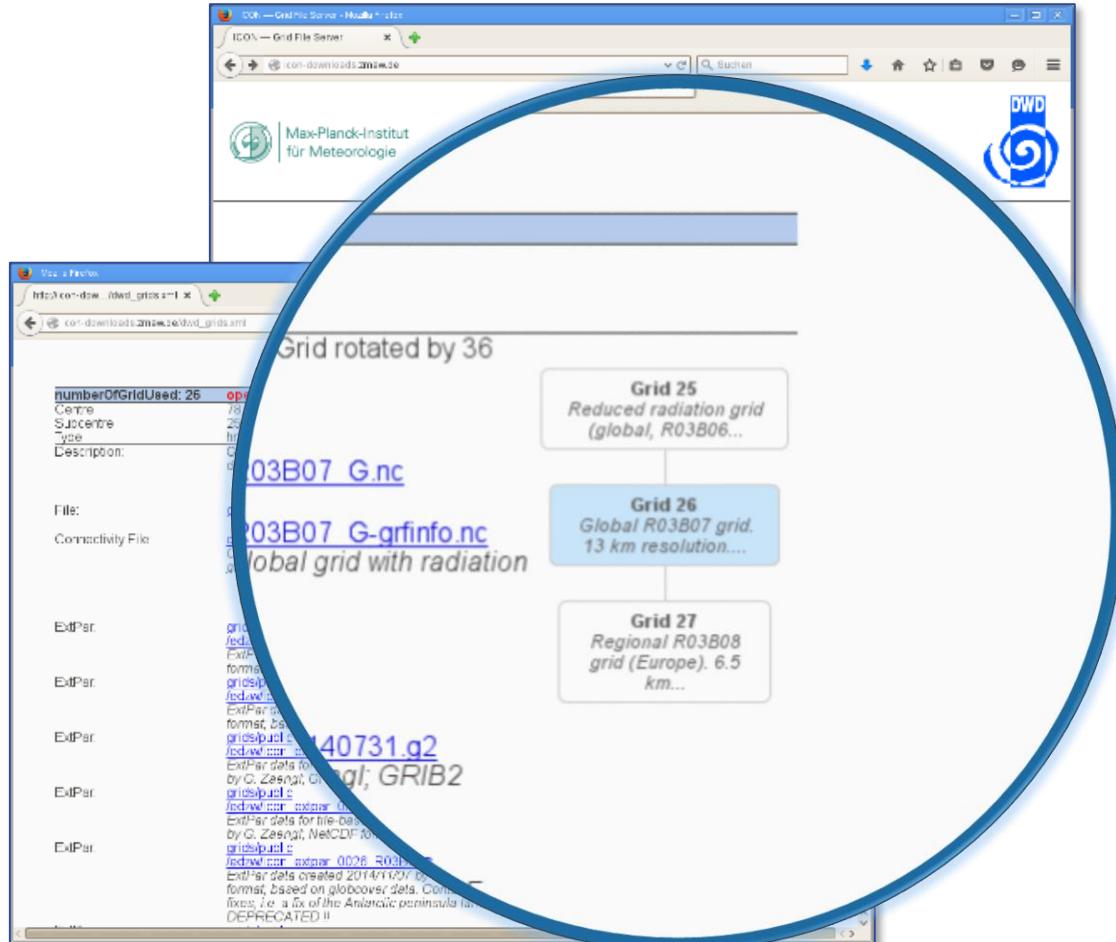
For fixed domain sizes and mesh resolutions a list of grid files has been pre-built for the ICON model:
<http://icon-downloads.mpimet.mpg.de>

- Grid list contains corresponding coarse radiation grids and the external parameters.

The pre-defined grids are identified by attributes:

- **centre** number (DWD/edzw: 78)
- **subcentre** number (DWD/edzw: 255)
- **numberOfGridUsed**
- **uuidOfHGrid**

Public List of ICON Grids



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- **centre** number (DWD/edzw: 78)
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- **numberOfGridUsed**
uuidOfHGrid

Which Grid File is Related to my Data?

ICON data files do not (completely) contain the description of the underlying grid.

Input datasets and output files contain **reference to** the triangular **grid file**

These meta-data values allow to track the horizontal grid in all products and through all transformations of the scientific workflow.

- external parameter files
- analysis data for forecast input
- data files (diagnostic output)
- checkpoint files

numberOfGridUsed

- Integer number
- Reference number in list of published grids
- Mostly used internally (DWD)

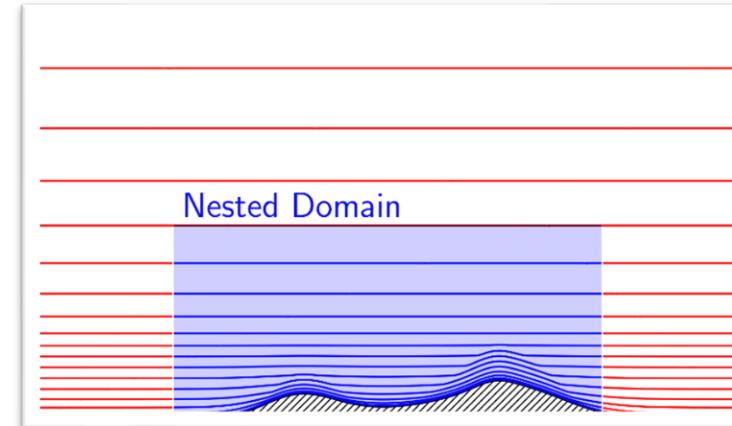
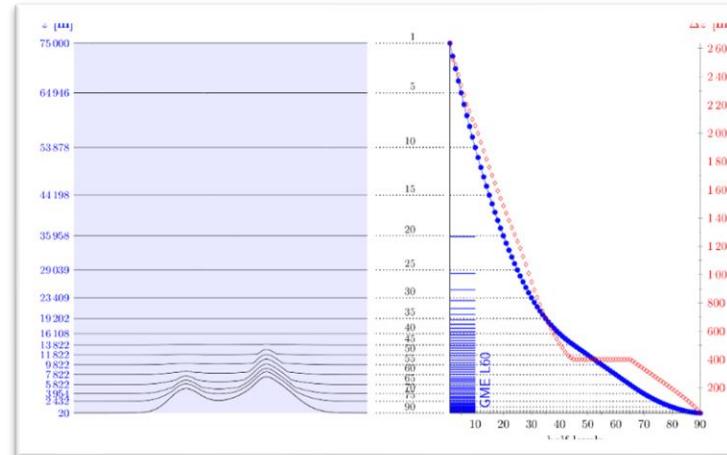
uuidOfHGrid

- Binary fingerprint
- Not human-readable
- Used for automatic consistency checks

Remark on Vertical Grids

ICON generates level heights during model setup, these are **not read from file!**

- Smooth Level Vertical (SLEVE) coordinate; level ordering: top-down
- topography (external parameters) can be smoothed during model start-up



Note: the above graph shows ICON's older 90-level vertical setup (since 11/2022: 120 levels)

External Parameters



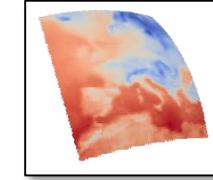
Computational
Grids



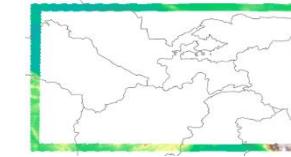
External
Parameters

Zonda

Grid & Extpar
Web Tool



Initial Data



Lateral
Boundary Data

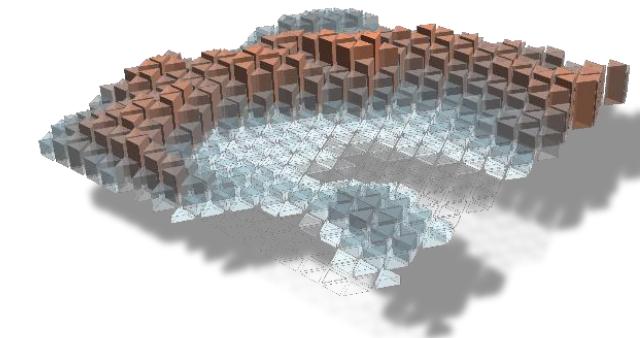
External Parameter Files

In addition to the grid, real-data ICON runs require **external parameter** files:

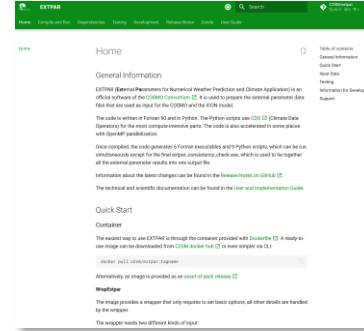
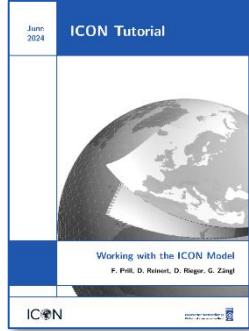
- land-sea mask, GLOBE/MERIT orography, soil type, surface albedo, angle of sub-grid scale orography and other geographical datasets (tutorial book Section 2.4)
- generated by the ExtPar software
<https://c2sm.github.io/extpar/>

