

*A Description of the
Nonhydrostatic Regional COSMO-Model*

Part V:

Preprocessing:
Initial and Boundary Data for the COSMO-Model

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INT2LM 2.05

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www.cosmo-model.org



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Section 1

Overview on the Model System

1.1 General Remarks

The *COSMO-Model* is a nonhydrostatic limited-area atmospheric prediction model. It has been designed for both operational numerical weather prediction (NWP) and various scientific applications on the meso- β and meso- γ scale. The COSMO-Model is based on the primitive thermo-hydrodynamical equations describing compressible flow in a moist atmosphere. The model equations are formulated in rotated geographical coordinates and a generalized terrain following height coordinate. A variety of physical processes are taken into account by parameterization schemes.

Besides the forecast model itself, a number of additional components such as data assimilation, interpolation of boundary conditions from a driving host model, and postprocessing utilities are required to run the model in NWP-mode, climate mode or for case studies. The purpose of the *Description of the Nonhydrostatic Regional COSMO-Model* is to provide a comprehensive documentation of all components of the system and to inform the user about code access and how to install, compile, configure and run the model.

The basic version of the COSMO-Model (formerly known as *Lokal Modell (LM)*) has been developed at the *Deutscher Wetterdienst* (DWD). The COSMO-Model and the triangular mesh global gridpoint model GME form – together with the corresponding data assimilation schemes – the NWP-system at DWD, which is run operationally since end of 1999. The subsequent developments related to the model have been organized within COSMO, the *Consortium for Small-Scale Modeling*. COSMO aims at the improvement, maintenance and operational application of a non-hydrostatic limited-area modeling system, which is now consequently called the COSMO-Model. The meteorological services participating to COSMO at present are listed in Table 1.1.

For more information about COSMO, we refer to the web-site at www.cosmo-model.org.

The COSMO-Model is available free of charge for scientific and educational purposes, especially for cooperational projects with COSMO members. However, all users are required to sign an agreement with a COSMO national meteorological service and to respect certain conditions and restrictions on code usage. For questions concerning the request and the agreement, please contact the chairman of the COSMO Steering Committee. In the case of

Table 1.1: COSMO: Participating Meteorological Services

<i>DWD</i>	Deutscher Wetterdienst, Offenbach, Germany
<i>MeteoSwiss</i>	Meteo-Schweiz, Zürich, Switzerland
<i>USAM</i>	Ufficio Generale Spazio Aero e Meteorologia, Roma, Italy
<i>HNMS</i>	Hellenic National Meteorological Service, Athens, Greece
<i>IMGW</i>	Institute of Meteorology and Water Management, Warsaw, Poland
<i>ARPA-SIMC</i>	Agenzia Regionale per la Protezione Ambientale dell' Emilia-Romagna Servizio Idro Meteo Clima Bologna, Italy
<i>ARPA-Piemonte</i>	Agenzia Regionale per la Protezione Ambientale, Piemonte, Italy
<i>CIRA</i>	Centro Italiano Ricerche Aerospaziali, Italy
<i>ZGeoBW</i>	Zentrum für Geoinformationswesen der Bundeswehr, Euskirchen, Germany
<i>NMA</i>	National Meteorological Administration, Bukarest, Romania
<i>RosHydroMet</i>	Hydrometeorological Centre of Russia, Moscow, Russia

a planned operational or commercial use of the COSMO-Model package, special regulations will apply.

The further development of the modeling system within COSMO is organized in Working Groups which cover the main research and development activities: data assimilation, numerical aspects, upper air physical aspects, soil and surface physics aspects, interpretation and applications, verification and case studies, reference version and implementation and predictability and ensemble methods. In 2005, the COSMO Steering Committee decided to define *Priority Projects* with the goal to focus the scientific activities of the COSMO community on some few key issues and support the permanent improvement of the model. For contacting the Working Group Coordinators or members of the Working Groups or Priority Projects, please refer to the COSMO web-site.

The COSMO meteorological services are not equipped to provide extensive support to external users of the model. If technical problems occur with the installation of the model system or with basic questions how to run the model, questions could be directed via email to cosmo-support@cosmo-model.org. If further problems occur, please contact the members of an appropriate Working Group. We try to assist you as well as possible.

The authors of this document recognize that typographical and other errors as well as discrepancies in the code and deficiencies regarding the completeness may be present, and your assistance in correcting them is appreciated. All comments and suggestions for improvement

or corrections of the documentation and the model code are welcome and may be directed to the authors.

1.2 Basic Model Design and Features

The nonhydrostatic fully compressible COSMO-Model has been developed to meet high-resolution regional forecast requirements of weather services and to provide a flexible tool for various scientific applications on a broad range of spatial scales. When starting with the development of the COSMO-Model, many NWP-models operated on hydrostatic scales of motion with grid spacings down to about 10 km and thus lacked the spatial resolution required to explicitly capture small-scale severe weather events. The COSMO-Model has been designed for meso- β and meso- γ scales where nonhydrostatic effects begin to play an essential role in the evolution of atmospheric flows.

By employing 1 to 3 km grid spacing for operational forecasts over a large domain, it is expected that deep moist convection and the associated feedback mechanisms to the larger scales of motion can be explicitly resolved. Meso- γ scale NWP-models thus have the principle potential to overcome the shortcomings resulting from the application of parameterized convection in current coarse-grid hydrostatic models. In addition, the impact of topography on the organization of penetrative convection by, e.g. channeling effects, is represented much more realistically in high resolution nonhydrostatic forecast models.

In the beginning, the operational application of the model within COSMO were mainly on the meso- β scale using a grid spacing of 7 km. The key issue was an accurate numerical prediction of near-surface weather conditions, focusing on clouds, fog, frontal precipitation, and orographically and thermally forced local wind systems. Since April 2007, a meso- γ scale version is running operationally at DWD by employing a grid spacing of 2.8 km. Applications with similar resolutions are now run by most COSMO partners. We expect that this will allow for a direct simulation of severe weather events triggered by deep moist convection, such as supercell thunderstorms, intense mesoscale convective complexes, prefrontal squall-line storms and heavy snowfall from wintertime mesocyclones.

The requirements for the data assimilation system for the operational COSMO-Model are mainly determined by the very high resolution of the model and by the task to employ it also for nowcasting purposes in the future. Hence, detailed high-resolution analyses have to be able to be produced frequently and quickly, and this requires a thorough use of synoptic and high-frequency observations such as aircraft data and remote sensing data. Since both 3-dimensional and 4-dimensional variational methods tend to be less appropriate for this purpose, a scheme based on the observation nudging technique has been chosen for data assimilation.

Besides the operational application, the COSMO-Model provides a nonhydrostatic modeling framework for various scientific and technical purposes. Examples are applications of the model to large-eddy simulations, cloud resolving simulations, studies on orographic flow systems and storm dynamics, development and validation of large-scale parameterization schemes by fine-scale modeling, and tests of computational strategies and numerical techniques. For these types of studies, the model should be applicable to both real data cases and artificial cases using idealized test data. Moreover, the model has been adapted by other

communities for applications in climate mode (CCLM) and / or running an online coupled module for aerosols and reactive trace gases (ART).

Such a wide range of applications imposes a number of requirements for the physical, numerical and technical design of the model. The main design requirements are:

- (i) use of nonhydrostatic, compressible dynamical equations to avoid restrictions on the spatial scales and the domain size, and application of an efficient numerical method of solution;
- (ii) provision of a comprehensive physics package to cover adequately the spatial scales of application, and provision of high-resolution data sets for all external parameters required by the parameterization schemes;
- (iii) flexible choice of initial and boundary conditions to accommodate both real data cases and idealized initial states, and use of a mesh-refinement technique to focus on regions of interest and to handle multi-scale phenomena;
- (iv) use of a high-resolution analysis method capable of assimilating high-frequency synoptic data and remote sensing data;
- (v) use of pure Fortran constructs to render the code portable among a variety of computer systems, and application of the standard MPI-software for message passing on distributed memory machines to accommodate broad classes of parallel computers.

The development of the COSMO-Model was organized along these basic guidelines. However, not all of the requirements are fully implemented, and development work and further improvement is an ongoing task. The main features and characteristics of the present release are summarized below.

Dynamics

- **Model Equations** – Nonhydrostatic, full compressible hydro-thermodynamical equations in advection form. Subtraction of a hydrostatic base state at rest.
- **Prognostic Variables** – Horizontal and vertical Cartesian wind components, pressure perturbation, temperature, specific humidity, cloud water content. Optionally: cloud ice content, turbulent kinetic energy, specific water content of rain, snow and graupel.
- **Diagnostic Variables** – Total air density, precipitation fluxes of rain and snow.
- **Coordinate System** – Generalized terrain-following height coordinate with rotated geographical coordinates and user defined grid stretching in the vertical. Options for (i) base-state pressure based height coordinate, (ii) Gal-Chen height coordinate and (iii) exponential height coordinate (SLEVE) according to [Schaer et al. \(2002\)](#).

Numerics

- **Grid Structure** – Arakawa C-grid, Lorenz vertical grid staggering.
- **Spatial Discretization** – Second-order finite differences. For the two time-level scheme also 1st and 3rd to 6th order horizontal advection (default: 5th order). Option for explicit higher order vertical advection.

- **Time Integration** – Two time-level 2nd and 3rd order Runge-Kutta split-explicit scheme after [Wicker and Skamarock \(2002\)](#) and a TVD-variant (Total Variation Diminishing) of a 3rd order Runge-Kutta split-explicit scheme. Option for a second-order leapfrog HE-VI (horizontally explicit, vertically implicit) time-split integration scheme, including extensions proposed by [Skamarock and Klemp \(1992\)](#). Option for a three time-level 3-d semi-implicit scheme ([Thomas et al. \(2000\)](#)) based on the leapfrog scheme.
- **Numerical Smoothing** – 4th-order linear horizontal diffusion with option for a monotonic version including an orographic limiter. Rayleigh damping in upper layers. 2-d divergence damping and off-centering in the vertical in split time steps.

Initial and Boundary Conditions

- **Initial Conditions** – Interpolated initial data from various coarse-grid driving models (GME, ECMWF, COSMO-Model) or from the continuous data assimilation stream (see below). Option for user-specified idealized initial fields.
- **Lateral Boundary Conditions** – 1-way nesting by Davies-type lateral boundary formulation. Data from several coarse-grid models can be processed (GME, IFS, COSMO-Model). Option for periodic boundary conditions.
- **Top Boundary Conditions** – Options for rigid lid condition and Rayleigh damping layer.
- **Initialization** – Digital-filter initialization of unbalanced initial states ([Lynch et al. \(1997\)](#)) with options for adiabatic and diabatic initialization.

Physical Parameterizations

- **Subgrid-Scale Turbulence** – Prognostic turbulent kinetic energy closure at level 2.5 including effects from subgrid-scale condensation and from thermal circulations. Option for a diagnostic second order K-closure of hierarchy level 2 for vertical turbulent fluxes. Preliminary option for calculation of horizontal turbulent diffusion in terrain following coordinates (3D Turbulence).
- **Surface Layer Parameterization** – A Surface layer scheme (based on turbulent kinetic energy) including a laminar-turbulent roughness layer. Option for a stability-dependent drag-law formulation of momentum, heat and moisture fluxes according to similarity theory ([Louis \(1979\)](#)).
- **Grid-Scale Clouds and Precipitation** – Cloud water condensation and evaporation by saturation adjustment. Precipitation formation by a bulk microphysics parameterization including water vapour, cloud water, cloud ice, rain and snow with 3D transport for the precipitating phases. Option for a new bulk scheme including graupel. Option for a simpler column equilibrium scheme.
- **Subgrid-Scale Clouds** – Subgrid-scale cloudiness is interpreted by an empirical function depending on relative humidity and height. A corresponding cloud water content is also interpreted. Option for a statistical subgrid-scale cloud diagnostic for turbulence.
- **Moist Convection** – [Tiedtke \(1989\)](#) mass-flux convection scheme with equilibrium closure based on moisture convergence. Option for the Kain-Fritsch ([Kain and Fritsch \(1993\)](#)) convection scheme with non-equilibrium CAPE-type closure.
- **Shallow Convection** – Reduced Tiedtke scheme for shallow convection only.
- **Radiation** – δ two-stream radiation scheme after [Ritter and Geleyn \(1992\)](#) short and longwave fluxes (employing eight spectral intervals); full cloud-radiation feedback.
- **Soil Model** – Multi-layer version of the former two-layer soil model after [Jacobsen and Heise \(1982\)](#) based on the direct numerical solution of the heat conduction equation. Snow and interception storage are included. Option for the (old) two-layer soil model employing the extended force-restore method still included.

- **Fresh-Water Lake Parameterization** – Two-layer bulk model after [Mironov \(2008\)](#) to predict the vertical temperature structure and mixing conditions in fresh-water lakes of various depths.
- **Sea-Ice Scheme** – Parameterization of thermodynamic processes (without rheology) after [Mironov and B. \(2004\)](#). The scheme basically computes the energy balance at the ices surface, using one layer of sea ice.
- **Terrain and Surface Data** – All external parameters of the model are available at various resolutions for a pre-defined region covering Europe. For other regions or grid-spacings, the external parameter file can be generated by a preprocessor program using high-resolution global data sets.

Data Assimilation

- **Basic Method** – Continuous four-dimensional data assimilation based on observation nudging ([Schraff \(1996\)](#), [Schraff \(1997\)](#)), with lateral spreading of upper-air observation increments along horizontal surfaces. Explicit balancing by a hydrostatic temperature correction for surface pressure updates, a geostrophic wind correction, and a hydrostatic upper-air pressure correction.
- **Assimilated Atmospheric Observations** – Radiosonde (wind, temperature, humidity), aircraft (wind, temperature), wind profiler (wind), and surface-level data (SYNOP, SHIP, BUOY: pressure, wind, humidity). Optionally RASS (temperature), radar VAD wind, and ground-based GPS (integrated water vapour) data. Surface-level temperature is used for the soil moisture analysis only.
- **Radar derived rain rates** – Assimilation of near surface rain rates based on latent heat nudging ([Stephan et al. \(2008\)](#)). It locally adjusts the three-dimensional thermodynamical field of the model in such a way that the modelled precipitation rates should resemble the observed ones.
- **Surface and Soil Fields** – Additional two-dimensional intermittent analysis:
 - **Soil Moisture Analysis** – Daily adjustment of soil moisture by a variational method ([Hess \(2001\)](#)) in order to improve 2-m temperature forecasts; use of a Kalman-Filter-like background weighting.
 - **Sea Surface Temperature Analysis** – Daily Cressman-type correction, and blending with global analysis. Use of external sea ice cover analysis.
 - **Snow Depth Analysis** – 6-hourly analysis by weighted averaging of snow depth observations, and use of snowfall data and predicted snow depth.

