Consortium for Small-Scale Modelling

A Description of the

Nonhydrostatic Regional COSMO-Model

Part V:

Preprocessing:
Initial and Boundary Data for the COSMO-Model

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

Table 1.1: COSMO: Participating Meteorological Services

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

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 asynoptic 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 asynoptic 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.

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

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

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

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. 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 will replace GME early 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; GME2LM, ICON2LM
- ARPA-SIM: IFS2LM
- MeteoSwiss, DWD: LM2LM
- 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. Section 4.2 describes how to use the VCS (Version Control System: a programming environment tool developed at DWD) for working with the model. If the VCS is not available, the source code together with a Makefile for compiling and linking and scripts for running the model are provided. 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 (Grided 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 `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.

4.1.3 `libgrib_api.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). The source code for grib_api is available from the web pages of ECMWF `http://www.ecmwf.int`. For INT2LM, grib_api Version 1.11.0 or higher is needed.

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.

4.1.4 `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 Working with the VCS

The Version Control System is a programming environment tool based on the Concurrent Version System (CVS). The programming environment consists of several shell scripts (or command procedures) that are accessible from an administrator directory (on DWD systems this directory is `/e/rhome/for0adm/vcscmd`; on ECMWF cca it is `/home/ms/de/dfj/vcscmd`; you can refer to this directory with the shell variable `$ADM`, if it is set properly). These command procedures serve to simplify tasks and contain safety features which may otherwise be easily forgotten.

External users having a collaboration with DWD can access the code of the COSMO-Model (and also of other models), the necessary scripts for installing the programming environment tool, and a description of that tool via ftp. A list of all command procedures together with a short explanation can be obtained with `$ADM/help`.

4.3 Preparing the Code

Source Code Administrator (for VCS)
As a source code administrator you have to provide the external code and libraries. They have to be created on your system and put to a special directory. They also have to be specified as `EXTOBJ` in `LinkLibs`, in order to link them to the object files of the COSMO-Model.

User (with VCS)
If working with the VCS you have to create your own workbench within a special directory (e.g. `$HOME/model`) with the command

`$ADM/workbench int2lm`.

The following files and subdirectories are created:

`./CompilerFlags`	To specify, which module is compiled with which set of compiler options.
`./FileNames`	To define the names of binaries and/or libraries.
`./LinkLibs`	To define the libraries for the link step.
`./Makefile`	Link to a makefile for compiling and linking.
`./Options`	To set the compiler and linker options.
`./Parallel`	To set the number of parallel tasks for compiling.
`./edid`	Script to edit the SCCS-decks.
`./mk_batch`	Script to submit a batch job (optional).
`./obj`	Directory containing object files of the files in `src`.
`./src`	Directory containing modified source files.
`./work`	Directory containing files you are working on.

Normally, correct defaults are set by your administrator. You can change `Options`, `Parallel` and `LinkLibs` according to your needs (see also the part for the *Source Code Administrator*).

User (without VCS)
If the VCS is not available, 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 as in the DWD Version Control System (VCS). By de-taring, a directory is created with the following contents:

`DOCS`	Contains a short documentation of the changes in version `x`.
`edid`	Script to edit files in `src` and store them in `work`.
`Fopts`	Definition of the compiler options and also directories of libraries.
`LOCAL`	Contains several examples of `Fopts`-files for different computers.
`Makefile`	For compiling and linking the programs.
`./runxx2yy`	Scripts to define the `NAMELIST` input and run the model for special coarse grid models *xx* and applications *yy*.
`src`	Subdirectory for the source code.
`obj`	Subdirectory where the object files are written.
`ObjDependencies`	Definition of the dependencies between the different source files.
`Objfiles`	Definition of the object files.
`work`	Subdirectory for intermediate files.

Here, also the source code for `mpe_io2.f90` is included in `src`. 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.

4.4 Compiling and Linking

You have to choose the options for compiling the code in the file `Options` (if working within the VCS) or in `Fopts` (otherwise). See the User Guide of your computer system for necessary and/or desired options. Before linking check that the Grib library, necessary for the I/O, the external object files `mpe_io2.o` and the necessary external libraries (see 4.1) are available.

