ICON input guide

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Contents

1   Initial and boundary conditions for ICON-ESM

The climate system is forced by the following transient "boundary conditions":

1. monthly ozone concentrations

2. monthly aerosol optical properties

3. solar irradiance

4. yearly concentrations of CO_2, CH_4, N_2O, and CFCs

In addition, atmosphere-only runs require monthly or 6-hourly sea surface temperature and sea ice concentration.

The initial conditions of the atmosphere originate from IFS analysis e.g. 1979-01-01. As for ocean initial conditions, these are usually taken from decades-long integrated ocean-only simulations.

Here is a brief guideline to preparing input files, like the grid file, as well as initial and boundary conditions for ICON-ESM and ICON-A experiments. Note that ICON-ESM refers to the coupled setup, in which case we will take the example that uses a R02B04 (158km) atmosphere and a R02B06 (40km) ocean. For the atmosphere-only setup, we refer to them as ICON-A, and will use a R02B04 atmosphere as an example. Similarly, ocean-only setup is referred to as ICON-O and uses a R02B06 ocean.

1.1   Grid Files

Grid generation is done using the MPI-M GridGenerator[1] provided by Leonidas Linardakis.

```
git clone git@gitlab.dkrz.de:mpim-sw/grid-generator.git GridGenerator
cd GridGenerator
config/dkrz/mistral.intel --enable-openmp
make -j 8
cp run/grid_creators/grid.create_Earth_Ocean_grids run/.
make_runscripts grid.create_Earth_Ocean_grids
cd run
sbatch grid.create_Earth_Ocean_grids.run
```

See also https://code.mpimet.mpg.de/projects/icon-grid-generator/wiki

The GridGenerator creates filenames with grid spacing in metric units.

A1 Global_IcosSymmetric_<distance>_rotatedZ37d_modified_srtm30_1min.nc

---

[1]git@gitlab.dkrz.de:mpim-sw/grid-generator.git

A2 OceanOnly_Global_IcosSymmetric_<distance>_rotatedZ37d_modified_srtm30_1min.nc

A3 Earth_Global_IcosSymmetric_<distance>_rotatedZ37d_modified_srtm30_1min.nc

Break down of these files can also be found on
https://code.mpimet.mpg.de/projects/dyamondpp/wiki/Fractional_Land-Sea_mask
where <distance> takes one of the following string values:

grid	distance
R2B04	0158km
R2B05	0079km
R2B06	0039km
R2B07	0020km
R2B08	0010km
R2B09	4932m
R2B10	2466m
R2B11	1233m

A1 contains the global coverage of cells and would have to be registered as the atmospheric grid. For us, this is registered with grid ID **0013**. It is not necessary for this file to contain land-sea mask.

A2 is the ocean-only grid that contains ocean cells and some coastal points and small islands. Most land points have been removed (akin to the file having "holes") to speed up model integration of ICON-O. This file can be registered as the ocean grid if you want to use an R02B06 ocean.

A3 contains again the global grid together with a global land-sea mask. It does not have to be registered, but can be.

Since we would be coupling the R02B04 atmosphere to R02B06 ocean, we will need the grid files for R02B06:

B1 Global_IcosSymmetric_0039km_rotatedZ37d_modified_srtm30_1min.nc

B2 OceanOnly_Global_IcosSymmetric_0039km_rotatedZ37d_modified_srtm30_1min.nc

B3 Earth_Global_IcosSymmetric_0039km_rotatedZ37d_modified_srtm30_1min.nc

In our case, **B2** has been registered with grid ID **0035**. To create the fractional land-sea mask (discussed in section 3.2.2), files A1 and B3 will be required.

One could potentially find some of these files on Mistral in /pool/data/ICON/oes/-grids/Earth and /pool/data/ICON/oes/grids/OceanOnly

Note that the GridGenerator provides several options required for ocean grids and masks especially at coarser resolutions, e.g. to keep Panama on the map or the Black Sea connected to the Mediterranean Sea. Whenever the ocean land-

sea mask is changed the fractional mask will change, an a new set of bc_land and ic_land files has to be generated (see Sec. 1.2.5 and 1.2.6).