Code and Parallelization

- **Code Structure** – Modular code structure using standard Fortran constructs.
- **Parallelization** – The parallelization is done by horizontal domain decomposition using a soft-coded gridline halo (2 lines for Leapfrog, 3 for the Runge-Kutta scheme). The *Message Passing Interface* software (MPI) is used for message passing on distributed memory machines.
- **Compilation of the Code** – The compilation of all programs is performed by a Unix shell script invoking the Unix *make* command. All dependencies of the routines are automatically taken into account by the script.
- **Portability** – The model can be easily ported to various platforms; current applications are on conventional scalar machines (UNIX workstations, LINUX and Windows-NT PCs), on vector computers (NEC SX series) and MPP machines (CRAY, IBM, SGI and others).
- **Model Geometry** – 3-d, 2-d and 1-d model configurations. Metrical terms can be adjusted to represent tangential Cartesian geometry with constant or zero Coriolis parameter.

Table 1.2: COSMO Documentation: A Description of the Nonhydrostatic Regional COSMO-Model

<i>Part I:</i>	Dynamics and Numerics
<i>Part II:</i>	Physical Parameterization
<i>Part III:</i>	Data Assimilation
<i>Part IV:</i>	Implementation Documentation
<i>Part V:</i>	Preprocessing: Initial and Boundary Data for the COSMO-Model
<i>Part VI:</i>	Postprocessing
<i>Part VII:</i>	User's Guide

1.3 Organization of the Documentation

For the documentation of the model we follow closely the *European Standards for Writing and Documenting Exchangeable Fortran 90-Code*. These standards provide a framework for the use of Fortran-90 in European meteorological organizations and weather services and thereby facilitate the exchange of code between these centres. According to these standards, the model documentation is split into two categories: external documentation (outside the code) and internal documentation (inside the code). The model provides extensive documentation within the codes of the subroutines. This is in form of procedure headers, section comments and other comments. The external documentation is split into seven parts, which are listed in Table 1.2.

Parts I - III form the scientific documentation, which provides information about the theoretical and numerical formulation of the model, the parameterization of physical processes and the four-dimensional data assimilation. The scientific documentation is independent of (i.e. does not refer to) the code itself. Part IV will describe the particular implementation of the methods and algorithms as presented in Parts I - III, including information on the basic code design and on the strategy for parallelization using the MPI library for message passing on distributed memory machines (not available yet). The generation of initial and boundary conditions from coarse grid driving models is described in Part V. This part is a description of the interpolation procedures and algorithms used (not yet complete) as well as a User's Guide for the interpolation program INT2LM. Available postprocessing utilities will be described (in the future) in Part VI. Finally, the User's Guide of the COSMO-Model provides information on code access and how to install, compile, configure and run the model. The User's Guide contains also a detailed description of various control parameters in the model input file (in NAMELIST format) which allow for a flexible model set-up for various applications. All parts of the documentation are available at the COSMO web-site (<http://www.cosmo-model.org/content/model/documentation/core/default.htm>).

Section 2

Introduction

This part of the documentation for the COSMO-Model is the description of the interpolation program INT2LM, which performs the interpolation from coarse grid model data to initial and/or boundary data for the COSMO-Model. “LM” (LokalModell) was the former name of the COSMO-Model. The following coarse grid models are possible (at the moment):

- GME: the global DWD grid point model on a icosahedral grid.
- ICON: the new global DWD grid point model (also on an icosahedral grid), which has replaced GME in February 2015.
- IFS: the global ECMWF spectral model.
- COSMO-Model: the COSMO-Model can be nested into itself.

It is also possible to process the data from other climate models (like ECHAM), but another *pre-pre-processor* is needed then. These *pre-pre-processor* are available from the CLM-Community, which operates the “CLimate Mode of the COSMO-Model”.

Originally, INT2LM has been a joint development within COSMO and originates from the former GME2LM. The climate mode has been added by members of the CLM-Community. The development tasks were distributed as follows:

- DWD: parallel framework of the program; GME→COSMO, ICON→COSMO
- ARPA-SIM: IFS→COSMO
- MeteoSwiss, DWD: COSMO→COSMO
- CLM-Community: climate mode and processing data from other climate models

This documentation is not yet complete. Missing are the description of the initial and boundary data that are necessary to run the COSMO-Model and the scientific documentation of the interpolation algorithms used. Nevertheless, it provides a User Guide of how to install the program and how to run it. Therefore it serves as a complete reference for all the NAMELIST groups and variables.

Section 3

The Interpolation Procedures

to be completed

Section 4

Installation of the INT2LM

This chapter explains the steps necessary to compile and run the interpolation program. Section 4.1 lists the external libraries that are necessary to run the program and what can be done, if these libraries are not available. The next sections give detailed information on how to prepare, compile, link and run the INT2LM.

4.1 External Libraries for the INT2LM

INT2LM uses external libraries for data I/O. Usage of most of these libraries can be controlled by conditional compilation. To handle this, the C preprocessor (cpp) must be called. Most Fortran compilers activate the C preprocessor for files ending with a capital F in the suffix: .F or .F90. INT2LM does not use capital letters in the suffix, therefore a special compiler option has to be set, to activate this preprocessor. Take a look to the manual of your compiler to find out about this option.

4.1.1 libgrib1.a

The original implementation of INT2LM and the COSMO-Model used GRIB (Gridded Binary), Version 1, as standard format. Coding and decoding of GRIB1 records can be done with the DWD GRIB1 library, the `libgrib1.a`. This library also contains C-routines to write data to and read it from disk. The Grib library is available from DWD and is provided together with the source code for the COSMO-Model. A short guide for the installation is included in the tar-file of the Grib library.

With GRIB1, DWD used a Grib file format, where all records are starting and ending with additional bytes, the so-called *controlwords*. To process these controlwords properly, you have to set the environment variable

```
export LIBDWD_FORCE_CONTROLWORDS=1
```

Usage of the DWD GRIB1 library can be controlled by conditional compilation and setting the macro `GRIBDWD`. If this macro is not set during compilation, the parts of the source code

that do use `libgrib1.a` calls are not compiled and the library will not be linked to the binary.

4.1.2 `libgrib_api.a`, `libgrib_api_f90.a`

Since INT2LM Version 1.14, another grib library can be used to read grib data. This is the `grib_api` (Application Programmer's Interface) from ECMWF. With this library it is possible to read and write also GRIB2 data (i.e. GRIB, Version 2). To use `grib_api` properly, two sets of definition files are necessary for running the programs: one contains all original definitions from ECMWF (`definitions`), the other set is compiled and maintained by DWD and must be used for the INT2LM and the COSMO-Model (`definitions.edzw`). Also, some special sample files are needed by both programs.

The source code for `grib_api` is available from the web pages of ECMWF <http://www.ecmwf.int>. Both sets of definition files and the necessary samples, which have to correspond to the `grib_api` version used, are distributed together with the INT2LM by DWD. For INT2LM and the COSMO-Model, `grib_api` Version 1.11.0 or higher is required to read GRIB2 data. For writing GRIB2 data, `grib_api` Version 1.13.1 is required.

Please read more on `grib_api` and its usage in the Section on *Data Formats for I/O* in the COSMO-Model User Guide.

Usage of the `grib_api` library can be controlled by conditional compilation and setting the macro `GRIBAPI`. If this macro is not set during compilation, the parts of the source code that do use `grib_api` calls are not compiled and the library will not be linked to the binary.

4.1.3 `libcsobank.a`, `libsupplement.a`

Before COSMO-Model 4.25 and INT2LM 2.1

The COSMO-Model and INT2LM use a tool for parallel asynchronous GRIB I/O from or to files or a data base system (only for Grib). The routines for that tool are grouped together in a module `mpe_io.f90`. In the VCS of DWD, `mpe_io.f90` is provided as an external module, hence it is not in the source code of the model library. `mpe_io.f90` uses the two libraries `libcsobank.a` and `libsupplement.a`.

For users outside DWD, `mpe_io.f90` has been included in the source code of the COSMO-Model and also in the INT2LM. To satisfy the calls from `mpe_io` to the data base system, an additional file `dummy_db.f90` is provided.

- **NEW:**

Since COSMO-Model Version 4.25 and INT2LM Version 2.1, `mpe_io.f90` has been replaced by a modified version `mpe_io2.f90`, which does not support the database access any more. Therefore the usage of these external libraries is now obsolete.

4.1.4 libnetcdf.a

Since Version 1.7, input and output of data can be done in the NetCDF format (Network Common Data Format). Using NetCDF requires an external library `libnetcdf.a`. The source code of this library can be downloaded from <http://www.unidata.ucar.edu>

Usage of the NetCDF library can be controlled by conditional compilation and setting the macro `NETCDF`. If this macro is not set during compilation, the parts of the source code that do use NetCDF calls are not compiled and the library will not be linked to the binary.

NEW: Since INT2LM 2.1 the processing of ICON2LM also needs the NetCDF library to read the ICON grid files and external parameters. If you want to run ICON2LM, you have to compile with `-DNETCDF`.

4.2 Preparing the Code

You have got a tar-file `int2lm_yymmdd.x.y`, where `yymmdd` describes the date in the form "Year-Month-Day" and `x.y` gives the version number. By de-taring, a directory is created with the following contents:

<code>DOCS</code>	Contains a short documentation of the changes in version <code>x</code> .
<code>edid</code>	Script to edit files in <code>src</code> and store them in <code>work</code> .
<code>Fopts</code>	Definition of the compiler options and also directories of libraries.
<code>LOCAL</code>	Contains several examples of <code>Fopts</code> -files for different computers.
<code>Makefile</code>	For compiling and linking the programs.
<code>RUNSCRIPTS</code>	Several examples of scripts (<code>runxxx2yyy</code>) to set the <code>NAMelist</code> values for an interpolation from model / configuration <code>xxx</code> to <code>yyy</code> and start the program.
<code>src</code>	Subdirectory for the source code.
<code>obj</code>	Subdirectory where the object files are written.
<code>ObjDependencies</code>	Definition of the dependencies between the different source files.
<code>Objfiles</code>	Definition of the object files.
<code>work</code>	Subdirectory for intermediate files.

The directories `./obj` and `./work` are empty and can therefore get lost by the tar-process. If so, you have to create them again. In `edid` you have to adapt the pathnames if you want to work with it.

4.3 Compiling and Linking

You have to choose the options for compiling the code in the file `Fopts`. See the User Guide of your computer system for necessary and/or desired options. In particular you have to set the macros to select external libraries. Before linking check that all necessary external libraries (see 4.1) are available.

All other input variables for the program can be determined before running the program with the `NAMelist`-input (see Chapter 7).

The INT2LM is parallelized for distributed memory parallel computers using the domain decomposition technique and explicit message passing with the Message Passing Interface (MPI). Thus it can run on parallel platforms but also on sequential platforms where MPI is not available. For this purpose an additional module `dummy_mpi.f90`, together with a file `mpif.h`, are provided in the directory `LOCAL`. Place these files in the `src`-directory before compiling and linking. Then you can only create `sequential` binaries (see below).

You can invoke a `make-run` by typing `make entry`. For INT2LM only the two entries for a parallel or for a sequential binary are available:

`parexe` A binary for parallel execution is created.

`seqexe` A binary for sequential execution is created.

4.4 Running the Code

To run the code, an ASCII-file `INPUT` has to be provided that contains values for the `NAMelist` variables. The form of this `INPUT` file is described in Chapters 6 and 7. This file is created by the provided run-scripts.

The run-scripts also contain the command to invoke the binary, which you have to adapt. While a sequential binary usually can be invoked just by typing `<name_of_binary>`, a parallel binary must be invoked by a special tool. Often this tool is `mpirun`, but also other tools are possible. See the manual for your system on how to invoke the binary created in the last step.

Section 5

Necessary Initial and Boundary Data for the COSMO-Model

This chapter lists all initial and boundary data which are necessary to run the COSMO-Model. Some of the data depend on special namelist settings in the COSMO-Model and the INT2LM, resp. This will be explained in detail.

5.1 Initial Data for the COSMO-Model

The data necessary to start the COSMO-Model can be divided into three groups:

5.1.1 External parameters

The COSMO-Model needs information about the lower boundary of the domain and also of some background fields, like ozone content. The necessary information is either provided by an *external parameter* file (see also Section 6.2), which is produced for a certain region and resolution or computed directly in the INT2LM.

Constant external parameters for the surface

The following constant external parameters are needed in any case to start a simulation with the COSMO-Model. They are provided in an external parameter file.

HSURF	Height of surface topography
FIS	(alternatively) Geopotential of surface
FR_LAND	Fraction of land in the grid cell
SOILTYP	Soil type of the land (keys 0-9)
Z0	Roughness length

Additional external parameters are provided, that can be used in selected components of the COSMO-Model. Older external parameter files might not carry these informations, therefore usage of the corresponding fields can be controlled by namelist switches. The names of these switches are the same in INT2LM and in the COSMO-Model.

Subgrid scale orography scheme

The sub-grid scale orography (SSO) scheme by Lott and Miller (1997) has been implemented in the COSMO-Model (from Version 4.5 on). It is also included in the DWD global model. The scheme deals explicitly with a low-level flow which is blocked when the sub-grid scale orography is sufficiently high. For this blocked flow separation occurs at the mountain flanks, resulting in a form drag. The upper part of the low-level flow is lead over the orography, while generating gravity waves. The following external parameters are necessary to run the subgrid scale orography scheme:

SSO_STDH	standard deviation of subgrid scale orography [m]
SSO_GAMMA	anisotropy of the orography [-]
SSO_THETA	angle between the principal axis of orography and east [rad]
SSO_SIGMA	mean slope of subgrid scale orography [-]

The usage of the subgrid scale orography scheme is controlled by the Namelist switch `lssso`.

Topographical corrections in the radiation scheme

Topographical corrections for radiation calculations have been introduced. The following external parameters are necessary to compute these corrections.