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` is provided, which has to be linked with the model then.

sequential	On single processor systems you can create a binary for sequential execution without using MPI. To avoid warning messages by the linker, a file `dummy_mpi.f90` is provided to satisfy the MPI external references.
parallel	On parallel computers with distributed memory you can create a binary for parallel execution, if MPI is available. You can also create a sequential binary, which can only run on one processor.

In the VCS environment the creation of one or more certain binaries is fixed. Ask your administrator, if you want to change the default. Outside the VCS you can choose the binary by modifying `Makefile`.

You can invoke a `make`-run by typing `make` *entry*. On batch-machines you can start a batch job for a `make`-run with `mk_batch` *entry*. Within VCS type `make help` for a list of available entries.

4.5 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. 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 `lsso`.

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 `nhori` sectors

The usage of the topographical corrections is controlled by the Namelist switch `lradtopo`. The field `HORIZON` is treated as three-dimensional array with `nhori` levels. `nhori` 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.

Mimimum 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

VIO3	Vertical integrated ozone content
HMO3	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. 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.

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.

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	llb_qi	lprog_qi
QR	Specific rain content	llb_qr_qs	lprog_qr_qs
QS	Specific snow content	llb_qr_qs	lprog_qr_qs
QG	Specific graupel content	llb_qg	lprog_qg

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
VIO3	Vertical integrated ozone content
HMO3	Ozone maximum
T_S	Temperature of surface
	and only if `itype_aerosol = 2`
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

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 splitted 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 following table shows the different files available from DWD's ftp-server with a short characterization. The filename contains information about the domain (`d0, d1, d3, d5`), the resolution in meters (`_07000_` for about 7000 meters) and the size of the fields in grid points (`961x769`).

These files already contain the external parameters for the Subgrid Scale Orography scheme. External parameters for minimum stomata resistance of plants, the thermal radiative surface emissivity, the normalized differential vegetation index and mean values for the aerosol types are not yet provided. because the corresponding code parts are still under testing and evaluation at DWD. These parameters will be provided to the public later on.

lm_d0_02800_1605x1605.g1	dlat = dlon = 0.025	(*)
lm_d1_07000_961x769.g1	dlat = dlon = 0.0625	
lm_d1_07000_961x769_new.g1	dlat = dlon = 0.0625	(*)
lm_d1_07000_961x769.g1_2009121700	dlat = dlon = 0.0625	(**)
lm_d1_14000_481x385.g1	dlat = dlon = 0.125	
lm_d1_14000_481x385.g1_2009121700	dlat = dlon = 0.125	(**)
lm_d1_21000_321x257.g1	dlat = dlon = 0.1875	
lm_d1_21000_321x257.g1_2009121700	dlat = dlon = 0.1875	(**)
lm_d1_28000_241x193.g1	dlat = dlon = 0.25	
lm_d1_28000_241x193.g1_2009121700	dlat = dlon = 0.25	(**)
lm_d1_56000_121x113.g1	dlat = dlon = 0.5	
lm_d1_56000_121x113.g1_2009121700	dlat = dlon = 0.5	(**)
lm_d5_07000_965x773.g1	dlat = dlon = 0.0625	(*)
lm_d5_07000_965x773.g1_2009121700	dlat = dlon = 0.0625	(**)
lm_d5_14000_483x387.g1	dlat = dlon = 0.125	(*)
lm_d5_14000_483x387.g1_2009121700	dlat = dlon = 0.125	(**)

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 `pollon` give the coordinates of the rotated north pole in real geographical coordinates. Files indicated by (*) are produced using a newer raw data set. Files indicated by (**) also are produced with the newer raw data set and they contain the SSO-parameters.

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

External parameter files 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. Depending on the available raw data set, the highest possible resolution is about 2 km (`dlat=dlon=0.02`).

In the CLM-Community there is work going on to produce a preprocessor for the external parameters called PEP (Preparation of External Parameters). This preprocessor will use the DWD software, but add some own functionality, like the use of the ECOCLIMAP data set.