Remarks:

- Topography might be processed at ICON start-up
≠ external parameters!
- COSMO software, not part of the official release ...
... use Zonda (*see following slides*)



Raw Datasets



Raw datasets from which the ICON external parameter fields are derived: see the **ICON tutorial book, Section 2.4** ... or the **ExtPar documentation** <https://c2sm.github.io/extpar/>

ALB_DIF12

`irad_aero=6,9` (namelist `radiation_nml`)

Shortwave ($0.3 - 5.0 \mu\text{m}$) albedo for diffuse radiation (monthly mean)

`albedo_type=2` (namelist `radiation_nml`)

UV-visible ($0.3 - 0.7 \mu\text{m}$) albedo for diffuse radiation (monthly mean)

`albedo_type=2` (namelist `radiation_nml`)

Near infrared ($0.7 - 5.0 \mu\text{m}$) albedo for diffuse radiation (monthly mean)

`albedo_type=2` (namelist `radiation_nml`)

Lake depth

Surface longwave (thermal) emissivity

`itype_lwemiss=1` (namelist `extpar_nml`)

Surface longwave (thermal) emissivity derived from satellite measurements (monthly mean)

`itype_lwemiss=2` (namelist `extpar_nml`)

ALB_UV12

ALB_NI12

DEPTH_LK

EMIS_RAD

EMISS

FOR_D

FOR_E

FR_ICE

FR_LAKE

MODIS

MODIS

MODIS

GLDB

GlobCover 2009

CAMEL
(combined
ASTER and
MODIS)