SKYVIEW	sky view [1]
SLO_ASP	slope aspect [rad]
SLO_ANG	slope angle [rad]
HORIZON	horizon array: The horizon is splitted in <code>nhoriz</code> sectors

The usage of the topographical corrections is controlled by the Namelist switch `lradtopo`. The field `HORIZON` is treated as three-dimensional array with `nhoriz` levels. `nhoriz` is also read as a namelist parameter.

NOTE: The topographical corrections are not yet available in the official code of the COSMO-Model.

External parameters for lakes

The usage of lake fraction and lake depth can be controlled by the Namelist switch `llake`. The COSMO software EXTPAR can provide external parameters for lakes but these have only been tested by DWD. Their usage can be switched off by setting `llake=.FALSE.` in INT2LM and the COSMO-Model. This is still the default.

FR_LAKE	lake fraction in a grid element [0,1]
DEPTH_LK	lake depth

It is possible to initialize all prognostic lake variables for a cold start using the switch `llake_coldstart`. More details on how to use this switch are given in Section 9.1.

Minimum stomata resistance of plants

Up to Version 4.10 the multi-layer soil model of the COSMO-Model used a constant minimum value of stomatal resistance for plants. Now an external map can be read, that provides values for every grid point. Its usage is controlled by the Namelist switch `lstomata`.

PRS_MIN	minimum stomata resistance of plants
---------	--------------------------------------

Thermal radiative surface emissivity

Up to Version 4.10 a constant value was used for the thermal radiative surface emissivity. Now an external map can be read, that provides values for every grid point. Its usage is controlled by the Namelist switch `lemiss`.

EMIS_RAD	thermal radiative surface emissivity
----------	--------------------------------------

Ground fraction covered by forests

The ground fraction covered by evergreen and deciduous forest, resp., can be used in the radiation scheme to determine the effect of snow covered forests on solar snow albedo. Their usage is controlled by the Namelist switch `lforest`.

FOR_E	ground fraction covered by evergreen forest
FOR_D	ground fraction covered by deciduous forest

Plant characteristics, ozone contents and aerosol types

These external fields are usually held constant for the duration of a simulation for numerical weather prediction. In climate simulations they are updated together with the boundaries.

Plant characteristics

The following fields have to be provided by the external parameter data set. Depending on the chosen options they are read by the INT2LM, processed if necessary, and passed on to the COSMO-Model.

PLCOV_MX	plant cover data set for vegetation time
PLCOV_MN	plant cover data set for time of rest
PLCOV12	12 monthly climatological mean values for plant cover
LAI_MX	leaf area index data set for vegetation time
LAI_MN	leaf area index data set for time of rest
LAI12	12 monthly climatological mean values for leaf area index
ROOTDP	root depth
NDVI_MRAT	ratio of monthly mean normalized differential vegetation index to annual maximum for 12 months

There are several options to compute these fields. They are controlled by the namelist parameter `itype_ndvi` and `itype_rootdp`, resp. Possible values for `itype_ndvi` are:

- 0: Data sets for vegetation and for rest are read from the external parameter file for plant cover and the leaf area index. The actual values for a special day are computed by producing a sinus-type annual cycle.
- 1: Plant cover and leaf area index for the COSMO-Model and for a special day are produced by using only the data set for vegetation and an averaged normalized differential vegetation index (ndvi) ratio. This ndvi ratio is computed as a weighted mean between monthly mean values, which are taken from the external parameter data set for the COSMO-Model (provided by DWD in Grib1).
- 2: plant cover, leaf area index and roughness length for the COSMO-Model and for a special day are produced by using 12 monthly climatological mean values for plant cover, leaf area index and roughness length. These values are read from the external parameter data set for the COSMO-Model (provided by CLM in NetCDF).

For the root depth, just one dataset is given. The options for computing actual values are given by `itype_rootdp`:

- 0: input from external parameter for the COSMO-Model is taken and modified with an annual cycle.
- 1: input from external parameter for the COSMO-Model is taken as is but with a minimal value of 0.12.
- 2: input from external parameter for the COSMO-Model is taken and modified with an annual cycle. In addition, the values are adapted to ECOCLIMAP niveau.
- 3: input from external parameter for the COSMO-Model is taken and modified with an annual cycle but without maximum cut off.
- 4: input from external parameter for the COSMO-Model is taken without any modifications.

Ozone contents

VI03	Vertical integrated ozone content
HM03	Ozone maximum

Aerosol characteristics

The default treatment of aerosols in the COSMO-Model is by assuming constant values for aerosols in rural, urban or desert areas and over sea. Now, 12 monthly mean values of the following aerosol types can be read from the external parameters:

AER_SO4	Tegen (1997) aerosol type sulfate drops
AER_DUST	Tegen (1997) aerosol type mineral dust
AER_ORG	Tegen (1997) aerosol type organic
AER_BC	Tegen (1997) aerosol type black carbon
AER_SS	Tegen (1997) aerosol type sea salt

What type of aerosols should be used for the COSMO-Model is controlled by the namelist parameter `itype_aerosol`:

- 0: Default: constant values are assumed in the COSMO-Model. No external parameters are read in INT2LM.
- 1: The 12 monthly mean values are read by INT2LM and actual values for a special day are computed by a linear interpolation between the corresponding months.

5.1.2 Soil and surface variables*Necessary surface variables*

T_SNOW	Temperature of snow surface
W_SNOW	Water content of snow
W_I	Water content of interception water
QV_S	Specific water vapor content at the surface
T_S	Temperature of surface

In an assimilation cycle, these variables are governed by the COSMO-Model, with regular updates by external analyses for `T_SNOW`, `W_SNOW` and `W_I` (at 00, 06, 12 and 18 UTC) and for `T_S` (at 00 UTC). The external analysis for `T_S` updates the values only over sea.

If no assimilation cycle is used, the fields are interpolated from the coarse grid model.

Necessary soil variables

Which soil variables are necessary, depends on the usage of the soil model and the new urban effects parameterization TERRA_URB.

For the multi-layer soil model, the following fields are necessary.

T_SO	Temperature of (multi-layer) soil levels
W_SO	Water content of (multi-layer) soil levels
FRESHSNW	Indicator for freshness of snow
RHO_SNOW	Prognostic snow density

In the COSMO-Model, the usage of the soil model is controlled by the namelist variable `lmulti_layer=.TRUE..`

In INT2LM, the corresponding variable is `lmulti_layer_lm=.TRUE..`, which indicates, that the output of INT2LM has to be for the multi-layer soil model. There is also the namelist variable `lmulti_layer_in=.TRUE..`, which indicates, that the input (coarse grid) model also used a multi-layer soil model. This can only be true for the DWD models GME and COSMO-Model. No other model uses a comparable multi-layer soil model.

Processing of the additional fields necessary for TERRA_URB is controlled by the namelist variable `lterra_urb=.TRUE..` The fields have to be included in the external parameter data set and are the following:

FR.PAVED	Paved fraction of surface (possible alternative name: ISA)
AHF	Yearly average of anthropogenic heat flux

Their processing is currently only possible as grib1 or NetCDF, i.e., the external parameter data set has to be in grib1 or NetCDF format the output format for the initial conditions file has to be either `'grib1'` or `'ncdf'`. Moreover, for grib1 the DWD `'libgrib1'` has to be used, not the `grib_api`. The formats `'apix'` (external parameter input) and `'api1'` (output) are not possible!

When interpolating coarse grid COSMO to fine grid and in the case where the soil type ice (1, therefore no soil moisture) of the coarse grid covers larger areas as the fine grid, the interpolation of the soil moisture variable W_SO can be modified. In this case, the original coarse grid COSMO soil moisture comes from the nearest grid point which is not an ice point and the interpolated fine COSMO grid points have a meaningful moisture different from 0. This procedure could be used in a similar way for the case of rock (SOILTYP 2 which neither has any soil moisture).

But because this procedure has some risks regarding to soil temperature and soil ice, it is not activated by default and cannot be activated by a namelist switch. The user has to activate it by changing the code (in module `src_coarse_interpol.f90`, subroutine `interpol_coarse_special_lm`, Section 2).

For the (old) two- or three-layer soil model, the following fields are necessary.

T_M	Temperature between upper and medium soil layer
T_CL	Temperature between medium and lower soil layer
WG_1	Water content of the upper soil layer
WG_2	Water content of the medium soil layer
WG_3 (*)	Water content of the lower soil layer
W_CL	Climatological water content of the lowest soil layer

These fields will be read by the COSMO-Model, if `lmulti_layer=.FALSE.` is set. In the INT2LM, `lmulti_layer_lm=.FALSE.` has to be used correspondingly. The field WG_3 only is necessary, if `nlgw_ini=3` in the namelist input for the COSMO-Model.

If an assimilation cycle is used, the soil fields are governed by the COSMO-Model (no matter, which soil model is used). There is the possibility to run a *Soil Moisture Analysis*, which is not really an external analysis, but adapts the soil moisture in the upper level in a way, that the temperature forecast is adjusted to the observations.

If no assimilation cycle is used, the fields are interpolated from the coarse grid model.

5.1.3 Atmospheric variables

The following atmospheric variables are necessary to initialize a COSMO-Model forecast.

U	Zonal wind speed
V	Meridional wind speed
W	Vertical wind speed (defined on half levels)
T	Temperature
PP	Pressure deviation from a reference pressure
QV	Specific water vapour content
QC	Specific cloud water content

Since the start of the development of the COSMO-Model, more humidity variables have been added to the set of equation. Since values for these fields are not available in older data sets or from certain coarse grid models, their usage can be controlled by specific namelist settings. In the following table, the 3rd column gives the namelist variable in the COSMO-Model, the last column the corresponding namelist variable in the INT2LM. **ana** indicates, that the corresponding variable refers to the *analysis* or initial file.

QI	Specific cloud ice content	lana_qi	lprog_qi
QR	Specific rain content	lana_qr_qs	lprog_qr_qs
QS	Specific snow content	lana_qr_qs	lprog_qr_qs
QG	Specific graupel content	lana_qg	lprog_qg

In an assimilation cycle all these fields are updated by the nudging analysis. If no assimilation cycle is used, they are interpolated from the coarse grid model.

These variables are used in the COSMO 1-moment cloud microphysical schemes. A nesting of runs with the alternative 2-moment scheme (additional number concentrations), which is not yet part of the official COSMO-Code but available as an additional module, is also possible. For this, the following variables are interpolated if they are present in the input files and if the corresponding switches in COSMO and INT2LM namelists are specified:

NCICE	Number concentration rain water	lana_qi	lprog_qi
NCLOUD	Number concentration cloud water	—	lprog_qn_crsg
NCRAIN	Number concentration rain	lana_qr_qs	lprog_qn_crsg
NCSNOW	Number concentration snow	lana_qr_qs	lprog_qn_crsg
NCGRAUPEL	Number concentration graupel	lana_qg	lprog_qn_crsg

Note that it is possible to run the COSMO-Model with 2-moment scheme without having the number concentrations in the analysis- and boundary files. In this case, the initial number concentrations in the COSMO-Model are guessed from reasonable assumptions on the particle size distribution from the initial specific hydrometeor contents. A certain spinup process of hydrometeor conversion rates and fallspeeds is the consequence.

The hail category in the 2-moment scheme is usually so transient and short-lived that it is not necessary to carry it over in initial- and boundary files.

5.2 Boundary Data for the COSMO-Model

The necessary boundary data for the COSMO-Model are the atmospheric variables and some surface variables. Boundary values have to be provided also for the old two-layer soil model. Some special considerations have to be done for the climate mode.

5.2.1 Soil and surface variables

Necessary surface variables

These fields are needed in any case:

T_SNOW	Temperature of snow surface
W_SNOW	Water content of snow
QV_S	Specific water vapor content at the surface

If the old two-layer soil model is used, also the following variables have to be provided:

T_S	Temperature of the surface
T_M	Temperature between upper and medium soil layer
WG_1	Water content of the upper soil layer
WG_2	Water content of the medium soil layer
WG_3 (*)	Water content of the lower soil layer

The field WG_3 only is necessary, if `nlgw.bd=3` in the namelist input for the COSMO-Model.

5.2.2 Atmospheric variables

The following atmospheric variables are necessary boundary fields for the COSMO-Model.

U	Zonal wind speed
V	Meridional wind speed
W (*)	Vertical wind speed (defined on half levels)
T	Temperature
PP	Pressure deviation from a reference pressure
QV	Specific water vapour content
QC	Specific cloud water content

Depending on the variable `lw_freeslip` in the namelist input for the COSMO-Model, also the vertical wind speed has to be provided. If `lw_freeslip=.TRUE.`, a free-slip condition is implemented, which does NOT need boundary values. If `lw_freeslip=.FALSE.`, boundary values have to be provided. In INT2LM the namelist variable `lvertwind_bd=.TRUE.` has to be set in this case.

Whether boundary values can be provided by the coarse grid model for the other humidity variables, can be controlled by the namelist variables given in the next table (3rd column: COSMO-Model; last column: INT2LM).

QI	Specific cloud ice content	<code>llb_qi</code>	<code>lprog_qi</code>
QR	Specific rain content	<code>llb_qr_qs</code>	<code>lprog_qr_qs</code>
QS	Specific snow content	<code>llb_qr_qs</code>	<code>lprog_qr_qs</code>
QG	Specific graupel content	<code>llb_qg</code>	<code>lprog_qg</code>

As for analysis data, there are corresponding switches for the additional number concentrations of the 2-moment cloud microphysical scheme:

NCICE	Number concentration rain water	llb_qi	lprog_qi
NCCLLOUD	Number concentration cloud water	—	lprog_qn_crsg
NCRAIN	Number concentration rain	llb_qr_qs	lprog_qn_crsg
NCSNOW	Number concentration snow	llb_qr_qs	lprog_qn_crsg
NCGRAUPEL	Number concentration graupel	llb_qg	lprog_qn_crsg

Again, these are optional, as for the initial data. The 2-moment scheme in the COSMO-Model can also be used without these fields at the boundaries, but at the expense of a certain spinup zone near the inflow boundaries.