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:

`invar_i128a`	resolution about 60 km
`invar_i192a`	resolution about 40 km
`invar_i192a.new`	resolution about 40 km; new raw data set
`invar_i384a`	resolution about 20 km

The file `invar_i192a_.new` must be used for GME data after October, 24^{th}, 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`).

  In contrast to GME, the ICON external parameters do not contain the global fields, but only fields for a special COSMO domain. This is due to the special ICON data structure and the ICON grid files (see next item).

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

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

  For every COSMO domain a special ICON grid file will be created, which covers just the specified COSMO 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.

  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

  `g`: GME (global model)
  `ig`: ICON (global model)
  `l`: COSMO-Model
  `e`: ECMWF model IFS (Integrated Forecast System)
  `c`: A general (global) climate model

- second character (in case of ICON third character):
  - `a`: analysis file (uninitialized)
  - `i`: analysis file (initialized)
  - `b`: boundary file
  - `f`: forecast files
  - `r`: restart files
- third character (in case of ICON fourth character): 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: `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
  - `c`: climate mode: the forecast range is given in the form `yyydddhh`, 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:

`lbff00050000`	COSMO-Model, file with boundary values for hour 5
`lfff01233000`	COSMO-Model, forecast at day 1, 23 hours and 30 minutes.
`lrff01000000`	COSMO-Model, restart file for day 1.

Section 7

Namelist Input for INT2LM

The execution of INT2LM can be controlled by 6 NAMELIST-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 LM grid
- DATABASE – specification of database job
- 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.

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='GME',
 lfilter_oro=.TRUE., eps_filter=0.1,
 ilow_pass_oro=1, ilow_pass_xso=0, rxso_mask=0.0,
 lfilter_pp=.FALSE., lbalance_pp=.FALSE., 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.,
 itype_ndvi=0, idbg_level=2,
/
&GRID_IN
 ni_gme = 384, i3e_gme = 60, kcontrol_fi =15, ke_soil_in=7,
/
&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,
/
&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/',
 yinext_lfn='invar.i384a',
 yinext_form_read='grb1',
 yinext_cat='/e/rhome/routfor/routfox/gme/const/',
 yin_form_read='grb1',
 yin_cat='/e/uscratch/uschaett/GME/data/',
 ybitmap_cat='/e/uscratch/uschaett/GME/bitmaps/'
 ybitmap_lfn='bitmp888',
 nbitmap=48000,
 ylm_cat='/e/uscratch/uschaett/COSMO_EU_input/'
 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

7.1 CONTRL — Parameters for the Model Run

Initial time and forecast range

Name	Type	Meaning	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	Meaning	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_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	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.
l_smi	LOG	switch for using an optional interpolation for the soil humidity	.FALSE.

Name	Type	Definition / Purpose / Comments	Default
lmixcld	LOG	switch for using an optional treatment of the humidity	.FALSE.
l_cressman	LOG	switch for using a cressman scheme during 'M'atch interpolation	.FALSE.
l_bicub_spl	LOG	switch for using a bicubic spline interpolation	.FALSE.
idbg_level	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
lprintdeb_all	LOG	In most cases, the debug output is only written from one processor (with ID=0). With lprintdeb_all=.TRUE., all processors will print the debug output.	.FALSE.
ltime_proc	LOG	detailed timings of the program (per PE)	.FALSE.
ltime_mean	LOG	detailed timings of the program (mean value)	.FALSE.
lroutine	LOG	run the program as routine-job	.FALSE.

Special Control Variables for ICON2LM

Name	Type	Definition / Purpose / Comments	Default
l_use_vn	LOG	use the normal velocity (VN: velocity normal to edges) instead of wind components U and V.	.FALSE.
nproma_icon	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
lcheck_uuid OfHGrid	LOG	to check the *unique universal Identifier* 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.

Controlling use of additional external parameters

Name	Type	Meaning	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.
lsso	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.
lurban	LOG	read and process external parameters for an urban module. NOTE: An urban module is NOT official COSMO code but has to be implemented on your own!	.FALSE.