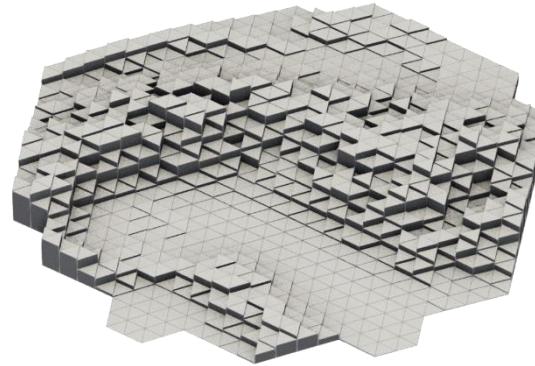
GlobCover 2009

GlobCover 2009

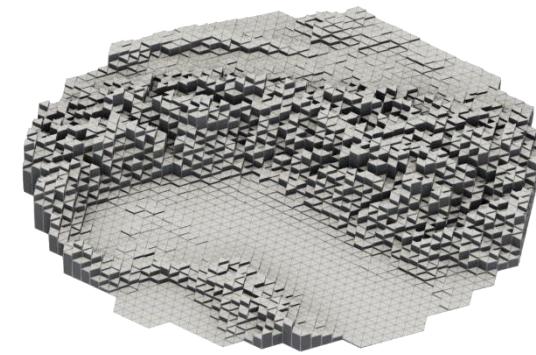
GLDB

Representation of Orography

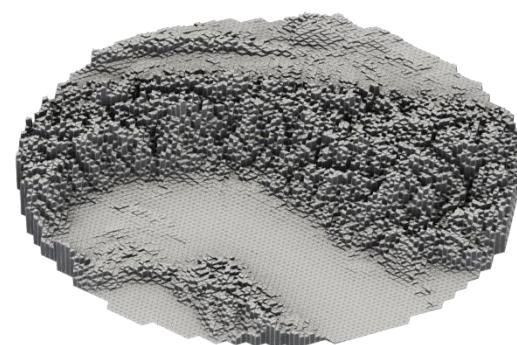
ICON-LAM
Alpine region
ASTER orography



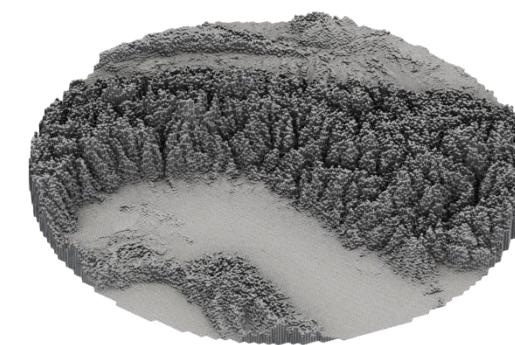
R03B07, 13 km grid size



R03B08, 6.5 km



R03B09, 3.28 km



R03B10, 1.64 km

Grid & EXTPAR Web Tool



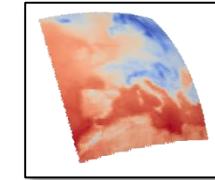
Computational
Grids



External
Parameters

Zonda

Grid & Extpar
Web Tool



Initial Data



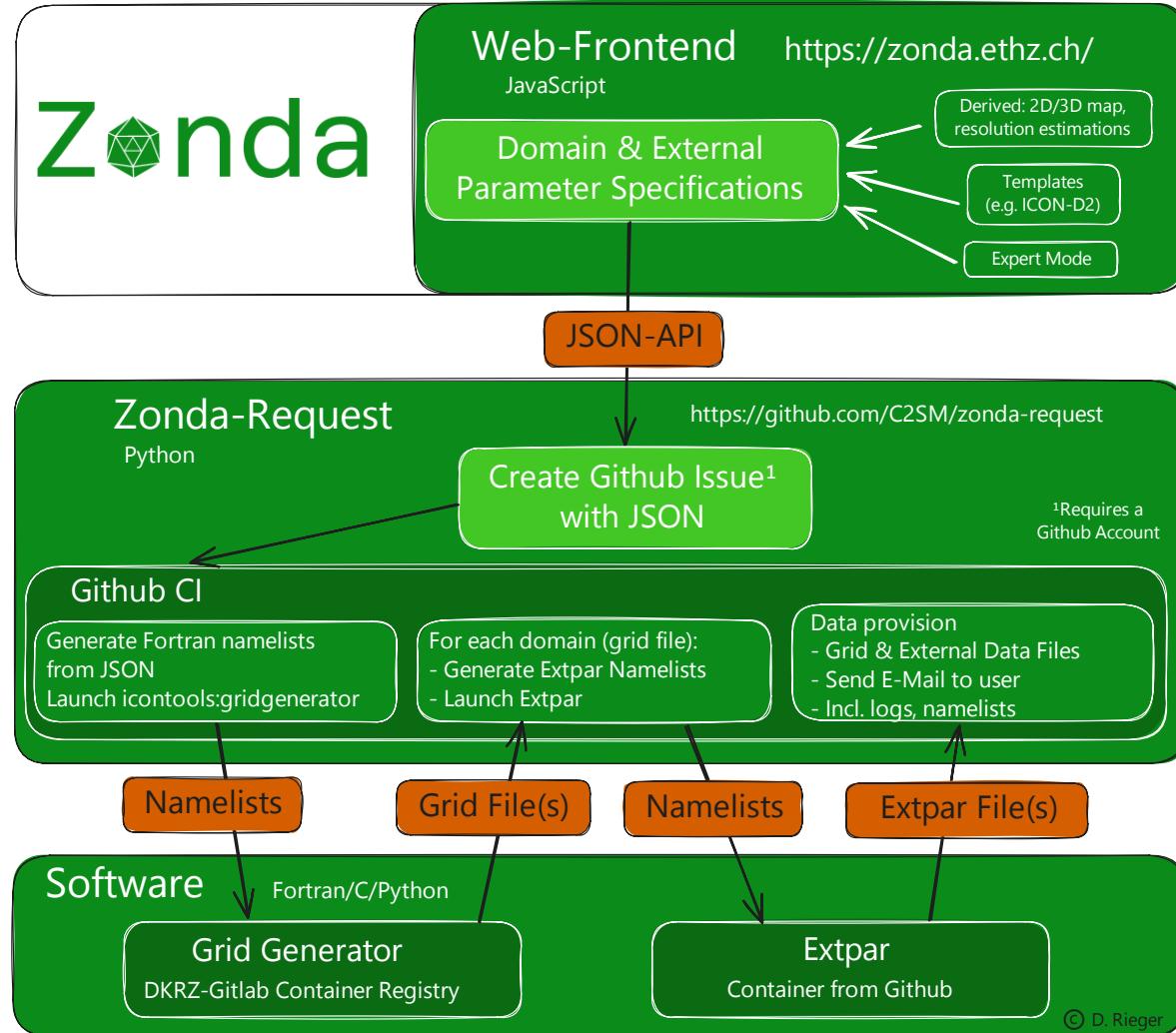
Lateral
Boundary Data

Zonda

M. Jaehn¹, J. Jucker¹, T. Kaspar², X. Lapillonne², D. Rieger³, M. Stellio¹
¹C2SM, ²MeteoSwiss, ³DWD



ICON Grid & EXTPAR Web Tool: Zonda



Zonda is a web interface designed to facilitate the generation of

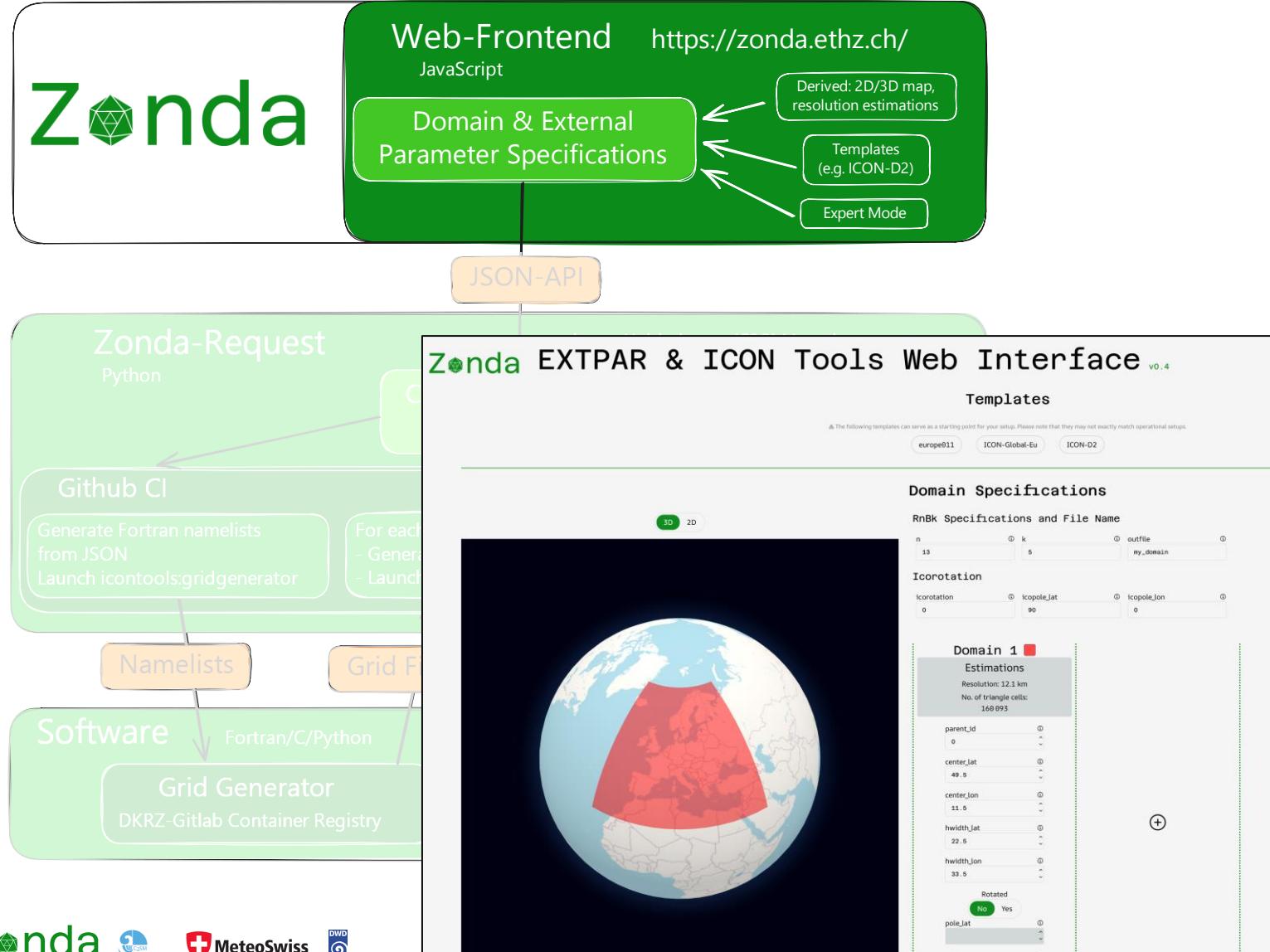
- **EXTPAR data**
- **on ICON triangular grids**

for research and on-demand simulations.

Joint project of C2SM (Centre for Climate Systems Modelling), MeteoSwiss and DWD led by **C2SM**.

Documentation is available at:
<https://zonda.ethz.ch/docs>

Zonda Frontend

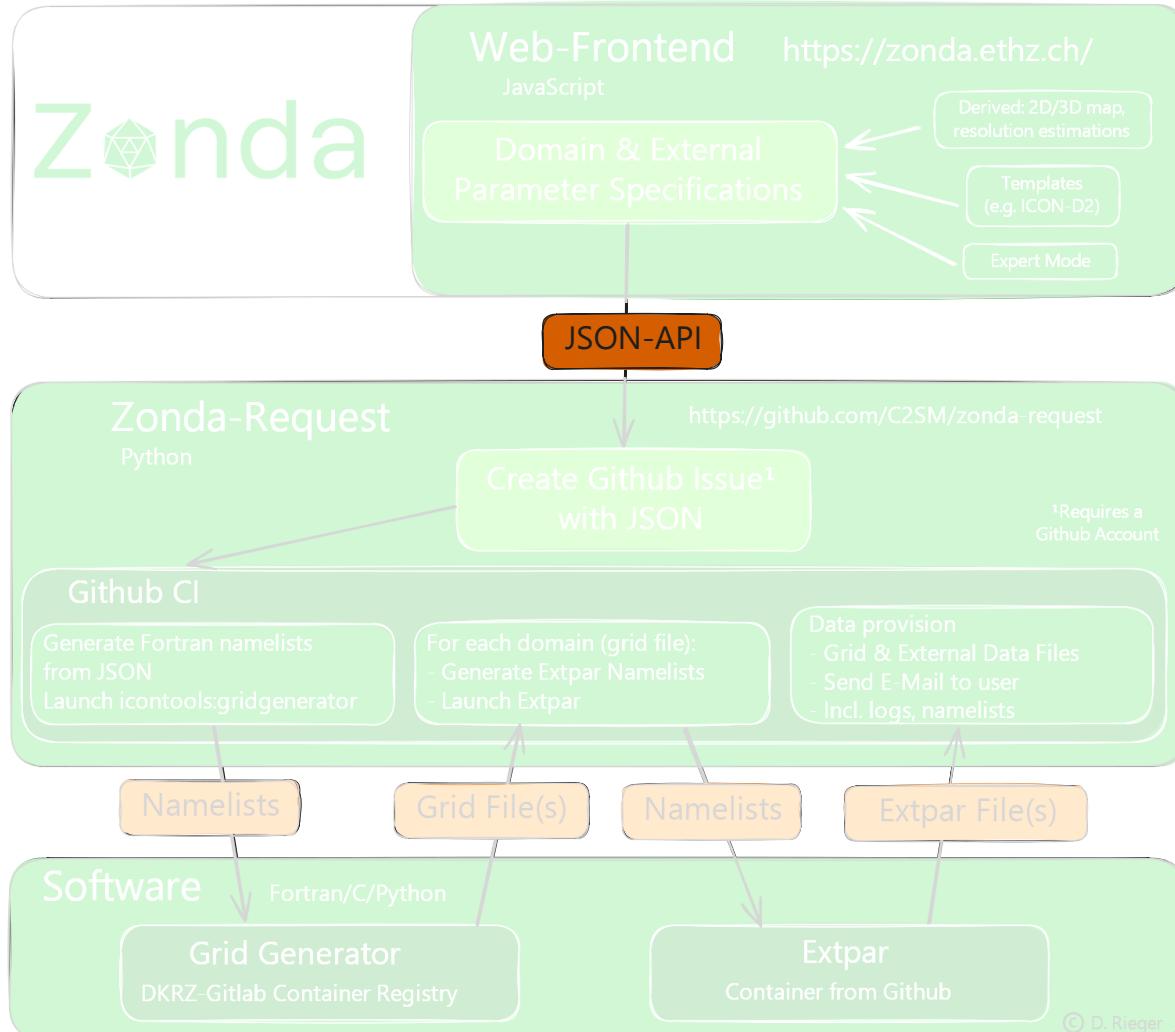


Zonda website <https://zonda.ethz.ch>

- Domain specifications (location, resolution, ...)
- Additional domains (Nests)
- ExtPar settings
- Expert mode available