5.2.3 Special considerations for the climate mode

If the COSMO-Model is run in climate mode, additional fields are necessary for the boundary updates, depending on the options chosen:

PLCOV	Plant cover
LAI	Leaf area index
ROOTDP	Root depth
VI03	Vertical integrated ozone content
HM03	Ozone maximum
T_S	Temperature of surface
	and only if <code>itype_aerosol = 2</code>
AER_S04	Tegen (1997) aerosol type sulfate drops
AER_DUST	Tegen (1997) aerosol type mineral dust
AER_ORG	Tegen (1997) aerosol type organic
AER_BC	Tegen (1997) aerosol type black carbon
AER_SS	Tegen (1997) aerosol type sea salt

Section 6

Input Files for the INT2LM

The INT2LM requires several input files.

- An ASCII-file, called **INPUT**, that contains the namelist variables. The form of this file is described in Section 6.1 The namelist groups, the variables, their meanings and possible values are described in Chapter 7.
- 2 files with external parameters for the COSMO-Model and for the coarse grid model. These files can be in Grib or NetCDF format.
- Files from the coarse grid model to compute the initial and/or boundary values. The name of these files are described in Section 6.6. These files can be in Grib or NetCDF format. If GME is used and the GME-files contain data that were selected by a bitmap, this bitmap must also be provided to INT2LM.

6.1 File for Namelist Input

The INT2LM uses **NAMELIST**-input to specify runtime parameters. The parameters are split-
ted into the groups

- **CONTRL** – parameters for the model run
- **GRID_IN** – specifying the domain and the size of the coarse grid
- **LMGRID** – specifying the domain and the size of the COSMO-Model grid
- **DATA** – controlling the grib input and output
- **PRICTR** – controlling grid point output

NEW: Since INT2LM 2.1 the namelist group **DATABASE** is not required any more.

The program provides default values for all parameters. To change a default value, an appropriate **NAMELIST** statement has to appear in the ASCII-file **INPUT**. The form of a **NAMELIST** statement depends on the specific platform you are using but is always similar to the following (refer to the Language Reference Manual of your system):

1. The ampersand (&) character, followed immediately by the name of the namelist group.
2. A sequence of zero or more

parameter=value,

 statements.
3. / to terminate the NAMELIST group.

Example:

In the following example new values are set for the parameters in the Namelist group `lmgrid`:

```
&LMGRID
  startlat_tot = -10.4, startlon_tot = -3.025,
  pollat=32.5,      pollon=-170.0,
  dlat=0.025,       dlon=0.025,
  ielm_tot=72,      jelm_tot=92,
/
```

For a complete reference of all NAMELIST parameters see Chapter 7. An example INPUT-file can be seen in Figure 7.1.

6.2 External Parameters

For both models, the coarse grid input model and the COSMO-Model, external parameters are required to perform the interpolations. The necessary and / or available external parameters for the COSMO-Model are listed in Section 5.1

If the file with the external parameters for the COSMO-Model does not exist, they could be interpolated from the coarse grid model. But this works only for the configuration GME → COSMO. Note, that this is not recommended for practical simulations!

Necessary parameters for the coarse grid model

HSURF (*)	Height of surface topography
FIS (*)	(alternatively) Geopotential of surface
FR_LAND	Fraction of land in the grid cell
SOILTYP (**)	Soil type of the land (keys 0-9)

(*) For ICON as coarse grid model, HSURF is not needed in the external parameter file, but it is read with the HHL-file (see Section 6.5).

(**) The soil type of some coarse grid models is not compatible to the soil types used in the COSMO-Model. These soil types are not used.

If external parameters for the COSMO-Model have to be interpolated from the coarse grid model, the following parameters are also necessary:

Z0	Roughness length
PLCOV	(Actual) plant cover during vegetation period
ROOTDP	(Actual) root depth

6.3 External Parameter Files for the COSMO-Model

External parameter files for the COSMO-Model are provided for different rotated coordinates, resolutions and domains. The software package which produces these files is called EXTPAR¹ and is official COSMO software. The files can be obtained from DWD, or from the web-based frontend tool WebPEP² (Preparation of External Parameters) of the CLM-Community.

The following table shows different files available from DWD's ftp-server with a short characterization. The filename contains information about the domain (e.g. d0, d1, d5), the resolution in meters (e.g. _07000_ for about 7000 meters) and the size of the fields in grid points (e.g. 961x769). External parameter files for other domains can be produced by DWD on request, if the domain (in rotated coordinates), the rotation (pollat, pollon) and the size of the domain (in grid points) is specified.

(Some of) these files already contain the external parameters for the Subgrid Scale Orography scheme, the minimum stomata resistance of plants, the thermal radiative surface emissivity, the normalized differential vegetation index and the monthly mean values for the Tegen (1997) aerosol climatology. The files with a (*) are older and only contain the Subgrid Scale Orography data.

cosmo_d0_02800_1605x1605.g1.2013111400	dlat = dlon = 0.025
cosmo_d1_07000_961x769.g1.2009121700	dlat = dlon = 0.0625 (*)
cosmo_d1_14000_481x385.g1.2009121700	dlat = dlon = 0.125 (*)
cosmo_d1_21000_321x257.g1.2009121700	dlat = dlon = 0.1875 (*)
cosmo_d1_28000_241x193.g1.2009121700	dlat = dlon = 0.25 (*)
cosmo_d1_56000_121x113.g1.2009121700	dlat = dlon = 0.5 (*)
cosmo_d5_07000_965x773.g1.2014060200	dlat = dlon = 0.0625
cosmo_d5_14000_483x387.g1.2013111400	dlat = dlon = 0.125
cosmo_africa_0.0625_1776x1617.g1	dlat = dlon = 0.0625
cosmo_asia_0.0625_1921x1601.g1	dlat = dlon = 0.0625
cosmo_southeastasia_0.0625_1761x1281.g1	dlat = dlon = 0.0625
cosmo_zimbabwe_0.025_1201x1201.g1	dlat = dlon = 0.025

The domains d1 are for a rotated grid with pollat=32.5 and pollon=-170.0. Domains d0 and d5 are for a rotated grid with pollat=40.0 and pollon=-170.0. pollat and

¹EXTPAR documentation:

http://www2.cosmo-model.org/content/model/modules/Extpar_201408_user_and_implementation_manual.pdf

²WebPEP: <http://www.clm-community.eu/index.php?menuid=221>

`pollon` give the coordinates of the rotated north pole in real geographical coordinates. The domains `africa`, `asia`, `southeastasia` and `zimbabwe` are unrotated (`pollat=90.0` and `pollon=-180.0`) and the coordinates are ordinary geographic.

The area covered by the different domains is given in the next table.

	Rotated coordinates				Geographical coordinates			
	startlat	endlat	startlon	endlon	startlat	endlat	startlon	endlon
d0	-20.05	20.05	-20.05	20.05	27.11 N	63.69 N	11.21 W	56.59 E
d1	-38.75	9.25	-26.75	33.25	14.54 N	51.49 N	11.26 W	70.36 E
d5	-24.125	24.125	-30.125	30.125	20.00 N	60.16 N	19.17 W	77.01 E
africa	-50.50	50.50	-30.50	80.4375	50.50 S	50.50 N	30.50 W	80.4375 E
asia	-20.00	80.00	30.00	150.00	20.00 S	80.00 N	30.00 E	150.00 E
southeastasia	-30.00	50.00	60.00	170.00	30.00 S	50.00 N	60.00 E	170.00 E
zimbabwe	-30.00	0.00	10.00	40.00	30.00 S	0.00 N	10.00 E	40.00 E

6.4 Available External Parameter Files for the GME

For DWD's global model GME, the following external parameter files are available on the ftp-server:

<code>invar_i128a</code>	resolution about 60 km
<code>invar_i192a</code>	resolution about 40 km
<code>invar_i192a.new</code>	resolution about 40 km; new raw data set
<code>invar_i384a</code>	resolution about 20 km

The file `invar_i192a.new` must be used for GME data after October, 24th, 2007, 12 UTC!

6.5 Available External Parameter and additional Files for ICON

To run ICON2LM, 3 different files are necessary besides the ICON forecast or analysis data:

- **External Parameters:**

As for all other coarse grid input models, an ICON external data file is needed, which contains the land-sea-mask (`FR_LAND`) and the ICON soil typ used (`SOILTYP`).

If your ICON dataset is a cut-out domain produced by ICON-SUB and just covers a certain COSMO-domain (this should be the case for most external operational users), the corresponding ICON external parameters do not contain the global fields, but only fields for the cut-out domain. This is in contrast to GME and is due to the special ICON data structure.

NOTE: Up to now the external data file can only be given as NetCDF File.

- **ICON Grid Files:**

The computation of the ICON grid is very expensive (on the order of hours!) and cannot be done by INT2LM. Therefore all grid specifications are read from an external grid file.

As for the external parameters, a special ICON grid file will be created for every ICON-SUB domain.

NOTE:

This is a special ICON feature. For all other coarse grid input models, INT2LM can compute the corresponding grids and takes necessary information from namelist input.

NOTE:

The ICON grid file is available only in NetCDF format!

- **ICON HHL:**

ICON as a non-hydrostatic model also uses the new general vertical coordinate (similar to COSMO). To specify the vertical ICON grid, a three-dimensional field called HHL (height of half levels) is necessary for the computations. The lowest level of this field just specifies the height of the orography, **HSURF**. HHL can either be available in the first ICON data file, or it must be given by a separate file called “HHL-file”.

NOTE:

The optional file containing ICON’s HHL field has to be in GRIB2 format.

6.6 Conventions for File Names

The initial and boundary fields needed for the model are provided either in Grib or in NetCDF format. Also for the output files, one can choose between Grib or NetCDF. Restart files are written in binary format with full precision. There is one file for the initial fields and also for every set of boundary fields. The following conventions apply for the filenames.

A file name for the COSMO-Model or the INT2LM has the general form

```

yheader // ydate // yextension                (for Grib files),
or
yheader // ydate // yextension // '.nc'        (for NetCDF files),

```

where **yheader**, **ydate** and **yextension** have the following meaning:

yheader: File header (usually 3 characters, only in case of ICON 4 characters)

- first character: specifies the model (**except for ICON, see below!**)

g: GME (global model)

l: COSMO-Model

e: ECMWF model IFS (Integrated Forecast System)

c: A general (global) climate model

- second character (**except for ICON**):
 - a**: analysis file (uninitialized)
 - i**: analysis file (initialized)
 - b**: boundary file
 - f**: forecast files
 - r**: restart files
- third character (**except for ICON**): specifies the region covered by the data
 - f**: full model domain
 - s**: subdomain

ydate: There are two forms of specifying the date, either with the full date or relative to the start date:

- In the name of analysis files (second character in the header **a** or **i**) the full date is specified (**not for ICON at the moment!**): `ydate = 'yyyymmddhh'` with `yyyy`: year; `mm`: month; `dd`: day; `hh`: hour.

Example:

`laf1992072100` COSMO-Model, uninitialized analysis for full model domain
from July, 21st, 1992.

- In forecast, boundary or restart files, **ydate** consists of a single character (the time unit of forecast range, **ytunit**), followed by a string.

`ydate = ytunit // 'string'`

Depending on **ytunit**, the string has the following meaning:

- t**: timestep mode: forecast range given in timesteps
- f**: forecast mode: the forecast range is given in the form `ddhhmmss`, where `dd`: day, `hh`: hour, `mm`: minute, `ss`: second (**only possibility for ICON at the moment!**)
- c**: climate mode: the forecast range is given in the form `yyyddhh`, where `yyy`: year, `ddd`: day of the year, `hh`: hour
- d**: day mode: the full date is given in the form `'yyyymmddhh'`, where `yyyy`: year; `mm`: month; `dd`: day; `hh`: hour

NOTE: Since Version 1.20, the date for the *day mode* and for the analysis file can also be given with additional 4 digits (2 for minutes, 2 for seconds). The user can activate this by specifying the initial date in this form.

yextension (1 character, optional): Extension, e.g. data interpolated from model to pressure levels.

Examples:

1bfff00050000	COSMO-Model, file with boundary values for hour 5
1fff01233000	COSMO-Model, forecast at day 1, 23 hours and 30 minutes.
1rfff01000000	COSMO-Model, restart file for day 1.

ICON: The `yheader` is given by the namelist parameter `yicon_input_prefix` (free, up to 32 characters, default `'igfff'`). ICON data do not have strict prefixes for analysis- and forecast-data and do not follow the COSMO logic in this respect. For INT2LM, we expect the ICON data to consist of the prefix followed by a forecast time stamp, e.g.,

```
igfff000000000
igfff000300000
igfff000600000
igfff000900000
...
```

If this should be not the case with your data, rename your files accordingly or create links using the above name convention.

Section 7

Namelist Input for INT2LM

The execution of INT2LM can be controlled by 6 NAMELIST-groups:

- CTRL – parameters for the model run
- GRID_IN – specifying the domain and the size of the coarse grid
- LMGRID – specifying the domain and the size of the LM grid
- DATABASE – specification of database job
- DATA – controlling the input and output
- PRICTR – controlling grid point output

NEW: Since INT2LM 2.1 the namelist group DATABASE is not required any more.

All NAMELIST-groups have to appear in the input file INPUT in the order given above. Every group is read in a special subroutine called `input_groupname`. These subroutines set default values for all parameters and check most parameters that have been changed for correctness and consistency.