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

Name	Type	Definition / Purpose / Comments	Default
lvertwind_ini	LOG	compute vertical wind for initial data	.TRUE.
lvertwind_bd	LOG	compute vertical wind for boundary data	.FALSE.
lprog_qi	LOG	compute initial and boundary values for the cloud ice scheme	.FALSE.
lprog_qrqs	LOG	Renamed to lprog_qr_qs in Version 1.22	
lprog_qr_qs	LOG	compute initial and boundary values for rain and snow	.FALSE.
lprog_qg	LOG	compute initial and boundary values for the graupel scheme	.FALSE.
lprog_qni	LOG	compute initial and boundary values for the number densities QNICE	.FALSE.
lprog_qn_crsg	LOG	compute initial and boundary values for the number densities QNCLOUD, QNRAIN, QNSNOW and QNGRAUPEL	.FALSE.
qvmin	REAL	security minimum value for water vapor	1E-12
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	0

Name	Type	Definition / Purpose / Comments	Default
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
itype_rootdp	INT	to select the treatment of the external parameter for root depth 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
itype_aerosol	INT	to select the treatment of plant cover and leaf area index: 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. Actual values for the current day are computed and given to the COSMO-Model.	1

Name	Type	Definition / Purpose / Comments	Default
itype_ndvi	INT	to select the treatment of plant cover and leaf area index: 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
itype_albedo	INT	Switch to choose the type of solar surface albedo. This parameter has been introduced in Version 1.19. 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
lt_cl_corr	LOG	if .TRUE., perform an alternative height correction for `t_cl`	.FALSE.

Name	Type	Definition / Purpose / Comments	Default
luse_t_skin	LOG	if .TRUE., use ECMWF skin temperature for surface	.FALSE.
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	.FALSE.
eps_filter	REAL	parameter for the Raymond filtering of the orography	10.0
norder_filter	INT	p value of the Raymond orography filtering	1
ilow_pass_oro	INT	type of low-pass filter for orography 1: use the Raymond filter with eps_filter and norder_filter 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
numfilt_oro	INT	number of sequential applications of filter	1
ilow_pass_xso	INT	type of low-pass filter for extra smoothing of steep orography	0
numfilt_xso	INT	number of sequential applications of xso filter	1
lxso_first	LOG	do an extra smoothing of orography first	.FALSE.

Name	Type	Definition / Purpose / Comments	Default
rxso_mask	REAL	mask for extra smoothing of steep orography	0.0
rfill_valley	REAL	mask for valley filling	0.0
ifill_valley	REAL	type of valley filling	1
l_topo_z	LOG	additional smoothing of the topography for LM_Z	.FALSE.
llbc_smooth	LOG	run with a smooth orography transition at the lateral boundaries	.FALSE.
nlbc_smooth	INT	number of grid points for a smooth orography transition at the lateral boundaries	.FALSE.
hmax_sea	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 hmax_sea, the filtered value is set back to the original height of the orography. ($0 \leq$ hmax_sea ≤ 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
ni_gme	INT	resolution of GME	128
i3e_gme	INT	number of levels in the vertical	51
yicon_grid_cat	CHAR	Directory of the NetCDF file describing the horizontal ICON grid	' '
yicon_grid_lfn	CHAR	Name of the NetCDF file describing the horizontal ICON grid	' '
kcontrol_fi	INT	control level for geopotential	15
ie_in_tot	INT	ie for input grid (total domain)	141
je_in_tot	INT	je for input grid (total domain)	71
ke_in_tot	INT	ke for input grid (total domain)	60
nlevskip	INT	number of missing levels in input grid	0
ke_soil_in	INT	number of levels in input multi-layer soil model	6
czml_soil_in	REAL	depth of main input soil layers. The default specification is (in cm) / 0.005, 0.02, 0.06, 0.18, 0.54, 1.62, 4.86, 14.58 /	see left
pcontrol_fi	REAL	pressure of control level for geopotential	-1.0
pollat_in	REAL	geographical latitude of rotated north pole (in degrees, north > 0)	90.0
pollon_in	REAL	geographical longitude of rotated north pole (in degrees, east > 0)	180.0
dlon_in	REAL	Mesh size in east-west direction	0.5
dlat_in	REAL	Mesh size in north-south direction	0.5
startlat_in_tot	REAL	latitude of the lower left grid point of the input domain (in degrees, north > 0, rotated coordinates)	-35.0
startlon_in_tot	REAL	longitude of the lower left grid point of the input domain (in degrees, east > 0, rotated coordinates)	-30.0
endlat_in_tot	REAL	latitude of the upper right grid point of the input domain (in degrees, north > 0, rotated coordinates)	0.0