1.2 Preprocessing input files for ICON-ESM

A suite of input files are required before one can start running ICON. Most are dependent on the atmospheric resolution, some are independent of resolution. Those independent of resolution are forcing files associated with greenhouse gas, stratospheric aerosol (Stenchikov) and solar irradiance. At the moment (as of March 2020), the best place to find these files is /pool/data/ICON/grids/public/mpim/independent As for those dependent on only atmospheric resolution, they include initial conditions, SST and sea-ice surface forcing, background aerosol (Kinne) and ozone, as well as intermediate files like extpar and remap weights. For coupled simulations, SST and sea-ice forcing are not needed. Some input files for land depend on atmospheric resolution only, other files require both atmosphere and ocean resolution. Another crucial file for coupled simulation is fractional land-sea mask, which depends of both atmosphere and ocean resolution to create the file.

Preprocessing scripts for creating input files are available and can be obtained as follows:

```
git clone git@gitlab.dkrz.de:mpim-sw/icon-preprocessing
cd icon-preprocessing
git checkout icon-esm
cd scripts
```

Some of the scripts use cdo operators for remapping data. We recommend to use cdo version 1.9 or newer (preferably v1.9.8). These newer versions make use of more precise algorithms to calculate intersections and the conservative remapping which in turn is used e.g. to calculate the fractional mask. Also, the new cdo version uses the same algorithm as YAC, which makes it even more consistent for ICON.

In the following, we provide guidance through the sequence of scripts to run for preparing initial, boundary and forcing files. All scripts have to be edited to match the specific target configuration in mind. Below we provide an example setting, and usually it is sufficient to modify the values which we mark in red below.

1.2.1 Rename and metadata of grid files

Once the grid has been generated, their file names have to be renamed and metadata appropriately edited according to conventions. Files must be registered (through Monika Esch). Registered files can be found on http://icon-downloads.zmaw.de/mpim_grids.xml

Script: 00-icon-grids-modify-attributes.sh

For the atmosphere grid we set

```
number_of_grid_used=13
centre=252
subcentre=0
Atmos=true
Ocean=false
```

and for the ocean grid

```
number_of_grid_used=35
centre=252
subcentre=0
Atmos=false
Ocean=true
```

The Ocean, Earth, and Atmosphere grid files must be specified with the variable input|Atmos|Earth|Ocean|GridFile. `centre` and `subcentre` numbers are defined in the WMO code tables[2].

Files it should produce:

- For Atmosphere : icon_grid_0013_R02B04_G.nc

- For Ocean : icon_grid_0035_R02B06_O.nc and icon_mask_0035_R02B06_G.nc

The icon_mask file is considered as an auxiliary file and is generated together with the ocean grid file. It is used in a later step to calculate a fractional mask between a particular pair of ocean and atmosphere grid files.

In this example, the resulting atmosphere grid file should be placed in <dataroot>/0013 and the ocean grid files would go to <dataroot>/0035 .

An example for a <dataroot> value is /pool/data/ICON/grids/private/rene/mpim

1.2.2 Intermediate files

Intermediate files include remapping weights and orography/extpar.
Script: 08-icon-remap-weights.sh

```
source_grid=127    #255 is another option
target_dir=<dataroot>
revision=r0001
gridID="0013"
gridRefinement="R02B04"
```

---

[2]https://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/LatestVERSION/WMO306_vI2_CommonTable_en.pdf

The script made remap-weights files: wgtdis_T127_to_R02B04.nc & wgtdis_T255_to_R02B04.nc
stored in <dataroot>/0013/remap_weights/r0001

Script: 10-create-orography.sh

```
revision="r0001"
gridID="0013"
gridRefinement=R02B04
icon_grid_dir=<dataroot>/$gridID
workdir=<dataroot>/extpar_work
progdir=/work/mh0287/users/rene/extpar-5.0-gcc/bin
output_dir=<dataroot>/extpar.2016/$revision
```

The script creates an intermediate file icon_extpar_grid_0013_R02B04_G_20200319.nc
in <dataroot>0013/extpar.2016/r0001

The last 8 digits of the root name indicate the date on which the file was
generated and is thus subject to change.

This extpar file is later used by 12-land-ini-files-from-gauss-and-extpar.sh to
generate the initial and boundary conditions for the land (JSBACH).