The NAMELIST variables can be specified by the user in the run-scripts for the INT2LM, which then create the INPUT file. An example of INPUT is shown in Figure 7.1.

```

&CONTRL
  ydate_ini='2012051400', ydate_bd='2012051312',
  hstart=0.0, hstop=6.0, hincbound=1.0,
  linitial=.TRUE., lboundaries=.TRUE.,
  nprocx=4, nprocy=8, nprocio=0, lreorder=.FALSE.,
  yinput_model='ICON',
  lfilter_oro=.TRUE., eps_filter=0.1,
  ilow_pass_oro=1, ilow_pass_xso=0, rxso_mask=0.0,
  lfilter_pp=.FALSE., itype_balance_pp=2, lmultilay_deepsoil_clim_hcorr=.TRUE.,
  itype_fast_waves_lm=2, itype_profiles_vert_interp=2, norder_filter=5,
  lmulti_layer_in=.TRUE., lmulti_layer_lm=.TRUE., lprog_rho_snow=.TRUE.,
  lprog_qi=.TRUE., lprog_qr_qs=.TRUE., luvcor=.TRUE.,
  lsso=.TRUE., lforest=.TRUE., llake=.FALSE., lbdclim=.FALSE., lt_cl_corr=.TRUE.,
  lseaice=.TRUE., itype_ndvi=0, idbg_level=2,
  itype_albedo=3, itype_aerosol=2,
  lcheck_uuidOfHGrid=.FALSE., nproma_icon=8,
/
&GRID_IN
  ke_soil_in=7,
  ke_in_tot=90,
  yicon_grid_cat = '/path/to/icon/grid/file/',
  yicon_grid_lfn = 'icon_grid_0026_R03B07_G.nc',
  nrootdiv_icon = 3, nbisect_icon = 7, vcflat_icon = 16000.0,
  nlevskip=0
/
&LMGRID
  startlat_tot = -20.0, startlon_tot = -18.0,
  pollat=40.0,          pollon=-170.0,
  dlon=0.0625,          dlat=0.0625,
  ielm_tot=665,          jelm_tot=657,          kelm_tot=40,
  ke_soil_lm=7, ivctype=2, irefatm=2, delta_t=75.0, h_scal=10000.0,
  lanalyt_calc_t0p0=.TRUE., lnewVGrid=.true.,
/
&DATABASE
/
&DATA
  ie_ext=965, je_ext=773,
  ylmext_lfn='lm_d5_07000_965x773.sso.mol.g1',
  ylmext_cat='/e/rhome/routfor/routfox/lm/const/',
  ylmext_form_read='apix',
  yinext_lfn='icon_extpar_0026_R03B07_G_20140731.nc',
  yinext_form_read='ncdf',
  yinext_cat='/e/rhome/routfor/routfox/icon/const/',
  yin_form_read='apix',
  yin_cat='/e/uscratch/uschaett/ICON/data/',
  yinput_type='forecast',
  ylm_cat='/e/uscratch/uschaett/COSMO_EU_input/'
  ylm_form_write='grb1',
  nprocess_ini = 131, nprocess_bd = 132,
  nl_soil_in=2, nl_soil_lm=2,
  l_ke_in_gds=.TRUE.,
/
&PRICTR
  lchkin=.TRUE., lchkout=.TRUE.,
/

```

Figure 7.1: Example file INPUT for interpolation of ICON data

7.1 CONTRL — Parameters for the Model Run

Initial time and forecast range

Name	Type	Definition / Purpose / Comments	Default
ydate_ini	CHAR	start of the forecast	, ,
ydate_bd	CHAR	start of the forecast of the boundary model (if older forecast data shall be used)	, ,
itype_calendar	LOG	to specify a certain type of calender 0: Gregorian calendar (at the moment we still have the Julian calendar) 1: every year has 360 days 2: every year has 365 days	0
hstart	REAL	start of the forecast in hours	0.0
hstop	REAL	end of the forecast in hours	0.0
hincbound	REAL	time increment (in hours)	0.0
nincwait	INT	seconds to wait until next attempt if a ready file is not available	0
nmaxwait	INT	maximum seconds to wait until abort if a ready file is not available	0
ytrans_in	CHAR	directory for reading ready-files	, ,
ytrans_out	CHAR	directory for writing ready-files	, ,

Domain decomposition and parallelization

Name	Type	Definition / Purpose / Comments	Default
nprocx	INT	number of PEs in x -direction of the LM-grid	1
nprocy	INT	number of PEs in y -direction of the LM-grid	1
nprocio	INT	number of extra PEs for asynchronous I/O	0
nboundlines	INT	number of boundary lines of a subdomain	1
lreorder	LOG	if .TRUE., the PEs can be reordered for the cartesian MPI-communicator	.TRUE.
lasync_io	LOG	to run the model with extra (asynchronous) processors for I/O	.FALSE.
ldatatypes	LOG	if .TRUE., MPI-Datatypes for some communications shall be used	.FALSE.
ncomm_type	INT	type of communication	1

Basic Control

Name	Type	Definition / Purpose / Comments	Default
lgme2lm	LOG	eliminated from Version 1.14 on, now yinput_model='GME'	.TRUE.
lec2lm	LOG	eliminated from Version 1.14 on, now yinput_model='IFS'	.FALSE.
llm2lm	LOG	eliminated from Version 1.14 on, now yinput_model='GME'	.FALSE.
lcm2lm	LOG	eliminated from Version 1.14 on, now yinput_model='CM'	.FALSE.
yinput_model	CHAR*5	string to identify the input model; valid options: 'COSMO' : limited area model COSMO 'GME' : global model (GME) of the DWD New since Version 2.1 'ICON' : new global model (ICON) of DWD 'IFS' : Integrated Forecast System (IFS) of ECMWF 'CM' : climate model standard format	' '
lanafg	LOG	eliminated from Version 1.9 on. Use analyses as input data (first guess)	.FALSE.
linitial	LOG	compute initial data for the COSMO-Model	.FALSE.
lboundaries	LOG	compute lateral boundaries for the COSMO-Model	.TRUE.
lbdclim	LOG	produce additional boundary fields that are needed for long term simulations.	.FALSE.
leps_ana	LOG	produce initial data for ensemble mode Introduced in INT2LM 2.03.	.FALSE.
leps_bc	LOG	produce boundary data for ensemble mode	.FALSE.
lseaice	LOG	interpolate sea ice variables from GME to COSMO-Model	.FALSE.
luvcor	LOG	correct winds for given surface pressure tendency	.TRUE.
l_chemistry	LOG	switch to process additional chemistry fields Eliminated in Version 1.22 - Replaced by l_art	
l_art	LOG	switch to process additional fields for COSMO-ART	.FALSE.
l_art_nested	LOG	switch to process additional fields for COSMO-ART in case of nesting runs	.FALSE.

Name	Type	Definition / Purpose / Comments	Default
<code>l_smi</code>	LOG	switch for using an optional interpolation for the soil humidity	<code>.FALSE.</code>
<code>lmixcld</code>	LOG	switch for using an optional treatment of the humidity	<code>.FALSE.</code>
<code>l_cressman</code>	LOG	switch for using a cressman scheme during 'M'atch interpolation	<code>.FALSE.</code>
<code>l_bicub_spl</code>	LOG	switch for using a bicubic spline interpolation	<code>.FALSE.</code>
<code>idbg_level</code>	INT	Selects the verbosity of ASCII output during a model run. The higher the value, the more debug output is written to standard output.	2
<code>lprintdeb_all</code>	LOG	In most cases, the debug output is only written from one processor (with ID=0). With <code>lprintdeb_all=.TRUE.</code> , all processors will print the debug output.	<code>.FALSE.</code>
<code>ltime_proc</code>	LOG	detailed timings of the program (per PE)	<code>.FALSE.</code>
<code>ltime_mean</code>	LOG	detailed timings of the program (mean value)	<code>.FALSE.</code>
<code>lroutine</code>	LOG	run the program as routine-job	<code>.FALSE.</code>
<code>lextrpar_lm_only</code>	LOG	Process only the external parameters from COSMO at initial time. At all other times, atmospheric fields for boundary data can be processed as usual if <code>lboundaries=.TRUE.</code>	<code>.FALSE.</code>

Special Control Variables for ICON2LM

Name	Type	Definition / Purpose / Comments	Default
<code>l_use_vn</code>	LOG	use the normal velocity (VN: velocity normal to edges) instead of wind components U and V.	<code>.FALSE.</code>
<code>nproma_icon</code>	INT	chunk length for ICON fields internally used. With this variable, the size of the innermost loops for ICON variables can be adjusted. On cache based processors, a small value (8-16) is beneficial, while on vector processors, a value representing the machine internal vector length (e.g. 256 for NEC-SX9) would be used.	8

Name	Type	Definition / Purpose / Comments	Default
lcheck.uuid OfHGrid	LOG	to check the <i>unique universal Identifier</i> for ICON's horizontal grid. If true, the UUID of the records contained in the ICON grid file is checked against the UUIDs of the records read from the ICON forecast data. If they do not match, INT2LM aborts, because it must be assumed that different grids are used.	.TRUE.
lprog.prrcon_ prscon	LOG	If .TRUE., interpolation of the 3D convective rain rate (ICON shortName = "PRR_CON") and snow rate ("PRS_CON") from ICON input to COSMO for initial and boundary files. In COSMO, these rates are used to retain the moisture contained in convective precipitation either in the humidity field or in the grid scale rain- and snow hydrometeors to compensate their instantaneous removal from the atmosphere in ICON. THIS FEATURE IS STILL EXPERIMENTAL AND NOT YET AVAILABLE IN OFFICIAL COSMO!	.FALSE.

Controlling use of additional external parameters

Name	Type	Definition / Purpose / Comments	Default
lforest	LOG	read external parameters for the ground fraction of evergreen and deciduous forest	.FALSE.
lemiss	LOG	read a map from the external parameters for the thermal radiative surface emissivity	.FALSE.
lssso	LOG	read external parameters for the subgrid scale orography scheme	.FALSE.
lradtopo	LOG	read external parameters for the topographic corrections of radiation	.FALSE.
nhori	INT	number of sectors for the horizon array used by the topographic correction of the radiation	24
lstomata	LOG	read a map from the external parameters for the minimum stomata resistance of plants	.FALSE.
llake	LOG	read and process external parameters for lakes	.FALSE.
llake_coldstart	LOG	initialize prognostic lake variables for cold start	.FALSE.

Name	Type	Definition / Purpose / Comments	Default
<code>lurban</code>	LOG	read and process the external parameter ‘‘URBAN’’ for an urban module. NOTE: Not connected to the new COSMO urban module TERRA_URB! It is for another urban module which is NOT official COSMO code. This module has to be implemented on your own!	<code>.FALSE.</code>
<code>lterra_urb</code>	LOG	for the new urban module TERRA_URB in COSMO, read and process the external parameters ‘‘AHF’’ (anthropogenic heat flux) and ‘‘ISA’’ respectively ‘‘FR_PAVED’’ (Impervious surface area respectively paved fraction — both names denote the same field, and their name depends on the EXTPAR version) Currently only works for COSMO external parameters in grib1 or netcdf format, and if grib1, the reading has to be done by the old “lib-grib1” and not by grib_api (ylmext_form_read = ‘grb1’, not ‘apix’!). Introduced in INT2LM 2.03.	<code>.FALSE.</code>

Control over variables that have to be written for the COSMO-Model

Name	Type	Definition / Purpose / Comments	Default
<code>lvertwind_ini</code>	LOG	compute vertical wind for initial data	<code>.TRUE.</code>
<code>lvertwind_bd</code>	LOG	compute vertical wind for boundary data	<code>.FALSE.</code>
<code>lprog_qi</code>	LOG	compute initial and boundary values for the cloud ice scheme	<code>.FALSE.</code>
<code>lprog_qrqs</code>	LOG	Renamed to <code>lprog_qr_qs</code> in Version 1.22	
<code>lprog_qr_qs</code>	LOG	compute initial and boundary values for rain and snow	<code>.FALSE.</code>
<code>lprog_qg</code>	LOG	compute initial and boundary values for the graupel scheme	<code>.FALSE.</code>
<code>lprog_qni</code>	LOG	compute initial and boundary values for the number densities QNICE	<code>.FALSE.</code>
<code>lprog_qn_crsg</code>	LOG	compute initial and boundary values for the number densities QNCLOUD, QNRain, QNSNOW and QNGRAUPEL	<code>.FALSE.</code>
<code>qvmin</code>	REAL	security minimum value for water vapor	<code>1E-12</code>

Name	Type	Definition / Purpose / Comments	Default
qcmin	REAL	security minimum value for cloud water	1E-12
qimin	REAL	security minimum value for cloud ice content	1E-12
lmulti_layer_lm	LOG	compute fields for multi-layer soil model	.FALSE.
lmulti_layer_in	LOG	use multi-layer soil model variables from input fields	.FALSE.
lprog_rho_snow	LOG	read and interpolate the snow density to the COSMO-Model grid	.FALSE.
itype_w_so_rel	INT	to select the type of relative soil moisture input 0: use an artificial profile relative to the pore volume 1: relative to pore volume (read from coarse grid data) 2: relative to field capacity (read from coarse grid data) 3: the soil moisture profile in relation to the pore volume is kept constant below the deepest layer of the input soil model 4: the soil moisture profile related to field capacity is kept constant below the deepest layer of the input soil model	1
itype_t_cl	INT	to select the source for the deep soil (climatological) temperature 0: take t_cl from coarse grid model. 1: take t_cl from the external parameters for the COSMO-Model	0

Name	Type	Definition / Purpose / Comments	Default
<code>itype_rootdp</code>	INT	<p>to select the treatment of the external parameter for root depth</p> <ul style="list-style-type: none"> 0: input from external parameter for the COSMO-Model is taken and modified with an annual cycle. 1: input from external parameter for the COSMO-Model is taken as is but with a maximal value of 0.12. 2: input from external parameter for the COSMO-Model is taken and modified with an annual cycle. In addition, the values are adapted to ECOCLIMAP niveau. 3: input from external parameter for the COSMO-Model is taken and modified with an annual cycle but without maximum cut off. 4: input from external parameter for the COSMO-Model is taken without modifications. 	0

Name	Type	Definition / Purpose / Comments	Default
itype_aerosol	INT	<p>to select the treatment of aerosols:</p> <ol style="list-style-type: none"> 1: No additional fields for aerosol types are read from the external parameters. The COSMO-Model has to run with constant values for the aerosol distribution on rural areas, urban areas, desert areas or the sea. 2: Additional external parameters for the aerosol types of sulfate, mineral dust, organic, black carbon and sea salt are read as monthly mean values (Tegen et al. (1997)). Actual values for the current day are computed and given to the COSMO-Model. 3: Additional external parameter fields 'AOT12', 'SSA12', 'ASY12' from the Kinne et al. (2013) aerosol climatology (but in version v2, not v1) are read as monthly mean values. Actual values for the current day are computed and given to the COSMO-Model as 'TAU_KINNE', 'SSA_KINNE', and 'G_KINNE'. Experimental from COSMO Priority Project T²(RC)². Not usable in the official COSMO version right now! 4: Processing of CAMS aerosols from IFS (actual global aerosol forecasts). Experimental from COSMO Priority Project T²(RC)². Not usable in the official COSMO version right now! 	1

Name	Type	Definition / Purpose / Comments	Default
<code>itype_ndvi</code>	INT	<p>to select the treatment of plant cover and leaf area index:</p> <ul style="list-style-type: none"> 0: plant cover and leaf area index for the COSMO-Model and for a special day are produced by using the data sets for vegetation and for rest and modify these with an annual cycle. 1: plant cover and leaf area index for the COSMO-Model and for a special day are produced by using only the data set for vegetation and an averaged ndvi ratio. This ndvi ratio is computed as a weighted mean between monthly mean values, which are taken from the external parameter data set for the COSMO-Model (provided by DWD in Grib1). 2: plant cover, leaf area index and z0 for the COSMO-Model and for a special day are produced by using 12 monthly climatological mean values for plant cover, leaf area index and roughness length. These values are read from the external parameter data set for the COSMO-Model (provided by CLM in NetCDF). 	0
<code>itype_albedo</code>	INT	<p>Switch to choose the type of solar surface albedo. This parameter has been introduced in Version 1.19.</p> <ul style="list-style-type: none"> 1: surface albedo is a function of soiltype (method up to now and still default) 2: surface albedo is determined by two external fields for dry and for saturated soil. 3: A background albedo is prescribed by external fields, which give average values for every month. 4: The vegetation albedo is modified by forest fraction. 	1
<code>lt_cl_corr</code>	LOG	if <code>.TRUE.</code> , perform an alternative height correction for <code>t_cl</code>	<code>.FALSE.</code>
<code>luse_t_skin</code>	LOG	if <code>.TRUE.</code> , use ECMWF skin temperature for surface	<code>.FALSE.</code>

Name	Type	Definition / Purpose / Comments	Default
lante_0006	LOG	if .TRUE., force to use ECMWF dataset before 27 June 2000	.FALSE.
lpost_0006	LOG	if .TRUE., force to use ECMWF dataset after 27 June 2000	.FALSE.