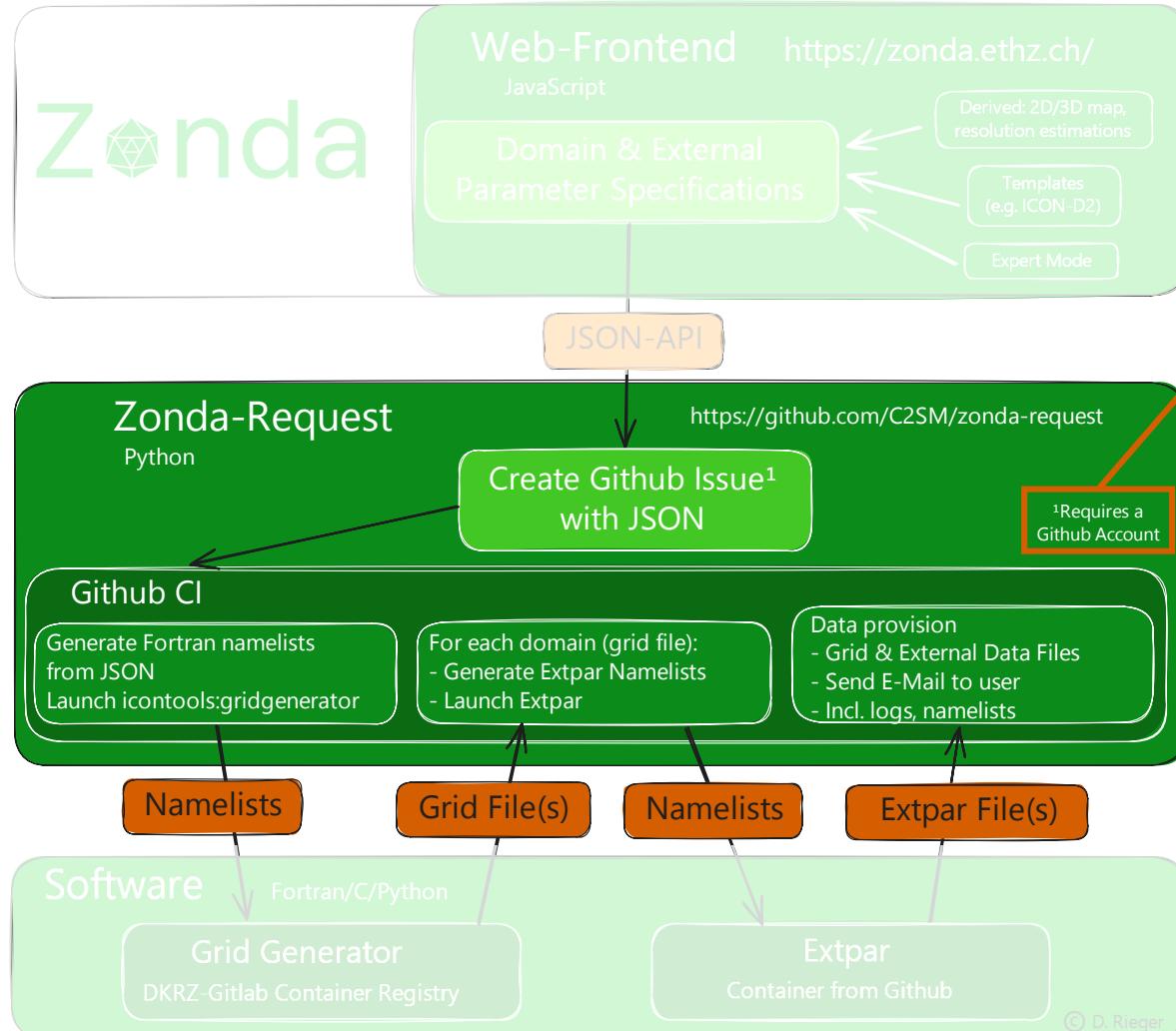
Result: JSON code containing the chosen settings which can be copied to clipboard.

Zonda JSON API



```
{
    "zonda": {
        "extpar_tag": "v5.17"
    },
    "basegrid": {
        "keep_basegrid_files": false,
        "grid_root": 19,
        "grid_level": 6,
        "outfile": "ICON-D2",
        "icorotation": 36,
        "icopole_lat": 90,
        "icopole_lon": 0
    },
    "domains": [
        {
            "domain_id": 1,
            "icontools": {
                "parent_id": 0,
                "region_type": 3,
                "lrotate": true,
                "pole_lat": 40,
                "pole_lon": -170,
                "center_lat": 0.85,
                "center_lon": -1,
                "hwidth_lat": 7.3,
                "hwidth_lon": 6.65
            },
            "extpar": {
                "iaot_type": 1,
                "ilu_type": 1,
                "ialb_type": 1,
                "isoil_type": 1,
                "itopo_type": 2,
                "it_cl_type": 2,
                "iera_type": 2,
                "iemiss_type": 1,
                "lradtopo": false,
                "enable_cdnc": false,
                "enable_edgar": false,
                "radtopo_radius": 40000,
                "enable_art": false,
                "use_array_cache": false
            }
        }
    ]
}
```

Zonda Request Backend



The screenshot shows the "Create new issue" page on GitHub:

Create new issue
ICON External Parameter Request · Choose a different template

Add a title *

Add a description

Write Preview

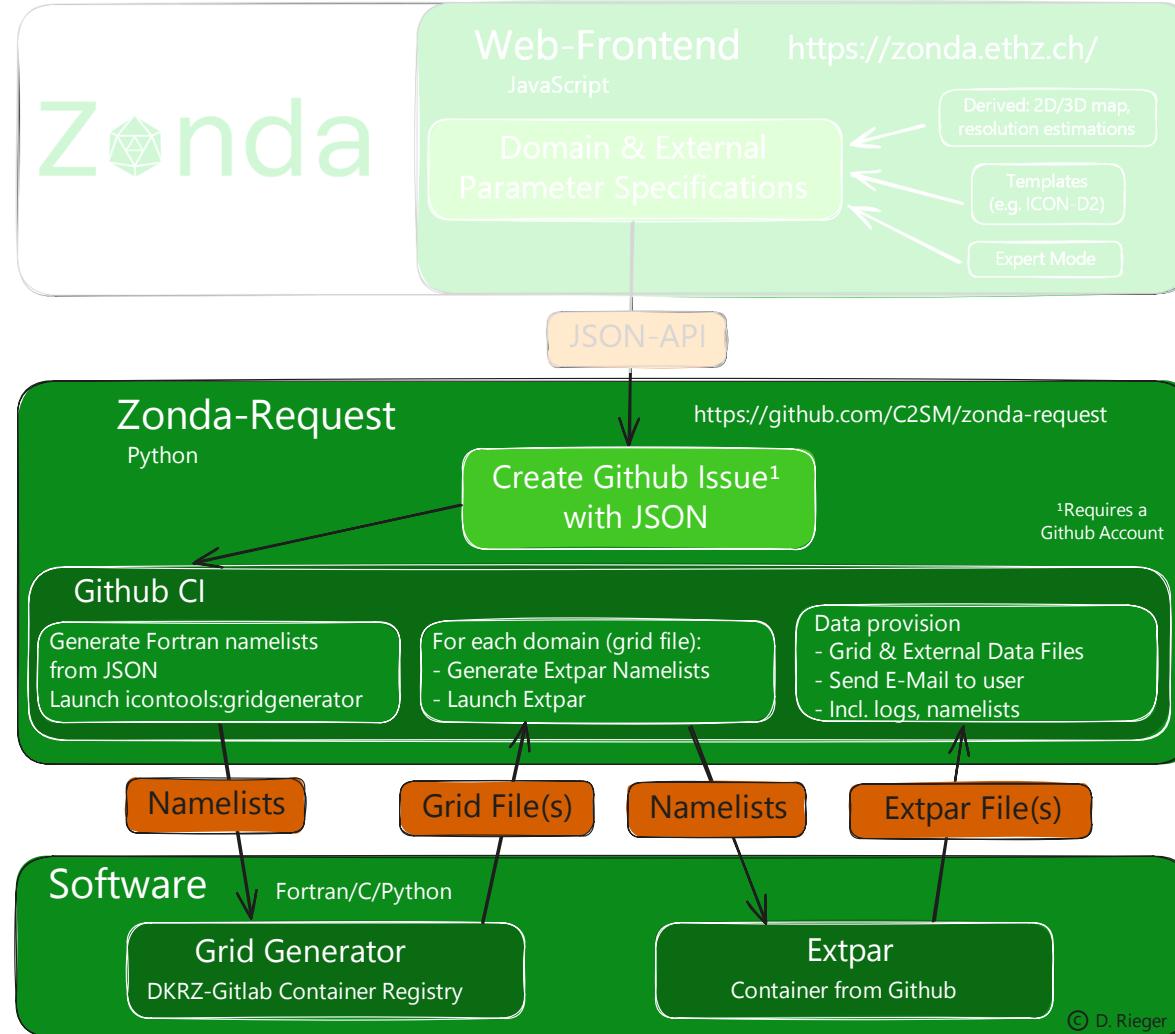
ICON External Parameter Request

Instructions

1. Give this issue a meaningful title (e.g. including domain name, grid specifications, project, etc.).
2. Replace `PASTE_YOUR_REQUEST_HERE` with your request that you copied to clipboard:
```json  
PASTE YOUR REQUEST HERE  
```
3. Click on the "Preview" tab (top left) to verify that the JSON format of your request is correctly formatted and displayed.
4. Click on "Create" below to submit the data request.

Zonda Request will now process your data based on your request. Once the processing is successful, it will...