1.2.3   SST and SIC forcing

Script: 09-remap-sst-and-seaice.sh

```
revision=r0001
gridID="0013"
gridRefinement="R02B04"
grid_path=<dataroot>
```

The following files would be created in <dataroot>/0013/sst_and_seaice/r0001:
bc_sic_1979_2016.nc & bc_sst_1979_2016.nc

1.2.4   Initial conditions

Initial conditions are interpolated from IFS, typically for either year 1979 or
1992. While the start year may not matter much, the month of the start time
is crucial. This means if you want to start at the beginning of the year, you
should have a Jan. 1st file. If you want to integrate from the month of August
onwards, then ensure your initial condition is for August.
Script: 11-make-initial-data-ifs2icon_1Jan1979.sh

```
rootdir=<dataroot>
revision="r0001"
gridID="0013"
refinement="R02B04"
ifsdate="1979010100"
```

```
ncdate="hours since 1979-1-1 00:00:00"
workdir=<dataroot>/preprocwork
IN_GRIDFILE=/pool/data/ICON/grids/private/mpim/icon_preprocessing/sourc⌋
↪  e/initial_condition/ifs_operod_T1279_201401010.grb
IN_DATAFILE=/pool/data/ICON/grids/private/mpim/icon_preprocessing/sourc⌋
↪  e/initial_condition/ifs_operod_T1279_201401010.grb
rootdir=<dataroot>
outputdir=$rootdir/$gridID/initial_condition/$revision
tooldir=/pool/data/ICON/grids/private/mpim/icon_preprocessing/tools/ico⌋
↪  ntools
GRIDFILE=icon_grid_$gridID_$refinement_G.nc
OUT_GRIDFILE=$rootdir/$gridID/$GRIDFILE
```

Here, one should use sbatch to run the script.

>> sbatch 11-make-initial-data-ifs2icon_1Jan1979.sh

The script uses IFS file from 2014 to make an initial condition file, set to year 1979, called ifs2icon_1979010100_R02B04_G.nc

Note that it matters which GPU processor (mg20x vs mg10x) and how many threads (18 vs 12) you use as this may be a likely cause for small differences, even with the same node processor and threads used.

1.2.5 Fractional land-sea mask

A fractional land-sea mask is required for building the input files for coupled simulations and may also be used for AMIP-type simulations. To create the fractional land-sea mask, we need the atmospheric grid file and the global mask of the ocean grid (including the land cells), which can be found in:

```
<dataroot>/0013/icon_grid_0013_R02B04_G.nc
<dataroot>/0035/icon_mask_0035_R02B06_O.nc
```

One can use the script, 00-fractional_mask.sh with the following options:

```
oceGridID=0035
oceRes=R02B06
atmGridID=0013
atmRes=R02B04
gridPath=<dataroot>
```

A file fractional_lsm_0013_0035.nc is created in <dataroot>/0013-0035/fractional_mask.

This fractional mask file does not have to be provided at run-time. Instead, the fractional mask will be read in at run time from one of the bc_frac files that are generated as described in Sec. 1.2.6.

1.2.6 Land

Now we build the initial files and boundary conditions (bc) for the land model, and bc for atmosphere. For building AMIP (atmosphere-only) configurations the fractional mask is not required but can be used if desired, while for coupled configurations it is mandatory.

Script: 12-land-ini-files-from-gauss-and-extpar.sh

```
rootdir=<dataroot>
atmGridID=0013
oceGridID=0035     # for fractional mask when coupled=true
atmRes=R02B04
fracMaskRev=r0002 # for fractional mask when coupled=true
revision=r0001
revision_ext=r0001
grid_path=<dataroot>
bisections="4"           #chooses R2B4 option
ggrids=""
start_year=1992
end_year=1992
coupled=true      # (fractional) land sea mask for coupled experiment
```

The following files were created in <dataroot>/0013/land/r0001:
bc_land_frac_1992.nc, bc_land_frac_11pfts_1992.nc, bc_land_soil_1992.nc, bc_land_phys_1992.nc, bc_land_sso_1992.nc, ic_land_soil_1992.nc

To generate the input for a historical run, set

```
start_year=1850
end_year=2016
coupled=true      # (fractional) land sea mask for coupled experiment
```

In this case the following files are generated: bc_land_frac_1850.nc, bc_land_frac_11pfts_1850.nc, bc_land_soil_1850.nc, bc_land_phys_1850.nc, bc_land_sso_1850.nc, ic_land_soil_1850.nc, plus additional bc_land_frac_11pfts_ and bc_land_frac_ files for years 1851 to 2016.