Treatment of orography and filtering

Basically the filtering of the orography should not be done with INT2LM because some other parameters (roughness length, topographical corrections in the radiation scheme, subgrid scale orography scheme) depend on the orography you choose. Therefore all the possible filtering mechanism described below have also been implemented in the program for the generation of the external parameters, called EXTPAR (during 2014).

Name	Type	Definition / Purpose / Comments	Default
lfilter_oro	LOG	if .TRUE., filter the orography	.FALSE.
lfilter_pp	LOG	if .TRUE., filter the pressure deviation after vertical interpolation	.FALSE.
lbalance_pp	LOG	if .TRUE., compute a hydrostatic balanced pp after vertical interpolation in LM2LM. Removed in INT2LM 2.03, now hardcoded always .TRUE.!	.FALSE.
itype_balance_pp	INT	Type of method for hydrostatic pressure balancing for nonhydrostatic input models: 1: Old method: very old code, perhaps consistent with the Leapfrog core? 2: New method: consistent to RK dynamical core, code overtaken from COSMO model (src.artifdata.f90). The exact mathematical formulation for option ‘2’ depends on new namelist parameter itype_fast_waves_lm. Introduced in INT2LM 2.03.	2
itype_fast_waves_lm	INT	Relevant in case of itype_balance_pp=2: Type of fast-waves solver in the COSMO model, should be consistent with the COSMO run. Introduced in INT2LM 2.03.	2
itype_profiles_vert_interp	INT	To choose the method for vertical adaptation of input profiles from the input orography to the COSMO orography, in case of non-hydrostatic input models (COSMO, ICON, UM, CM). "1" is the previous method, "2" is the new method. Introduced in INT2LM 2.03.	2

Name	Type	Definition / Purpose / Comments	Default
<code>lmultlay_</code> <code>deepsoil_clim_</code> <code>hcorr</code>	LOG	Effective in case of multi-layer soil model for input and output: to specify if blending to a climatological height correction of soil temperatures for deeper soil layers is desired. The normal method is to preserve the temperature differences to the lowest atmospheric temperature across the interpolation, and this method is then only applied in the upper soil levels with a decreasing weight with increasing depth. This should reduce the danger that, e.g., local extremes in near-surface air temperatures, which may have been artificially created by the PBL-profile adaption from coarse to fine orography, create also artificial extremes in deep-soil temperatures where they have a long memory. The climatological height correction is based on a constant temperature gradient of 0.007 K/m with respect to orography difference coarse minus fine levels. In this respect it is similar to the already existing option <code>lt_cl_corr</code> for the climatological deep-soil temperature <code>t_cl</code> in the old 2-layer soil model. Introduced in INT2LM 2.03.	<code>.TRUE.</code>
<code>eps_filter</code>	REAL	parameter for the Raymond (1988) filtering of the orography	10.0
<code>norder_filter</code>	INT	p value of the Raymond orography filtering	1
<code>ilow_pass_oro</code>	INT	type of low-pass filter for orography 1: use the Raymond filter with <code>eps_filter</code> and <code>norder_filter</code> 3: 9-point filter (approx. cutoff=3) 4: 9-point filter (approx. cutoff=4) 5: 13-point filter (approx. cutoff=5) 6: 9-point filter (approx. cutoff=6) 8: 13-point filter (approx. cutoff=8)	1
<code>numfilt_oro</code>	INT	number of sequential applications of filter	1
<code>ilow_pass_xso</code>	INT	type of low-pass filter for extra smoothing of steep orography	0
<code>numfilt_xso</code>	INT	number of sequential applications of xso filter	1
<code>lxso_first</code>	LOG	do an extra smoothing of orography first	<code>.FALSE.</code>
<code>rxso_mask</code>	REAL	mask for extra smoothing of steep orography	0.0

Name	Type	Definition / Purpose / Comments	Default
<code>rfill_valley</code>	REAL	mask for valley filling	0.0
<code>ifill_valley</code>	REAL	type of valley filling	1
<code>l_topo_z</code>	LOG	additional smoothing of the topography for LM.Z	.FALSE.
<code>llbc_smooth</code>	LOG	run with a smooth orography transition at the lateral boundaries	.FALSE.
<code>nlbc_smooth</code>	INT	number of grid points for a smooth orography transition at the lateral boundaries	.FALSE.
<code>hmax_sea</code>	REAL	maximal height in coastal areas, below which no filtering is done for sea points. This variable influences the filtering of the orography in coastal areas for grid points, which have a fraction of land less than 0.5 (sea points), but are given an orography height higher than 0.0. If such a grid point is surrounded by enough other sea points, and if the orography height is not heigher than <code>hmax_sea</code> , the filtered value is set back to the original height of the orography. ($0 \leq \text{hmax_sea} \leq 20.0$)	10.0

References:

Raymond, W.H., 1988: High-Order Low-Pass Implicit Tangent Filters for Use in Finite Area Calculations, MWR 116, 2132-2141.

7.2 GRID_IN — Specifying the Domain and the Size of the coarse Grid

`grid_in` contains variables that specify the size and resolution of the coarse grid.

Name	Type	Definition / Purpose / Comments	Default
<code>ni_gme</code>	INT	resolution of GME	128
<code>i3e_gme</code>	INT	number of levels in the vertical	51
<code>yicon_grid_cat</code>	CHAR	Directory of the NetCDF file describing the horizontal ICON grid	' '
<code>yicon_grid_lfn</code>	CHAR	Name of the NetCDF file describing the horizontal ICON grid	' '
<code>kcontrol.fi</code>	INT	control level for geopotential	15
<code>ie_in_tot</code>	INT	<code>ie</code> for input grid (total domain)	141
<code>je_in_tot</code>	INT	<code>je</code> for input grid (total domain)	71
<code>ke_in_tot</code>	INT	<code>ke</code> for input grid (total domain)	60
<code>nrootdiv_icon</code>	INT	Number of root divisions for the ICON grid (the “xx” in RxxByy). Mandatory for ICON input. Introduced in INT2LM 2.02.	-99
<code>nbisect_icon</code>	INT	Grid level for the ICON grid (the “yy” in RxxByy). Mandatory for ICON input. Introduced in INT2LM 2.02.	-99
<code>vcflat_icon</code>	REAL	Height in m above which the model levels are flat in ICON input grid. Relevant for the determination of the height level index at which $p \approx p_s - 150$ hPa for extrapolation of the PBL profiles towards the COSMO orography. Relevant for <code>itype_profiles_vert_interp=1</code> . Introduced in INT2LM 2.03.	16000.0
<code>nlevskip</code>	INT	number of missing levels in input grid, counted from model top	0
<code>ke_soil_in</code>	INT	number of levels in input multi-layer soil model	6
<code>czml_soil_in</code>	REAL	depth of main input soil layers (layer centers). The default specification is (in cm) / 0.005, 0.02, 0.06, 0.18, 0.54, 1.62, 4.86, 14.58 /	see left
<code>pcontrol.fi</code>	REAL	pressure of control level for geopotential	-1.0
<code>pollat_in</code>	REAL	geographical latitude of rotated north pole (in degrees, north > 0)	90.0

Name	Type	Definition / Purpose / Comments	Default
<code>pollon_in</code>	REAL	geographical longitude of rotated north pole (in degrees, east > 0)	180.0
<code>dlon_in</code>	REAL	Mesh size in east-west direction	0.5
<code>dlat_in</code>	REAL	Mesh size in north-south direction	0.5
<code>startlat_in_tot</code>	REAL	latitude of the lower left grid point of the input domain (in degrees, north > 0, rotated coordinates)	-35.0
<code>startlon_in_tot</code>	REAL	longitude of the lower left grid point of the input domain (in degrees, east > 0, rotated coordinates)	-30.0
<code>endlat_in_tot</code>	REAL	latitude of the upper right grid point of the input domain (in degrees, north > 0, rotated coordinates)	0.0
<code>endlon_in_tot</code>	REAL	longitude of the upper right grid point of the input domain (in degrees, east > 0, rotated coordinates)	-40.0
<code>p0sl_in</code>	REAL	constant reference pressure on sea-level	10000.0
<code>t0sl_in</code>	REAL	constant reference temperature on sea-level	288.15
<code>dt0lp_in</code>	REAL	$d(t_0) / d(\ln p_0)$	42.0
<code>lushift_in</code>	LOG	Only for <code>yinput_model='CM'</code> : use staggered grid for input u-velocity	.FALSE.
<code>lvshift_in</code>	LOG	Only for <code>yinput_model='CM'</code> : use staggered grid for input v-velocity	.FALSE.
<code>east_add_in</code>	INT	Only for <code>yinput_model='CM'</code> and NetCDF input: add an extra column to the east of the input domain taken from the west (periodic BCs), needed for COSMO domains across the date line. The data set of the coarse model has to be global or a global belt, not a regional subset.	0
<code>west_add_in</code>	INT	Only for <code>yinput_model='CM'</code> and NetCDF input: add an extra column to the west of the input domain taken from the east (periodic BCs), needed for COSMO domains across the date line. The data set of the coarse model has to be global or a global belt, not a regional subset.	0

Name	Type	Definition / Purpose / Comments	Default
<code>south_add_in</code>	INT	Only for <code>yinput.model='CM'</code> and NetCDF input: add an extra column to the south of the input domain taken from the south (0-gradient), needed for COSMO domains across North or South Pole. The data set of the coarse model has to be global or circumpolar (covering the COSMO domain).	0
<code>north_add_in</code>	INT	Only for <code>yinput.model='CM'</code> and NetCDF input: add an extra column to the north of the input domain taken from the north (0-gradient), needed for COSMO domains across North or South Pole. The data set of the coarse model has to be global or circumpolar (covering the COSMO domain).	0

7.3 LMGRID — Specifying the Domain and the Model Grid

`lmgrid` contains variables that specify the model domain in the rotated grid and the size of the total domain.

Name	Type	Definition / Purpose / Comments	Default
<code>pollat</code>	REAL	geographical latitude of rotated north pole (in degrees, north > 0)	32.5
<code>pollon</code>	REAL	geographical longitude of rotated north pole (in degrees, east > 0)	-170.0
<code>polgam</code>	REAL	Angle between the north poles of two rotated grids (in degrees, east > 0); necessary for transformation from one rotated grid to another rotated grid	0.0
<code>dlon</code>	REAL	Mesh size in east-west direction	0.0625
<code>dlat</code>	REAL	Mesh size in north-south direction	0.0625
<code>startlat_tot</code>	REAL	latitude of the lower left grid point of the total domain (in degrees, north > 0, rotated coordinates)	-14.375
<code>startlon_tot</code>	REAL	longitude of the lower left grid point of the total domain (in degrees, east > 0, rotated coordinates)	-6.875
<code>ielm_tot</code>	INT	number of gridpoints of the total domain in east-west direction	213
<code>jelm_tot</code>	INT	number of gridpoints of the total domain in north-south direction	213
<code>kelm_tot</code>	INT	number of gridpoints of the total domain in vertical direction	20
<code>ke_soil_lm</code>	INT	number of levels in multi-layer soil model for the COSMO-Model	6
<code>czml_soil_lm</code>	REAL	depth of main soil layers for the COSMO-Model. The default specification is / 0.005, 0.02, 0.06, 0.18, 0.54, 1.62, 4.86, 14.58 /	see left
<code>czvw_so_lm</code>	REAL	artificial volumetric soil water content profile for the COSMO-Model.	/0.75/

Name	Type	Definition / Purpose / Comments	Default
<code>irefatm</code>	INT	<p>type of reference atmosphere</p> <ol style="list-style-type: none"> 1: Default as used up to now 2: The reference atmosphere is based on a temperature profile $t_0(z) = (t_{0sl} - \Delta t) + \Delta t \cdot \exp\left(\frac{-z}{h_{scal}}\right),$ <p>where $z = \text{hhl}(\mathbf{k})$ is the height of a model grid point. If this option is used, the values for $\Delta t = \text{delta_t}$ and $h_{scal} = \text{h_scal}$ have also to be set.</p>	1
<code>lanalyt_calc_</code> <code>t0p0</code>	LOG	if set to <code>.TRUE.</code> , the values for the reference state of t_0 and p_0 are computed analytically. If it is set to <code>.FALSE.</code> , they are only averaged between the half levels.	<code>.FALSE.</code>
<code>ivctype</code>	INT	<p>kind of vertical coordinate system</p> <ol style="list-style-type: none"> 1: reference pressure based hybrid coordinate. 2: height based hybrid Gal-Chen coordinate. 3: height based hybrid SLEVE coordinate. In comparison to option 2, there is an additional blending to a smoothed orography before blending to horizontal coordinates at the height given by the parameter <code>vcflat</code> below. (not extensively tested). The exact blending behaviour can be influenced by the parameters <code>svc1</code> and <code>svc2</code> below. 4: NEW in Version 2.1 generalized SLEVE coordinate with a modified vertical decay of the topographic signature with height. (See Leuenberger, D., M. Koller and C. Schär, 2010: An improved formulation of the SLEVE coordinate. Mon. Wea. Rev., 138 (9), 3683-3689, DOI: 10.1175/2010MWR3307.1). 	2
<code>lnewVGrid</code>	INT	to indicate, that a new vertical grid file HHL has to be created	<code>.FALSE.</code>
<code>vcflat</code>	REAL	coordinate value where system changes back to z-system	0.220