Zonda Data Provision



After submitting the request

- Github CI takes over
- DWD ICONTOOLS & ExtPar

Upon completion

- E-Mail notification
- Notification in Github Issue
- Files available 7d for download

Zonda is a new tool!
<https://zonda.ethz.ch/docs>
Please provide feedback to:
c2sm.zonda@sympa.ethz.ch

Zonda

Initital Data



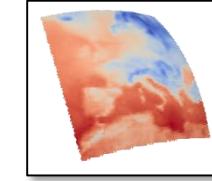
Computational
Grids



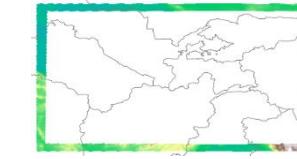
External
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Initial Data



Lateral
Boundary Data

Initial Datasets

DWD Uninitialized Analysis

- Start the model from the full analysis fields

Namelist

```
initicon_nml:  
  init_mode=1
```

DWD Uninitialized Analysis for IAU

- Analysis with incremental analysis update (IAU)

```
  init_mode=5
```

DWD Initialized Analysis

- Single file only, containing the analyzed state

list of fields: see
tutorial book 11.3

```
  init_mode=7
```

Other initial data

- E.g. IFS data from the ECMWF MARS database.

```
  init_mode=2
```

remapping required if different grid (spacing)

ICON Model

Initial Datasets

For external users we strongly recommend to use the **initialized analysis** for model initialization.

PAMORE¹ (PArallel MOdel data REtrieve from Oracle databases)

tool for retrieval of model data from DWD's meteorological database.

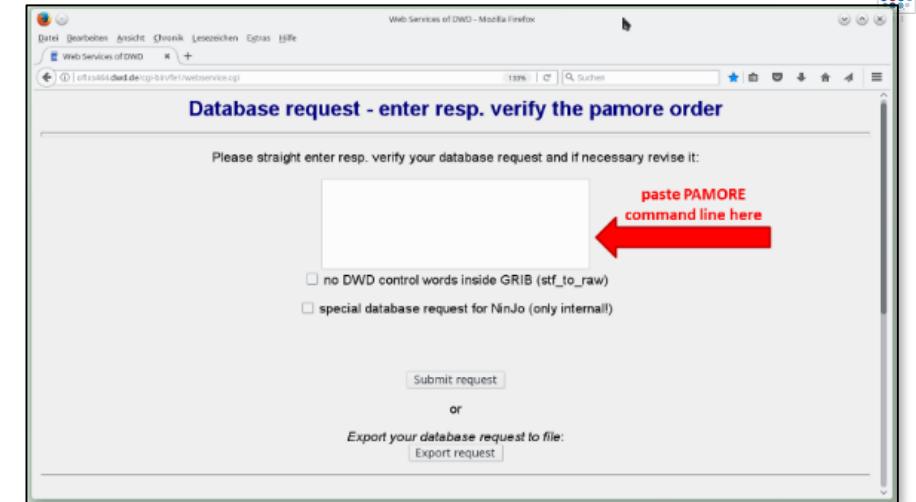
time range

```
pamore -d date -hstart 0 -hstop 0
       -lt a -model ieu -iconlam_startdata_0
```

analysis

ICON-EU

initialized analysis



¹web service requires registration

Pamore: Tutorial Book, Sections 2.2, 2.3

Examples for initial and boundary data, global and ICON EU/D2 nest

IFS Initial Data Set

Specifics of `init_mode=2`

- Supports only NetCDF format
- Includes vertical remapping

Example for Remapping

```
cdo -P 4 gencon,<targetgrid>:N1 <sourcedata> \
    weights.nc
cdo -f nc copy <sourcedata>.grb <sourcedata>.nc
cdo -s -r remap,<targetgrid>:N1,weights.nc \
    <sourcedata>.nc remapped.nc
```

Not shown: renaming of variables (alternative: dictionaries)

For older ICON grid files, the cell dimension needs a renaming:

```
ncrename -d cell,ncells remapped.nc remapped_ncells.nc
```

The screenshot shows the ECMWF 50 website's 'Access to forecasts' section. The top navigation bar includes links for Home, About, Forecasts, Computing, Research, Learning, Publications, and Anniversary. Below the navigation is a search bar and a login link. The main content area has a heading 'Access to forecasts' and a sub-heading 'This page details the various ways to obtain access to ECMWF forecast datasets and charts depending on who you are.' It features several sections: 'Open Data Roadmap', 'Access to real-time open data', 'Access to archive datasets', 'Use cases and licence conditions', 'Data pricing', 'Ordering', and 'Registration vs anonymous access'. To the right, there are three columns of images and descriptions: 'ECMWF members' (European map), 'World Meteorological Organization' (WMO logo), and 'Commercial customers' (wind turbines). Further down are sections for 'WMO members' (international map), 'Commercial customers' (solar panels), 'Researchers' (three people), 'Satellite data providers' (satellite image), and 'Public' (sunset image). Each section includes a brief description and a link to more information.

<https://www.ecmwf.int/en/forecasts/accessing-forecasts>

Lateral Boundary Data



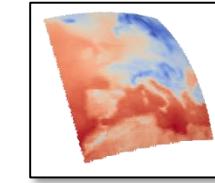
Computational
Grids



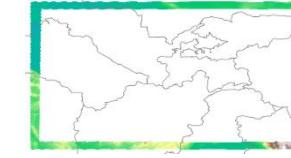
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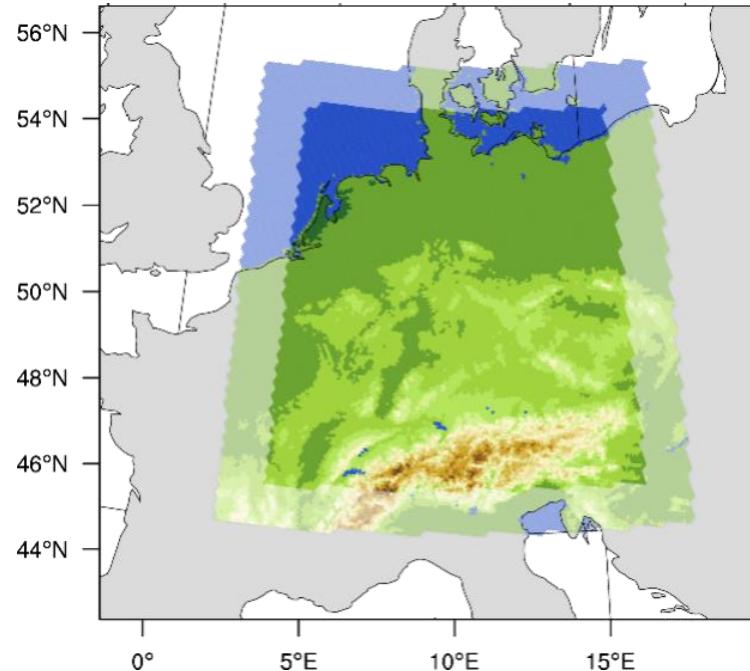


Initial Data



Lateral
Boundary Data

Boundary datasets: Limited Area Mode (LAM)



Limited Area Run

- Main switch for limited area run:
`l_limited_area=.TRUE. (grid_nml)`

ICON Namelist: `limarea_nml`

- Namelist setting specifying input frequency:
`dtime_latbc`
- Input file names with „wildcards“: `latbc_filename`
- Enable prefetching of **boundary data** overlaps read-in with computation (mandatory):
`num_prefetch_proc=1 (parallel_nml)`

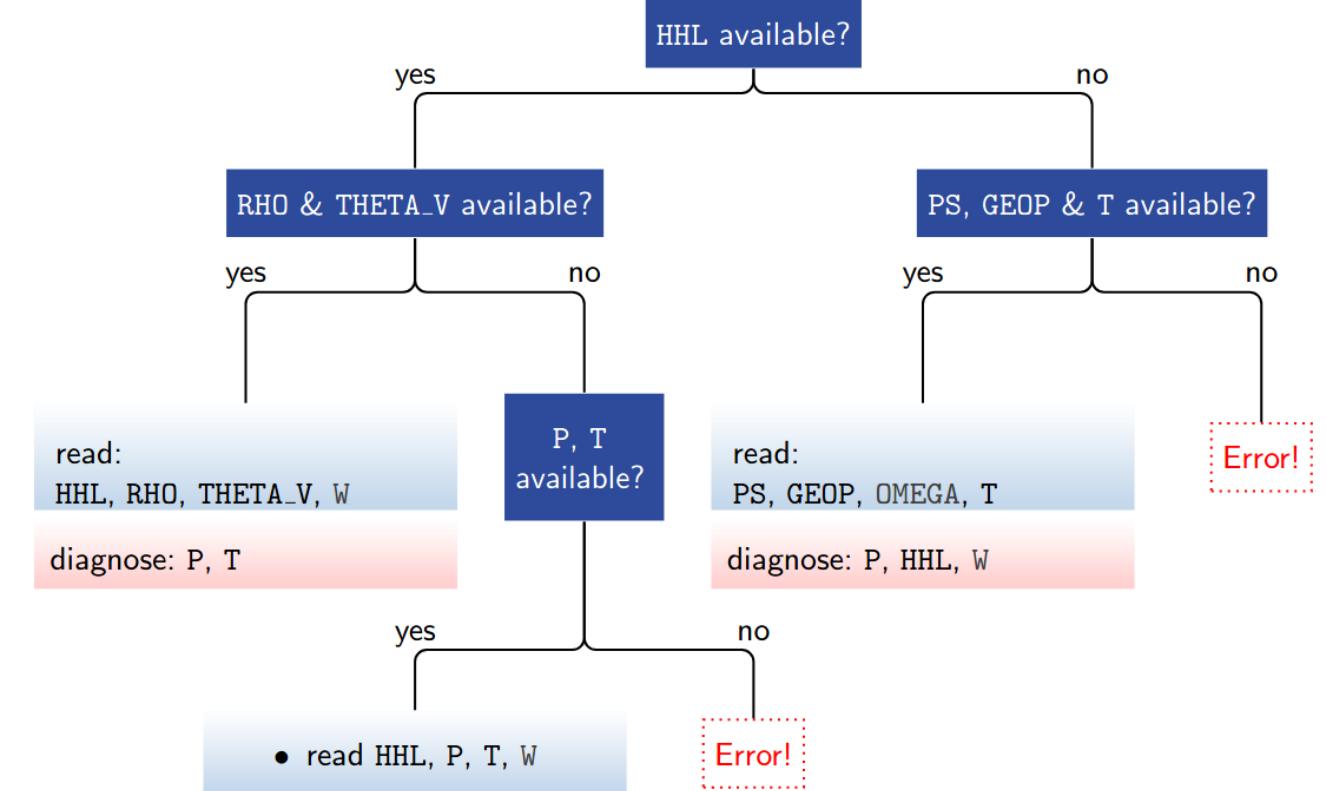
ICON-LAM **boundary data** can also be obtained via pamore requests.

```
pomore -d date -hstart hh -hstop hh -hinc hh
       -model iglo -ilam_boundary
```