Note: The script is run interactively and will ask for the username and password for accessing git.mpimet.mpg.de.

1.2.7 Kinne (troposhere) Aerosol

Script: 13-interpolate_kinne_aerosols.sh

```
revision="r0001"
gridID="0013"
refinement="R02B04"
grid_path=<dataroot>
```

The following files would be created in <dataroot>/0013/aerosol_kinne/r0001:
bc_aeropt_kinne_lw_b16_coa.nc, bc_aeropt_kinne_remapcon_weights.nc, bc_aeropt_kinne_sw_b14_coa.nc, bc_aeropt_kinne_sw_b14_fin_xxxx.nc; where xxxx=1845-19xx.

Note: Editing the variable "files" would allow you to select certain years or a time range.

See Sec. 2 for further explanation about the usage of aerosol files.

1.2.8   Ozone

Script: 15-remap_cmip6_ozone.sh

```
revision=r0001
outputdir_root=<dataroot>
weightdir_root=<dataroot>
griddir_root=<dataroot>
gridfiles="icon_grid_0013_R02B04_G.nc"
```

The following files were created in <dataroot>/0013/ozone/r0001:
bc_ozone_picontrol.nc and bc_ozone_historical_xxxx.nc; where xxxx=1978-2014.

These files are required when irad_o3 is set to 8.

1.2.9   River Routing

by Thomas Riddick

The hydrological discharge model runs with either one or two input files. The one necessary file is that containing the river routings and the parameters determining rate of flow; the bc_land_hd.nc file (also called the hdpara.nc file). The second optional file is the initial reservoir contents; the ic_land_hd.nc file (or hdstart.nc file).

Fractional land-sea mask and atmospheric grid files are required to generate the bc_land_hd.nc file and the file must be regenerated if either of these files are changed. For low-resolution ICON atmosphere grids (R02B03 to R02B06) river routings are determined using a combination of the Hydrosheds dataset and a specially corrected high-resolution orography on a latitude-longitude grid and then upscaled to the relevant ICON grid using an upscaling algorithm specifically designed for river routings. For high-resolutions ICON atmosphere grids (e.g. R02B09) river routings are generated directly from an orography on that grid. The parameters determining rate of flow are always generated directly from an orography on the intended ICON atmospheric grid. A full description and set of instruction for both low- and high-resolutions is given in the document 'Generation of HD Parameters Files for ICON Grids: Description and

Instructions'[3].

Additional comments:

1. Additional files are produced containing the river catchments and (dry) cumulative flow to each cell. Though these are not used by the model (the information contained in them being implicit in the routings given in the bc_land_hd.nc file), they can be useful for diagnostic purposes.

2. The ic_land_hd.nc (or hdstart.nc/hdrestart.nc) file is used to prefill the series of reservoirs used to simulate rivers. This file is necessary for short runs; if you run your model long enough this file isn't necessary as the reservoirs will fill during the integration - the only consequence of its omission might be that the ocean is getting less river input in the first months/years of the run (the exact time to reach equilibrium for the HD model isn't clear as it likely varies with resolution; for the old 0.5-degree ECHAM HD model was a year or two without lakes).

1.3 Grid-independent data

Depending on the selected forcing ICON requires additional input data from /pool/data/ICON/grids/public/mpim/independent . Data sets located below this directory tree do not have to be interpolated onto the model grid but can be read in directly.

- aerosol_stenchikov
- CMIP6Forcing
- MACv2_simple_plumes_merged
- solar_radiation

2 General Remarks about Aerosol Data

2.1 Tropospheric Aerosol

Based on input from Sebastian Rast

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[3]https://wiki.mpimet.mpg.de/lib/exe/fetch.php?media=models:icon:icon_hd_parameter_generation_instructions.pdf

These aerosol data consist of a natural background and an anthropogenic part. The Max-Planck-Aerosol Climatology Version 2 (MACv2)[4], also known as Kinne-climatology, contains both. The natural background is constant over time and represented by the year 1850. The Kinne-climatology contains data for years 1850 to 2100. Data from year 1851 onward contains the background plus the anthropogenic part of the respective year.