Name	Type	Definition / Purpose / Comments	Default
endlon_in_tot	REAL	longitude of the upper right grid point of the input domain (in degrees, east > 0, rotated coordinates)	-40.0
p0sl_in	REAL	constant reference pressure on sea-level	10000.0
t0sl_in	REAL	constant reference temperature on sea-level	288.15
dt0lp_in	REAL	d (t0) / d (ln p0)	42.0
lushift_in	LOG	shift of u-velocity due to grid staggering	.FALSE.
lvshift_in	LOG	shift of v-velocity due to grid staggering	.FALSE.
east_add_in	INT	add an extra column to the east	0
west_add_in	INT	add an extra column to the west	0
south_add_in	INT	add an extra column to the south	0
north_add_in	INT	add an extra column to the north	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
pollat	REAL	geographical latitude of rotated north pole (in degrees, north > 0)	32.5
pollon	REAL	geographical longitude of rotated north pole (in degrees, east > 0)	-170.0
polgam	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
dlon	REAL	Mesh size in east-west direction	0.0625
dlat	REAL	Mesh size in north-south direction	0.0625
startlat_tot	REAL	latitude of the lower left grid point of the total domain (in degrees, north > 0, rotated coordinates)	-14.375
startlon_tot	REAL	longitude of the lower left grid point of the total domain (in degrees, east > 0, rotated coordinates)	-6.875
ielm_tot	INT	number of gridpoints of the total domain in east-west direction	213
jelm_tot	INT	number of gridpoints of the total domain in north-south direction	213
kelm_tot	INT	number of gridpoints of the total domain in vertical direction	20
ke_soil_lm	INT	number of levels in multi-layer soil model for the COSMO-Model	6
czml_soil_lm	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
czvw_so_lm	REAL	artificial volumetric soil water content profile for the COSMO-Model.	/0.75/

Name	Type	Definition / Purpose / Comments	Default
irefatm	INT	type of reference atmosphere 1: Default as used up to now 2: The reference atmosphere is based on a temperature profile $$t_0(z) = (t_{0sl} - \Delta t) + \Delta t \cdot \exp\left(\frac{-z}{h_{scal}}\right),$$ where z = hhl(k) is the height of a model grid point. If this option is used, the values for Δt = delta_t and h_{scal} = h_scal have also to be set.	1
lanalyt_calc_t0p0	LOG	if set to .TRUE., the values for the reference state of t_0 and p_0 are computed analytically. If it is set to .FALSE., they are only averaged between the half levels.	.FALSE.
ivctype	INT	kind of vertical coordinate system 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 vcflat below. (not extensively tested). The exact blending behaviour can be influenced by the parameters svc1 and svc2 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
lnewVGrid	INT	to indicate, that a new vertical grid file HHL has to be created	.FALSE.
vcflat	REAL	coordinate value where system changes back to z-system	0.220

Name	Type	Definition / Purpose / Comments	Default
vcoord_d	REAL	vertical coordinate parameter list of pressure (ivctype=1) or height (ivctype=2/3/4) values. The usage of the fortran utility vcoord.f90 for preparation of the parameter values is recommended. For ivctype=1, values have to cover the range 0 to 1 in increasing order (σ coordinates). For ivctype=2, 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 ivctype=2 and kelm_tot=40,50. ivctype=3/4 and kelm_tot=50. If one of these sets should be used, only specify the respective kelm_tot and ivctype and leave vcoord_d out.	(missing)
p0sl	REAL	constant reference pressure on sea-level	10000.0
t0sl	REAL	constant reference temperature on sea-level	288.15
dt0lp	REAL	d (t0) / d (ln p0)	42.0
delta_t	REAL	temperature difference between sea level and stratosphere (for irefatm=2)	75.0
h_scal	REAL	scale height (for irefatm=2)	10000.0
svc1	REAL	decay rate for large-scale part of topography	10000.0
svc2	REAL	decay rate for small-scale part of topography	10000.0
nfltvc	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 Grib Input and Output