Name	Type	Definition / Purpose / Comments	Default
<code>vcoord_d</code>	REAL	vertical coordinate parameter list of pressure (<code>ivctype=1</code>) or height (<code>ivctype=2/3/4</code>) values. The usage of the fortran utility <code>vcoord.f90</code> for preparation of the parameter values is recommended. For <code>ivctype=1</code> , values have to cover the range 0 to 1 in increasing order (σ coordinates). For <code>ivctype=2</code> , values are heights in m and have to be in decreasing order from the desired model top height down to 0.0 m. Some default sets of height values already exist in the source code for <code>ivctype=2</code> and <code>kelm_tot=40,50</code> . <code>ivctype=3/4</code> and <code>kelm_tot=50</code> . If one of these sets should be used, only specify the respective <code>kelm_tot</code> and <code>ivctype</code> and leave <code>vcoord_d</code> out.	(missing)
<code>p0sl</code>	REAL	constant reference pressure on sea-level	10000.0
<code>t0sl</code>	REAL	constant reference temperature on sea-level	288.15
<code>dt0lp</code>	REAL	$d(t_0) / d(\ln p_0)$	42.0
<code>delta_t</code>	REAL	temperature difference between sea level and stratosphere (for <code>irefatm=2</code>)	75.0
<code>h_scal</code>	REAL	scale height (for <code>irefatm=2</code>)	10000.0
<code>svc1</code>	REAL	decay rate for large-scale part of topography	10000.0
<code>svc2</code>	REAL	decay rate for small-scale part of topography	10000.0
<code>nfltv</code>	REAL	number of filter applications for topo decomposition	100

7.4 DATABASE — Specification of Database Job

NOTE: Since INT2LM 2.1 this namelist group is obsolete.

Name	Type	Meaning	Default
yinit_order	CHAR	string for initializing csodaban	'ak=nix'
yana_tab	CHAR	database for initial data	'*****'
ybd_tab	CHAR	database for boundary data	'*****'
nout_sockets	INT	number of sockets for database output per PE (0 means File-IO)	0
nin_sockets	INT	number of sockets for database input per PE (0 means File-IO; has to be ≤ 1)	0
iretry	INT	number of seconds to retry on database failure	0
ibackup_size	INT	size of incore backup space (in bytes) by a database failure	-1
ybackup_dir	CHAR	directory for outcore backup	'.'
idbg_level	INT	debug level for mpe.io	0

7.5 DATA – Controlling the Input and Output

General control variables

Name	Type	Definition / Purpose / Comments	Default
<code>ncenter</code>	INT	originating center identification	78
<code>nprocess_ini</code>	INT	generating process identification for initial values	131
<code>nprocess_bd</code>	INT	generating process identification for boundary values	132
<code>nrbit</code>	INT	pack-rate for the grib code (in bit)	16
<code>nbitmap</code>	INT	user dimension for bitmaps	6000*2
<code>nl_soil_lm</code>	INT	number of prognostic soil water levels for the COSMO data	2
<code>nl_soil_in</code>	INT	number of prognostic soil water levels for the input data	2
<code>nvers</code>	INT	for documenting purposes (mainly in GRIB-Code)	1
<code>ymode_read</code>	CHAR	specify open mode for reading	'r'
<code>ymode_write</code>	CHAR	specify open mode for writing	'w'
<code>yvarini</code>	CHAR	list of variables for LM initial data	
<code>yvarbd</code>	CHAR	list of variables for LM boundary data	
<code>l_ke_in_gds</code>	LOG	write the number of vertical levels explicitly to the grid description section	.TRUE.
<code>ytunit_in</code>	CHAR	time unit for input data	'f'
<code>ytunit_out</code>	CHAR	time unit for output data	'f'
<code>yinput_type</code>	CHAR	type of input data 'forecast' forecast data 'analysis' analysis data 'ana_init' initialized analysis data	'forecast'

Variables for external data and HHL-files (needed for GRIB2)

Name	Type	Meaning	Default
<code>ylmext_cat</code>	CHAR	directory of the external fields for LM/HM	' '
<code>ylmext_lfn</code>	CHAR	name of the file with the external fields for LM/HM	' '
<code>ylm_hhl</code>	CHAR	name of the vertical grid HHL-file that has to be processed in case of COSMO GRIB2 output files. This file has to be in the directory <code>ylmext_cat</code>	' '
<code>yinext_cat</code>	CHAR	directory of the external fields for GME	' '
<code>yinext_lfn</code>	CHAR	name of the file with the external fields for GME	' '
<code>yin_hhl</code>	CHAR	name of the vertical grid HHL-file that has to be read in case of COSMO GRIB2 input files. This file has to be in the directory <code>yinext_cat</code>	' '
<code>ylmext_form_read</code>	CHAR	input format of external data	'grb1'
<code>yinext_form_read</code>	CHAR	input format of external data from coarse grid 'grb1' input is read with DWD's Grib library and has to be GRIB1. 'apix' input is read with ECMWF's Grib library <code>grib_api</code> and can be Grib1 or Grib2. 'ncdf' input format is NetCDF.	'grb1'
<code>ie_ext</code>	INT	west-east size of fields with external parameters	1081
<code>je_ext</code>	INT	north-south size of fields with external parameters	1081

Variables for the models

Name	Type	Definition / Purpose / Comments	Default
yin_cat	CHAR	directory of the GME-fields	' '
yin_form_read	CHAR	input format of data from coarse grid	'grb1'
yicon_input_prefix	CHAR	Prefix of the input data. ICON data do not have strict prefixes for analysis- and forecast-data and do not follow the COSMO logic in this respect. For int2lm, we expect the ICON data to consist of the prefix given in the namelist variable yicon_input_prefix, followed by a forecast time stamp, e.g., <ul style="list-style-type: none"> • igfff00000000 • igfff00030000 • igfff00060000 • igfff00090000 If this should be not the case with your data, rename your files accordingly or create links using the above name convention.	'igfff'
ybitmap_cat	CHAR	directory of an optional bitmap for GME data	' '
ybitmap_lfn	CHAR	name of the file with an optional bitmap for GME data	' '
ylm_cat	CHAR	directory of the output COSMO-Model data	' '
ylm_form_write	CHAR	output format of COSMO-Model data <p>'grb1' data are written with DWD's Grib library in GRIB1.</p> <p>'api1' data are written with ECMWF's Grib library grib_api in Grib1</p> <p>'api2' data are written with ECMWF's Grib library grib_api in Grib2</p> <p>'ncdf' data are written in NetCDF.</p>	'grb1'
npstrframe	INT	thickness of output frames	8
lbd_frame	LOG	if .TRUE., boundary fields include only frames	.FALSE.

Additional specifications for NetCDF-IO

Name	Type	Definition / Purpose / Comments	Default
yncglob_institution	CHAR	originating center name	'_'
yncglob_title	CHAR	title string for the output	'_'
yncglob_source	CHAR	program name and version	'_'
yncglob_contact	CHAR	contact e.g. email address	'_'
yncglob_project_id	CHAR	identification of the project of simulation	'_'
yncglob_experiment_id	CHAR	identification of the experiment of simulation	'_'
yncglob_references	CHAR	URL, report etc.	'_'
ncglob_realization	INT	number of the realization of the experiment	1

7.6 PRICTR — Controlling grid point output

Name	Type	Definition / Purpose / Comments	Default
nlev1pr	INT	k-index for printing the first model layer	10
nlev2pr	INT	k-index for printing the second model layer	20
igp_tot	INT	i-index for printing selected grid points (max. nmaxgp)	
jgp_tot	INT	j-index for printing selected grid points (max. nmaxgp)	
lprps	LOG	print some ps- and fis-fields	.FALSE.
lprt	LOG	print t at 2 levels (nlev1pr,nlev2)	.FALSE.
lpru	LOG	print u at 2 levels (nlev1pr,nlev2)	.FALSE.
lprv	LOG	print v at 2 levels (nlev1pr,nlev2)	.FALSE.
lprgrh	LOG	print grh at 2 levels (nlev1pr,nlev2)	.FALSE.
lprqv	LOG	print qv at 2 levels (nlev1pr,nlev2)	.FALSE.
lprqc	LOG	print qc at 2 levels (nlev1pr,nlev2)	.FALSE.
lprud	LOG	print ud (divergent wind correction)	.FALSE.
lprvd	LOG	print vd (divergent wind correction)	.FALSE.
lprdpdt	LOG	print dpdt (tendency of surface pressure)	.FALSE.
lprgp	LOG	print profiles at selected grid points	.FALSE.
lchkin	LOG	print check-values of input-fields	.FALSE.
lchkout	LOG	print check-values of output-fields	.FALSE.

7.7 EPSCTL — Characterizations for the Ensemble of Boundary Data

The namelist group EPSCTL is only read, if the switch(es) `leps_ana` and/or `leps_bc` in the group CTRL is/are set to `.TRUE..`

Name	Type	Definition / Purpose / Comments	Default
<code>iepsmem_ana</code>	INT	ID of the member in the ensemble of initial conditions (must be ≥ 0). Introduced in INT2LM 2.03	-1
<code>iepstyp_ana</code>	INT	ID of the initial conditions ensemble generation type (must be ≥ 0). Introduced in INT2LM 2.03	-1
<code>iepstot_ana</code>	INT	total number of initial conditions ensemble members (must be ≥ 0). Introduced in INT2LM 2.03	0
<code>lchk_bc_ana</code>	LOG	if <code>.TRUE.</code> , check member ID of input data for initial conditions. Introduced in INT2LM 2.03	<code>.FALSE.</code>
<code>iepsmem_bc</code>	INT	ID of the member in the ensemble of boundary conditions (must be ≥ 0).	-1
<code>iepstyp_bc</code>	INT	ID of the boundary ensemble generation type (must be ≥ 0).	-1
<code>iepstot_bc</code>	INT	total number of boundary ensemble members (must be ≥ 0).	0
<code>lchk_bc_typ</code>	LOG	if <code>.TRUE.</code> , check member ID of input data for boundary conditions.	<code>.FALSE.</code>

Section 8

Driving Models for the COSMO-Model

Since INT2LM Version 2.1 this chapter is included to describe in more detail, how different coarse grid models can be used as driving models for COSMO. This chapter is especially necessary for DWD's new global model ICON, because there are now some additional features and things necessary to run INT2LM in the ICON2LM mode. Up to now it also is the only section available in this chapter, we hope to complete it soon.

8.1 Using data from ICON

8.1.1 About ICON

The ICON (ISOsahedral Nonhydrostatic) modeling framework is a joint project between the Deutscher Wetterdienst (DWD) and the Max-Planck-Institute for Meteorology (MPI-M) for developing a unified next-generation global NWP and climate modeling system.

The main goals formulated in the initial phase of the collaboration were

- better conservation properties than in the existing global models, with the obligatory requirement of exact local mass conservation and mass-consistent transport,
- better scalability on future massively parallel high-performance computing architectures, and
- the availability of some means of static mesh refinement. ICON is capable of mixing one-way nested and two-way nested grids within one model application, combined with an option for vertical nesting in order to allow the global grid to extend into the mesosphere (which greatly facilitates the assimilation of satellite data) whereas the nested domains extend only into the lower stratosphere in order to save computing time.

In addition, the data of ICON simulations can be used to drive regional models, namely the COSMO-Model. But there is a speciality about ICON, which make the interpolation of

ICON data to the COSMO grid different than interpolations implemented so far. This is the grid used for ICON and its implementation in the ICON code. In principal the ICON grid is similar to the GME grid, but in contrast to GME it is implemented as an unstructured grid. All neighboring relations are implemented via indirect addressing.

This technical issue, but also the algorithms used to construct the grid, make the grid generation a very expensive process, which cannot be done during INT2LM runs. In order to process ICON data, it is necessary to load precalculated horizontal grid information as an input. This information is stored within so-called grid files. These grid files are provided either for the global ICON grid or for special cut-out domains tailored to encompass specific COSMO-Model domains.

8.1.2 Compiling and Linking INT2LM for ICON2LM

To activate the interpolation of ICON data to the COSMO grid, INT2LM has to be compiled and linked with the NetCDF library, because the ICON grid file is available in NetCDF only. Therefore the pragma `-DNETCDF` has to be specified for compiling.

ICON forecast data can be given as GRIB2 or as NetCDF files. If GRIB2 is used, INT2LM has to be compiled and linked with the `grib_api` library. Therefore the pragma `-DGRIBAPI` has to be specified for compiling.

8.1.3 Running INT2LM for ICON2LM

The following steps are necessary to run INT2LM successfully with ICON data:

1. Basic Settings:

The basic namelist switch to activate the interpolation of ICON data is:

- `yinput_model='ICON'`

This namelist variable is already contained in the group `/CONTRL/`.

For users who received data from the global DWD-ICON but cutted to a limited domain (not the entire globe), it is mandatory to avoid the UUID check for the grid, because this check currently always fails for cut-out domains:

- `lcheck_uuidOfHgrid='.FALSE.'`

Note that in this case strange errors happen when running INT2LM with a wrong grid file (namelist parameter `yicon_grid_lfn`, see below).

Reading and interpolating ICON forecast data is implemented in a new module named `src_icon_interp.f90` (similar to `src_gme_interp.f90`).

2. Specification of the ICON grid:

The ICON grid file necessary for the COSMO-Domain has to be specified. This can be done by setting the new namelist variables in the group `/GRID-IN/`.

- `yicon_grid_cat`: directory of the netcdf file describing the horizontal ICON grid
- `yicon_grid_lfn`: name of the netcdf file describing the horizontal ICON grid

Note, that these files are available only in NetCDF format!