The MACv2 simple plumes[5] contains the anthropogenic part, but represented by parameterised functions. These MACv2 simple plumes have to be used together with the MACv2 background aerosol (year 1850, see above). Parameterisations are available for different scenarios.

2.2 Stratospheric Aerosol

Similar to the treatment of tropospheric aerosols, stratospheric aerosols consist of a natural background part (year 1850) which is constant over the years and a time-dependent part. In this case, the time-dependent part comes from the volcanic aerosols.

A first version of these data was published by G. Stenchikov. These Stenchikov aerosol data can now be considered as deprecated and should not be used anymore, and cannot be read in by ICON since the release version 2.6.2. As a replacement, a new data set is provided and supported by ICON since the release version 2.6.2. This would be the CMIP6 volcanic aerosol that covers the time range from year 1850 to 2014.

2.3 Aerosol Forcing: irad_aero explained

Different values of irad_aero require different combinations of aerosol input data. Note that AMIP configurations (lamip = .TRUE) require input files of the form bc_aeropt_cmip6_volc_lw_b16_sw_b14_<year>.nc, where year is the current model year.

irad_aero = 0

No aerosol data need to be provided.

irad_aero = 13

Use transient Kinne climatology tropospheric aerosols (include anthropogenic part).

troposphere:

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[4]https://acp.copernicus.org/articles/19/10919/2019/
[5]https://gmd.copernicus.org/articles/10/433/2017/, https://gmd.copernicus.org/articles/12/989/2019/

- bc_aeropt_kinne_lw_b16_coa.nc

- bc_aeropt_kinne_sw_b14_coa.nc

- bc_aeropt_kinne_sw_b14_fin_<year>.nc

irad_aero = 14

Use constant natural background stratospheric aerosols.

stratosphere:

- bc_aeropt_cmip6_volc_lw_b16_sw_b14.nc, sym link
  to bc_aeropt_cmip6_volc_lw_b16_sw_b14_1850.nc

irad_aero = 15

Use transient Kinne climatology tropospheric aerosols (include anthropogenic part) and constant natural background stratospheric aerosols. Combination of 13 & 14.

troposphere:

- bc_aeropt_kinne_lw_b16_coa.nc

- bc_aeropt_kinne_sw_b14_coa.nc

- bc_aeropt_kinne_sw_b14_fin_<year>.nc

stratosphere:

- bc_aeropt_cmip6_volc_lw_b16_sw_b14.nc sym link
  to bc_aeropt_cmip6_volc_lw_b16_sw_b14_1850.nc

irad_aero = 18

Use transient MACv2 simple plumes scheme for tropospheric aerosols and constant natural background stratospheric aerosols.

troposphere:

- bc_aeropt_kinne_lw_b16_coa.nc

- bc_aeropt_kinne_sw_b14_coa.nc

- bc_aeropt_kinne_sw_b14_fin.nc (sym link
  to bc_aeropt_kinne_sw_b14_fin_1850.nc) , only background

- MACv2 simple plumes (e.g. sym link to MACv2.0-SP-merged-historical-and-SSP2-45_v1.nc)

stratosphere:

- bc_aeropt_cmip6_volc_lw_b16_sw_b14.nc sym link
  to bc_aeropt_cmip6_volc_lw_b16_sw_b14_1850.nc

irad_aero = 19[6]

Use constant natural background tropospheric aerosols.

troposhere:

- bc_aeropt_kinne_lw_b16_coa.nc

- bc_aeropt_kinne_sw_b14_coa.nc

- bc_aeropt_kinne_sw_b14_fin.nc (sym link
  to bc_aeropt_kinne_sw_b14_fin_1850.nc) , only background

3   Coupling Configuration

The YAC coupling library that handles the coupling between any two ICON components has to be configured with a coupling xml file. Existing ICON coupled configurations have this xml file already included in the job template. In this xml section the coupling and model time steps are set as shell variables. Upon execution of the job script, the shell variables are replaced by its assigned values, and the whole xml section is then extracted and stored as coupling.xml.

The structure of the xml file and its relation to the Fortran interface is explained in the ICON-ESM Redmine Wiki[7] and references and links therein.

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[6]not yet available in icon-2.6.2-rc
[7]https://code.mpimet.mpg.de/projects/icon-esm/wiki/YAC_Coupler