General control variables:

Name	Type	Meaning	Default
ncenter	INT	originating center identification	78
nprocess_ini	INT	generating process identification for initial values	131
nprocess_bd	INT	generating process identification for boundary values	132
nrbit	INT	pack-rate for the grib code (in bit)	16
nbitmap	INT	user dimension for bitmaps	6000*2
nl_soil_lm	INT	number of prognostic soil water levels for the COSMO data	2
nl_soil_in	INT	number of prognostic soil water levels for the input data	2
nvers	INT	for documenting purposes (mainly in GRIB-Code)	1
ymode_read	CHAR	specify open mode for reading	'r '
ymode_write	CHAR	specify open mode for writing	'w '
yvarini	CHAR	list of variables for LM initial data	
yvarbd	CHAR	list of variables for LM boundary data	
l_ke_in_gds	LOG	write the number of vertical levels explicitly to the grid description section	.TRUE.
ytunit_in	CHAR	time unit for input data	'f'
ytunit_out	CHAR	time unit for output data	'f'
yinput_type	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
ylmext_cat	CHAR	directory of the external fields for LM/HM	' '
ylmext_lfn	CHAR	name of the file with the external fields for LM/HM	' '
ylm_hhl	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 ylmext_cat	' '
yinext_cat	CHAR	directory of the external fields for GME	' '
yinext_lfn	CHAR	name of the file with the external fields for GME	' '
yin_hhl	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 yinext_cat	' '
ylmext_form_read	CHAR	input format of external data	'grb1'
yinext_form_read	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 grib_api and can be Grib1 or Grib2. 'ncdf' input format is NetCDF.	'grb1'
ie_ext	INT	west-east size of fields with external parameters	1081
je_ext	INT	north-south size of fields with external parameters	1081

Variables for the models

Name	Type	Meaning	Default
yin_cat	CHAR	directory of the GME-fields	' '
yin_form_read	CHAR	input format of data from coarse grid	'grb1'
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 LM/HM-fields	' '
ylm_form_write	CHAR	output format of COSMO-Model data 'grb1' data are written with DWD's Grib library in GRIB1. 'api1' data are written with ECMWF's Grib library grib_api in Grib1 'api2' data are written with ECMWF's Grib library grib_api in Grib2 'ncdf' data are written in NetCDF.	'grb1'
npstrframe	INT	thickness of output frames	8
lbd_frame	LOG	if .TRUE., boundary fields include only frames	.FALSE.

Additional specifications for NetCDF-IO:

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	Meaning	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 leps_bc in the group CONTRL is set to .TRUE..

Name	Type	Meaning	Default
iepsmem_bc	INT	ID of the member in the ensemble of boundary conditions (must be ≥ 0.	-1
iepstyp_bc	INT	ID of the boundary ensemble generation type (must be ≥ 0.	-1
iepstot_bc	INT	total number of boundary ensemble members (must be ≥ 0.	0
lchk_bc_typ	LOG	if .TRUE., check member ID of input data	.FALSE.

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 parameter. This information is stored within so-called grid files. These grid files are provided for special COSMO-Model domains.

8.1.2 Compiling and Linking INT2LM with 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 with 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/`.

   Reading and interpolating ICON forecast data is implemented in a new module named `src_icon_interpol.f90` (similar to `src_gme_interpol.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!

   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 (`SOILTYP`) 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:
   ICON forecast data can be given in GRIB2 or in NetCDF. DWD will only provide GRIB2 data.

   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)

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.`.

`llake_coldstart`	initialize all prognostic lake variables for cold start

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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