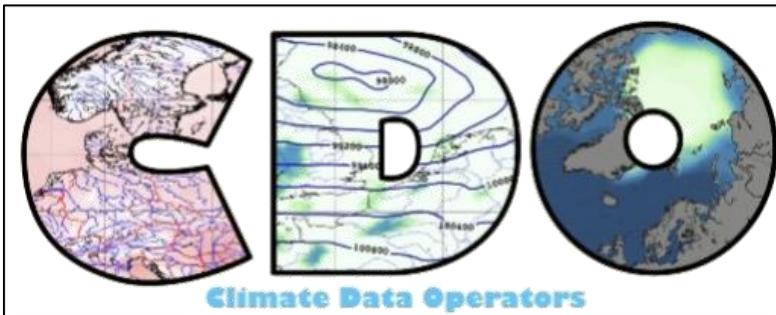
Boundary Dataset: Decision Tree

Read-in of boundary data is based on a **decision tree**.

- Pro:** the user does not need to select a specific mode that fits the data.
- Con:** when fields are missing (e.g. HHL), the model tries to interpret the remaining data and might abort with a non-intuitive error message.



ICON-LAM Data Pre-processing



After the successful download, the analysis/boundary data must be interpolated onto the ICON target grid. For example,

```
cdo remapcon,localgrid.nc:N1 -selname,FIELDS \
-setgrid,ingrid.nc:N2 data-file.nc out-file.nc
```

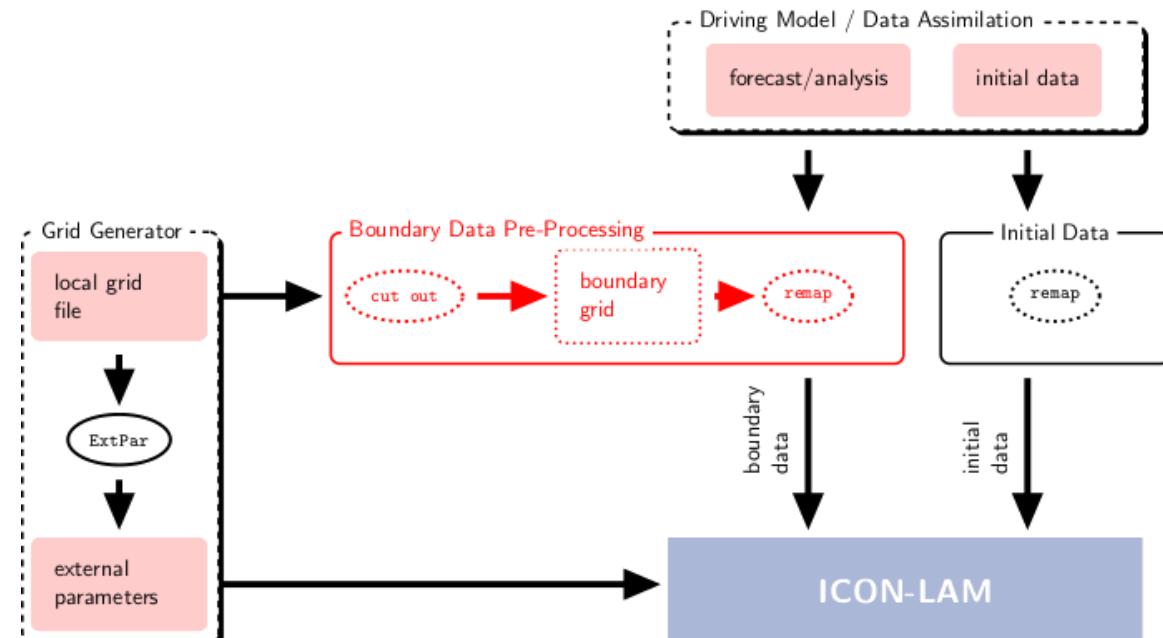
Vertical interpolation: no need for pre-processing; performed during read-in.

ICON-LAM accepts boundary data on the **full domain** or on a **sparse boundary strip**.

Pre-processing tools:

- Option 1: **CDO utilities**
- Option 2: **ICONREMAP**
(DWD ICON Tools).

see the Tutorial Section 2.2.3



DWD OpenData

DWD forecasts available without retention time under

- <https://dwd-geoportal.de/> (beta)
- <http://opendata.dwd.de>

A source for driving ICON-LAM? – Not yet, ...

- the current datasets cover the boundary data fields required by the ICON model, but they do not contain all fields of the initial dataset (e.g. age of snow indicator "FRESHSNW").
- OpenData data are forecasts, and not the so-called **initialized analysis** of the ICON model.



Set I (e.g. ICON)

$$\left\{ \begin{array}{l} U, V \\ \text{or} \\ VN \end{array} \right\}, \quad W, \quad \text{THETA_V}, \quad \text{DEN}, \quad QV, \quad QC, \quad QI, \quad QR, \quad QS, \quad HHL$$

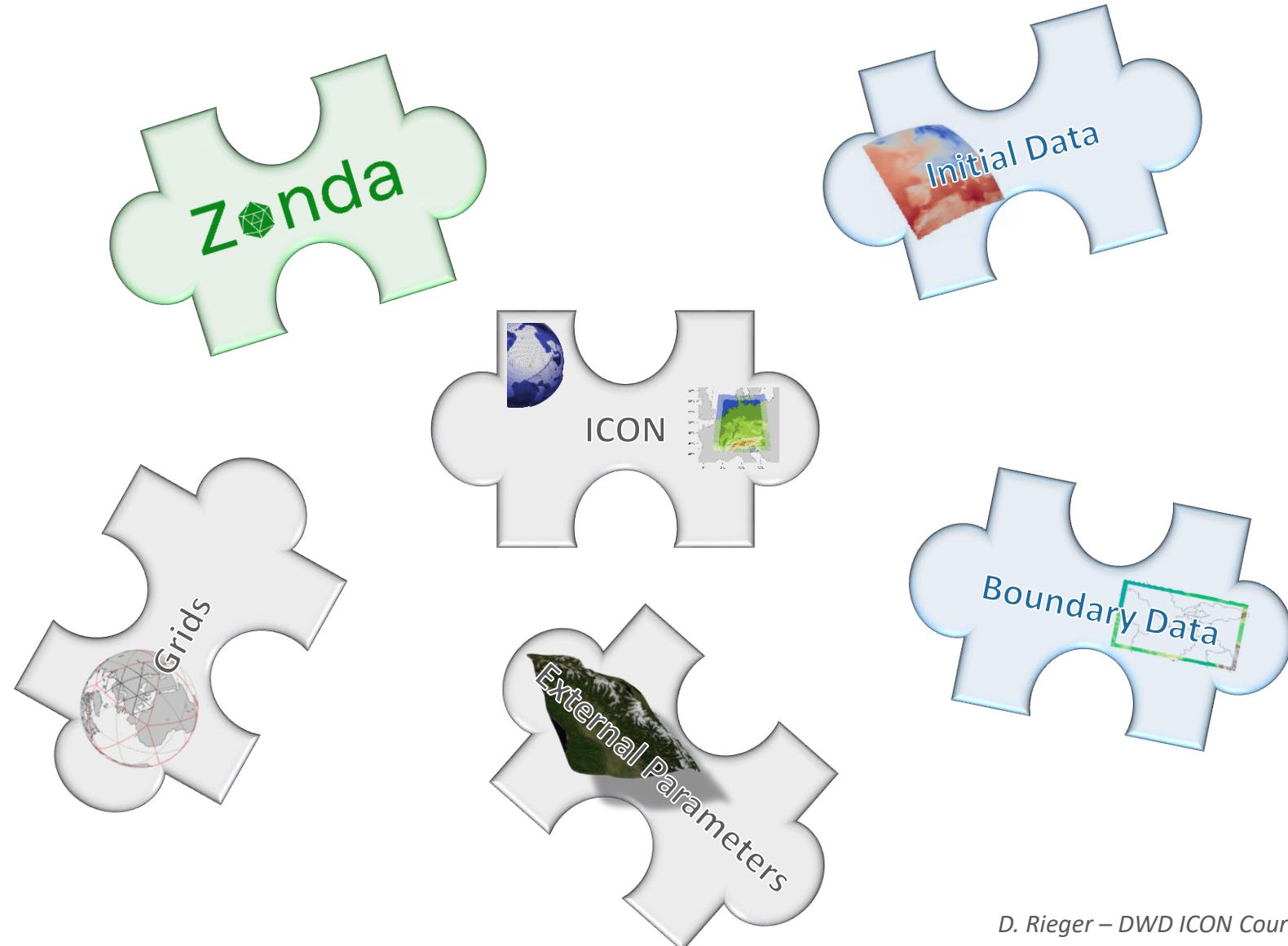
Set II (e.g. COSMO)

$$U, \quad V, \quad W, \quad T, \quad P, \quad QV, \quad QC, \quad QI, \quad QR, \quad QS, \quad HHL$$