Also, the ICON grid specification (RxxByy) has to be given explicitly by two new namelist variables:

- **nrootdiv_icon**: Number of root divisions (the “xx”),
- **nbisect_icon**: Grid level (the “yy”),

and the height, above which ICON levels become flat:

- **vcflat_icon**: specify, if different from default (= 16000.0 m). (Introduced in INT2LM 2.03)

In addition, the (already existing) namelist variables have to be set in /GRID-IN/:

- **ke_in_tot**: number of vertical levels of ICON data.
ke_in_tot has to be specified to the number of levels originally used to compute the ICON data, regardless whether ICON vertical levels are skipped by using **nlevskip** > 0 (see below).
Example: If ICON was run with 90 levels, **ke_in_tot** has to be set to 90 even if you use **nlevskip** > 0 and your ICON data input file may or may not contain less than 90 levels.
- **nlevskip** (optional): number of missing levels in input grid.
With **nlevskip**, the number of vertical layers actually used for computations can be decreased (counted from model top) to save computing time and memory. **nlevskip** has to be smaller than the level index of the first ICON model layer above the intended COSMO-Model domain.
Note that, if using ICON grib2-input format, different values of **nlevskip** might lead to slightly different results because of the vertical cubic spline interpolation.

3. ICON external data:

An ICON external data file is needed, which contains the land-sea-mask (**FR_LAND**) and the ICON soiltyp (**S0ILTYP**) used. Up to now the external file can only be given as NetCDF File.

Also for GME an external file must be specified, but while the GME external file contains the global fields, the ICON external file only contains the fields for a specified COSMO domain, which must correspond to the horizontal grid determined by the ICON grid file (see 2).

The following namelist variables in group /DATA/ have to be specified:

- **yinext_cat**: directory which contains file with ICON external parameters
- **yinext_lfn**: name of the file with ICON external parameters
- **yinext_form_read**: only 'ncdf' possible at the moment.

Note that it is not possible to interpolate the ICON external parameters to the COSMO grid. The namelist setting **ylmext_lfn** = 'interpolate' is not possible with ICON as input model.

4. ICON HHL:

ICON as a non-hydrostatic model also uses the new general vertical coordinate (similar to COSMO). To specify the vertical ICON grid, a field called HHL (height of half levels) is necessary for the computations.

HHL can either be available in the first ICON data file, or it must be given by a separate file. The filename of an extra file must be given in namelist group `/DATA/` by the variable:

- `yin_hhl`: name of the input HHL file

The file has to be in the directory `yinext_cat`, specified for the external parameters.

Note: The optional file containing ICON's HHL field has to be in GRIB2 format.

5. ICON driving data:

From DWD, at the moment only ICON forecast data (not the analysis files) can be used as initial and boundary data for COSMO. The reason is that due to the large data amount DWD does not store every analysed prognostic field necessary for COSMO in its data base, because the start time `vv=0` of every forecast already contains the analyses and double storage is to be avoided.

ICON forecast data can be given in GRIB2 or in NetCDF. DWD will only provide GRIB2 data. These data have the prefix `'igfff'`. However, in future data from other providers might have a different suffix, which then can be specified via the namelist parameter `yicon_input_prefix` in group `/DATA/`. Its default is `'igfff'`.

The fields necessary from ICON are the same that are necessary from GME, but an additional field for the ground temperature (`T_G`) is needed.

Fields necessary to produce initial data for the COSMO-Model:

- atmospheric fields: `U`, `V`, `W`, `T`, `P`, `QV`, `QC`, `QI`, `QR`, `QS` (`W` is only necessary, if `lvertwind_ini=.TRUE.`, which is usually the case)
- surface fields: `T_SNOW`, `W_SNOW`, `FRESHSNW`, `RHO_SNOW`, `T_G`, `W_I`, `QV_S`, `H_ICE`, `T_ICE`
- soil fields: `T_SO`, `W_SO`

Fields necessary to produce boundary data for the COSMO-Model:

- atmospheric fields: `U`, `V`, `W`, `T`, `P`, `QV`, `QC`, `QI`, `QR`, `QS` (`W` is only necessary, if `lvertwind_bd=.TRUE.`)
- surface fields: `T_SNOW`, `W_SNOW`, `T_G`
- soil fields: `T_SO(0)` (which in fact is a surface field)

8.1.4 ICON domain check

Since INT2LM 2.03 there is a domain check for ICON. This is relevant for ICON data from a nest domain (such as DWD's ICON-EU), or for regional data sets which have been cut-out from the global ICON data by the utility ICON-SUB to reduce the data amount for internet transfers.

In previous versions, INT2LM just crashed with a segmentation fault if the COSMO domain was outside the ICON-covered part of the globe. This is not nice to the user and therefore a new domain checking for ICON input has been implemented:

- If the debug level “high enough”, (`idbg_level > 10`), new ASCII output files
 - `YUICON_COSMO_DOMAINS_[suv]`

(“s”=scalar points, “u”=u-points, “v”=v-points) are generated in the directory from which the INT2LM has been started, showing the ICON- and overlapping COSMO domains as ASCII-ART geographic maps. The annotated coordinates are always geographic longitudes and latitudes, even if the COSMO domain is rotated. Fig. 8.1 shows an example of the contents of such a file. This is a valuable information for the user even if there are no actual mismatches.

- In case of not fully overlapping domains, (a) similar file(s)
 - `YUERROR_ICON_COSMO_DOMAINS_MISMATCH_[suv]`

is/are generated regardless of the debug level, and INT2LM stops with a corresponding error message. Fig. 8.2 shows an example of such a file. The generated ASCII-ART maps immediately show graphically where the problem is located.

Additionally, for ICON-SUB generated data sets, the parameters of the rotated lat/lon grid are checked and additional diagnostic error messages are generated.

Graphical depiction of ICON-domain and excessing COSMO domain

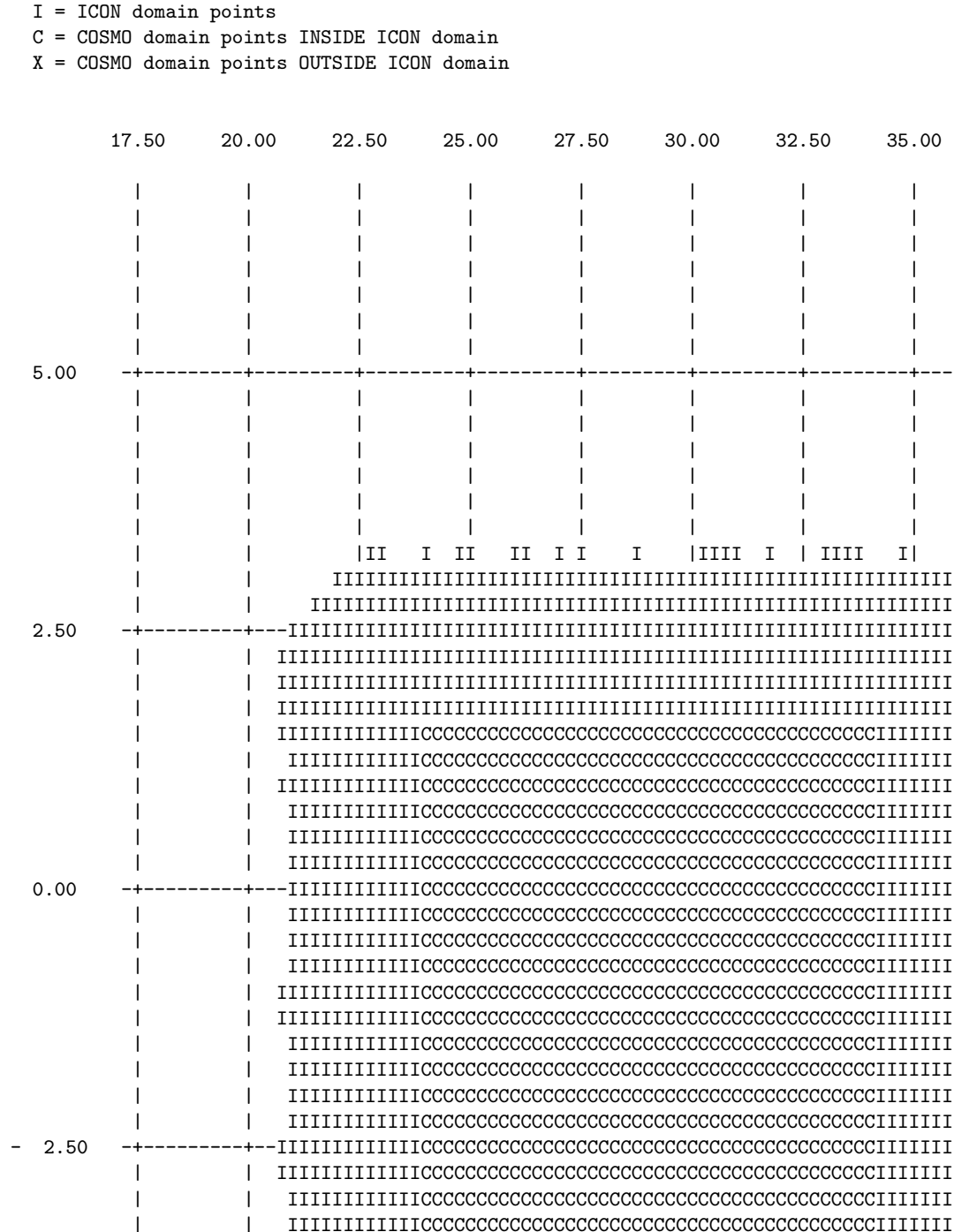


Figure 8.1: Example of a file YUICON_COSMO_DOMAINS_s for an ICON cut-out domain in East Africa. The grid coordinates are geographic longitudes and latitudes. An **I** denotes regions where ICON grid cells are located and at **C** locations the COSMO points are all within enclosing ICON grid cells. At **X** locations there would be **problematic** COSMO points outside the ICON region, but this is not the case here.

Section 9

More Details on Special Options

Since INT2LM Version 2.1 this chapter is included to describe some special features of INT2LM in more detail. First section included is on the fresh water lake model (FLake) and how to get initial data for the corresponding prognostic variables.

9.1 Cold Start of the Lake Parameterisation Scheme FLake

As the external-parameter fields of lake fraction and lake depth are generated and the logical switch `llake` is set `.TRUE.`, initial values of FLake prognostic variables should be specified. This can be done on the basis of observational data. Some caution is required since FLake prognostic variables are functionally related through the mean temperature of the water column and cannot be set completely independent. In most situation of interest in NWP and climate modeling, no empirical information is available to initialise FLake prognostic variables for all lakes present in the model domain. Then, initial values of FLake variables can be taken from previous COSMO-Model runs performed with the same numerical domain and horizontal resolution. For NWP applications this procedure is strongly recommended!

If such runs have not been performed or their results are inappropriate for the initialisation for one reason or other, a *cold start* initialisation of FLake prognostic variables should be performed. This can be switched on by setting the namelist variable `llake_coldstart` from group `/CONTRL/` to `.TRUE.` (default value is `.FALSE.`).

<code>llake_coldstart</code>	initialize all prognostic lake variables for cold start
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The initial prognostic variables of FLake are:

SALT_LK	lake salinity [g/kg]
T_B1_LK	temperature at the bottom of the upper layer [K]
H_B1_LK	thickness of the upper layer [m]
T_WML_LK	mixed-layer temperature [K]
T_MNW_LK	mean temperature of the water column [K]
T_BOT_LK	temperature at the water-bottom sediment [K]
C_T_LK	shape factor with respect to the temperature profile in lake thermocline [-]
H_ML_LK	thickness of the mixed-layer [m]

For the salinity an extra external parameter `SALT_LK` can be provided, but this is not done by `EXTPAR`. The CLM-Community has some means to do that. If this parameter is not available, the salinity is initialized to zero.

No ice is assumed at the cold start; the ice thickness is set to zero and the ice surface temperature is set to the fresh-water freezing point. The mixed-layer temperature is set equal to the water surface temperature from the COSMO sea surface temperature (SST) analysis. If data from the SST analysis are not available, as may be the case for climate runs, an alternative data source should be used to provide a reasonable estimate of the water surface temperature. In any case, an estimate of the water surface temperature for the lake-type grid boxes should be available at the cold start. The mixed-layer thickness is set to 10 m or to the lake depth, whichever is smaller, i.e. mixing down to the lake bottom is assumed for the grid boxes with the lake depth smaller than 10 m. The bottom temperature is set to the temperature of maximum density of fresh water if the lake depth exceeds 10 m and to the mixed-layer temperature otherwise. The shape factor with respect to the temperature profile in the thermocline is set to its minimum value. Finally, the mean temperature of the water column can be computed. Once a cold start is made, FLake runs freely, i.e. without any correction of the FLake variables. Notice that the cold start initialisation should be performed only once for each COSMO-model configuration in terms of the model domain and horizontal resolution. The *warm start* initialisation procedure utilises the values of FLake prognostic variables from the end of the previous run (e.g., this occurs every time a new COSMO-model run is started during the assimilation cycle).

For the non-lake-type grid boxes (ocean/sea and land), the mixed-layer depth is set to zero, the shape factor with respect to the temperature profile in the thermocline is set to its minimum value, and the mixed-layer temperature, the bottom temperature and the mean temperature of the water column are set equal to the temperature of maximum density of fresh water. This setting of the FLake variables is kept during all COSMO-Model runs. Although the setting of the FLake temperatures for the non-lake-type boxes is formal and should not directly affect the model results, the temperatures should never be reset to zero as it results in a two orders of magnitude temperature difference between lake-type and non-lake-type grid boxes and may lead to a loss of accuracy due to GRIB encoding-decoding.

As mentioned in Section 12 of Part II of the COSMO-Model Documentation, snow over lake ice is not considered explicitly. For the lake-type grid boxes, the snow surface temperature is equal to the ice surface temperature and the snow thickness remains zero. For the non-lake-type grid boxes, the initial values of the snow and ice characteristics are specified by the surface analysis procedure. The values of the ice thickness and the ice surface temperature depend on whether the sea ice parameterisation scheme is activated.

A word of caution is appropriate concerning the performance of FLake following a cold start. Since the cold-start values of FLake variables are rather ad hoc, they may not satisfactorily reflect the actual situation in lakes in question. Then, the simulated lake characteristics may fail to agree with observations until the memory of initial conditions is faded. Care should be exercised in the interpretation of model results during the spin-up period. For deep stratified lakes the spin-up period of several months may be required. Experience suggests, however, that a few weeks of spin-up are usually sufficient if the cold start is made during late spring or early summer and a reasonable estimate of the water surface temperature is available.

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