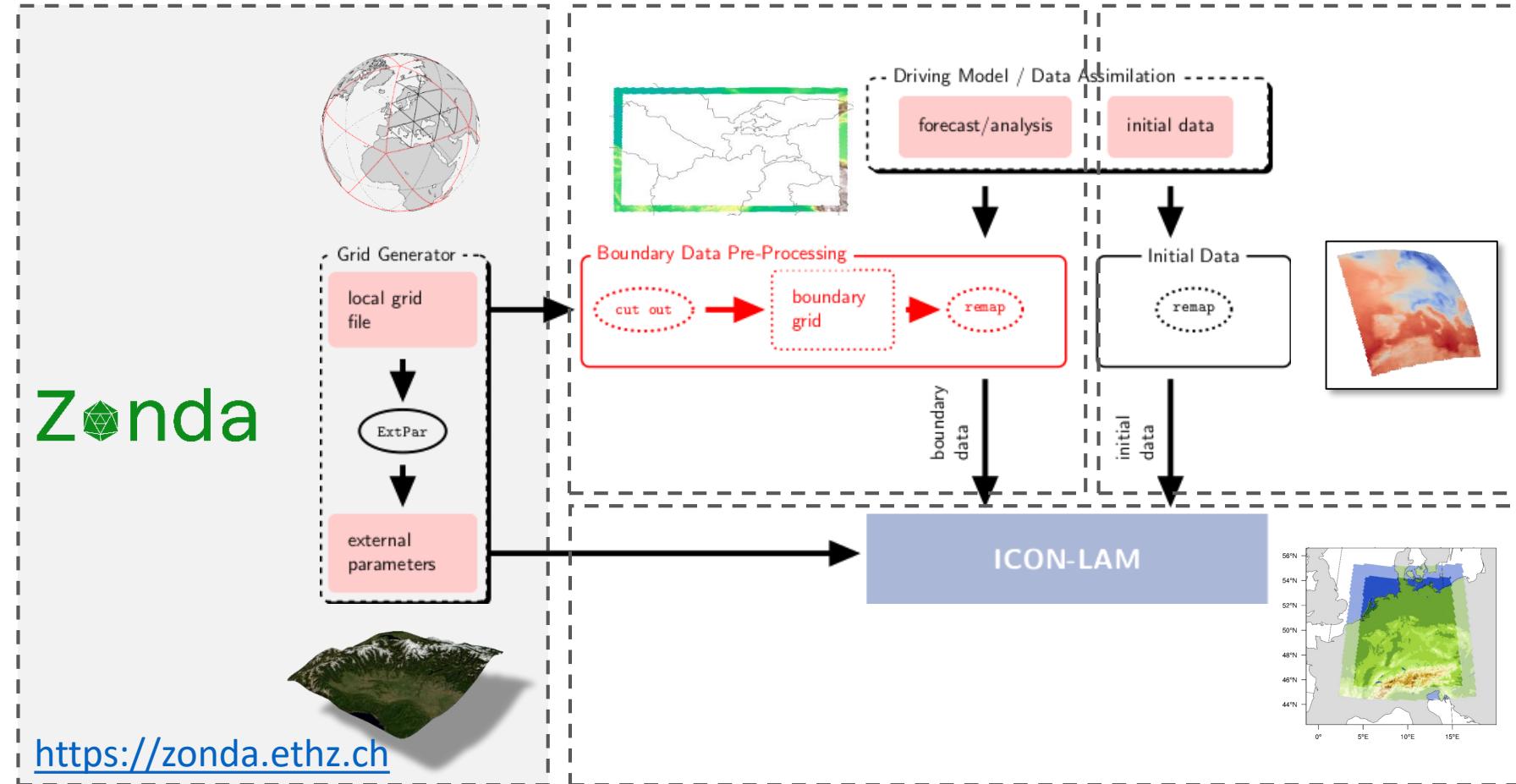
Set III (e.g. IFS)

$$U, \quad V, \quad OMEGA, \quad T, \quad LNSP, \quad QV, \quad QC, \quad QI, \quad QR, \quad QS, \quad FI$$

Summary: Bringing the Pieces Together



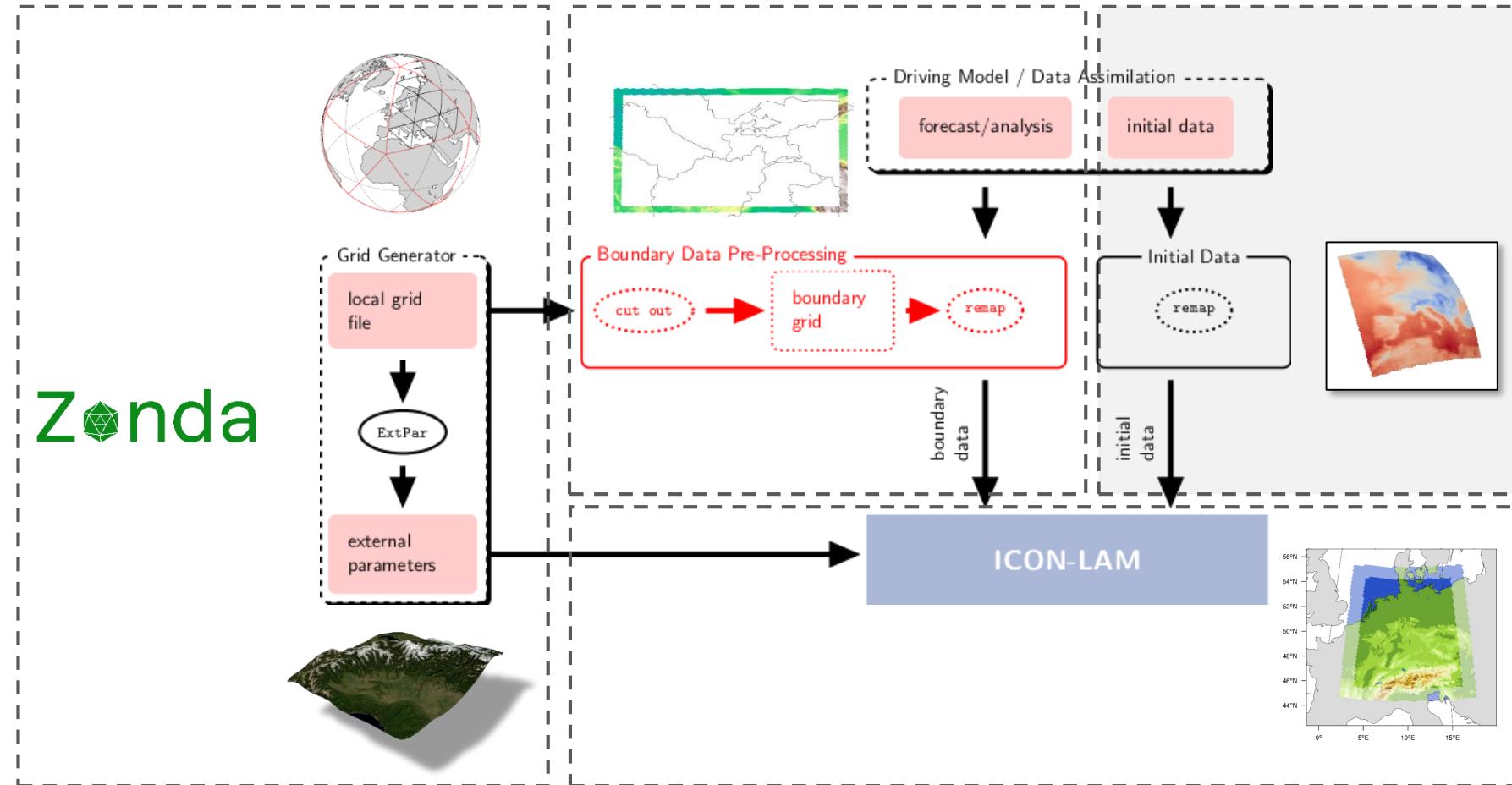
Summary – Grid & External Parameters



Summary – Initial Data

<https://www.dwd.de/EN/ourservices/pamore/pamore.html>

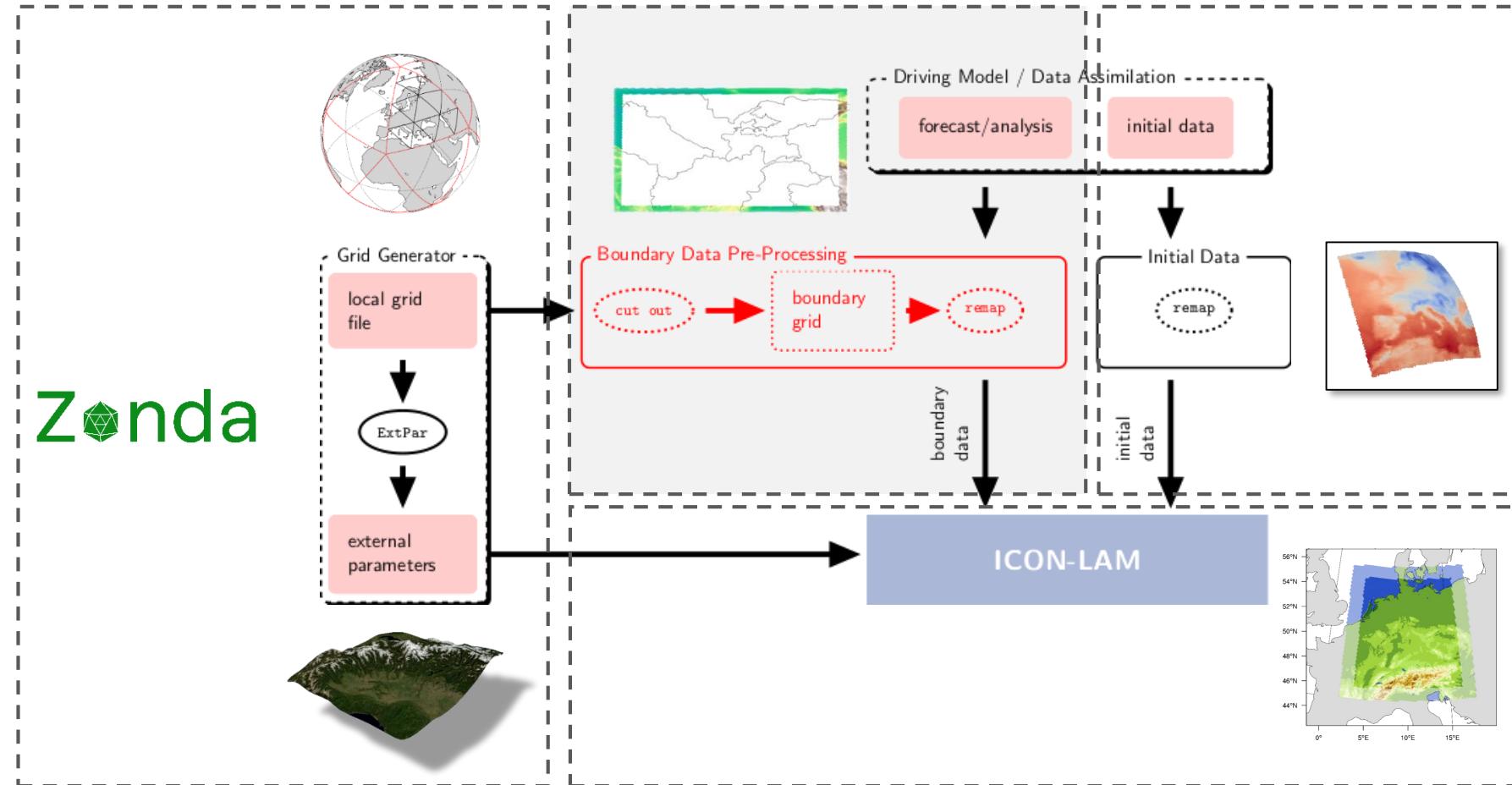
<https://www.ecmwf.int/en/forecasts/accessing-forecasts>



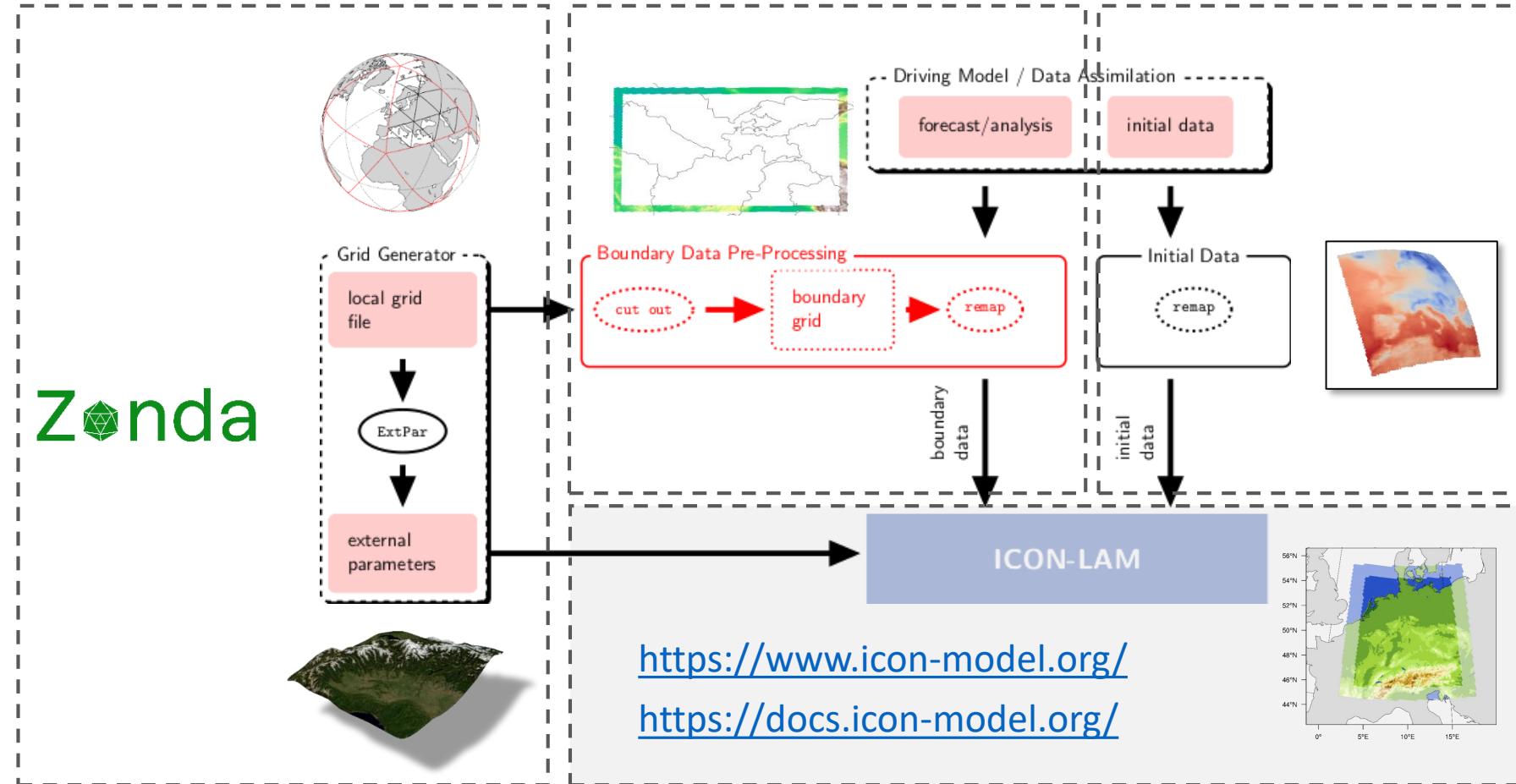
Summary – Lateral Boundary Data

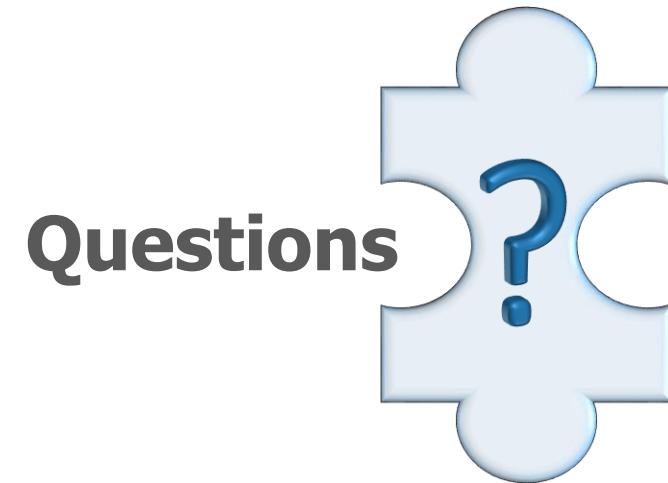
<https://www.dwd.de/EN/ourservices/pamore/pamore.html>

<https://www.ecmwf.int/en/forecasts/accessing-forecasts>



Summary – Everything Ready for ICON(-LAM)





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