Overview of the COSMO NWP model

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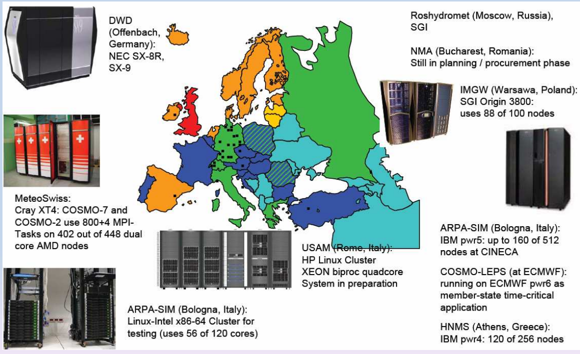
Outline

- Overview of the COSMO Model and its Users
- Preprocessor: Int2lm Package
- Components of the COSMO Model
- Running the COSMO Model
- Results using COSMO
  - NWP
  - Regional Climate Simulations

Overview

- The COSMO-Model System is a non-hydrostatic limited area atmospheric prediction system.
- It can be used for regional numerical weather prediction (NWP) and Regional Climate Modelling (RCM).
- The CLM Community deployed it for the IPCC runs and for various scientific purposes in climate mode. For these applications the model is called COSMO-CLM or CCLM.

Overview



Overview

- At UCD we use COSMO on the 'stokes' Linux cluster at the Irish Centre for High-End Computing (ICHEC).
- Stokes is an SGI Altix ICE 8200EX with 320 compute nodes.
- Each compute nodes has two Intel Xeon E5462 quad-core processors and 16GB of RAM.
- On its release in 2008 it was ranked 118 in the top 500 Super Computer List (Now ~300).

Overview

The Intel FORTRAN & C/C++ compilers were used to compile the code.

The Speed-Up of CLM with increasing CPUs:

Machine	Compiler	# CPUs	Optimization Flags	Time (hr)
Walton	Pathscale	**24**	-O3 -ipa -OPT:Ofast -fno-math-errno -m64 -march=auto	**3.75**
Stokes	Intel	**24**	-O2 -xT –ip	**1.2**
Stokes	Intel	**24**	-O3 -xT -ip -no-prec-div	**1.15**
Stokes	Intel	**32**	-O2 -xT –ip	**0.88**
Stokes	Intel	**48**	-O2 -xT –ip	**0.6**
Stokes	Intel	**64**	-O2 -xT –ip	**0.5**
Stokes	Intel	**96**	-O2 -xT –ip	**0.4**

Overview

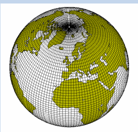
COSMO Software Package:

- **External parameters** to describe the earth´s surface:
  - constant data, e.g.: orography, land-sea-mask, soil type
  - (not so constant) data, e.g.: plant characteristics
- **INT2LM:** Interpolation program which reads data from a driving model to prepare initial and boundary conditions for the COSMO-Model
- **COSMO Model:** The forecast/climate model itself

Preprocessor: Int2lm Package

Preprocessor: Int2lm

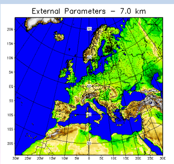
- The INT2LM program interpolates the coarse resolution driving data & external fields on to the high resolution COSMO domain.



Coarse Driving Data. Eg, ECMWF 25km Global Data

INT2LM

Initial/Boundary Files used to run COSMO at high resolution (say 7kr



External Fields

Necessary data for Int2lm

•To run the COSMO-Model, several fields have to be provided (Depending on the chosen configuration)

- External parameters: Constant or slowly varying fields for :
  - HSURF (FIS), FR_LAND, SOILTYP, Z0, FR_LAKE, DEPTH_LK,
  - FOR_E, FOR_D, constant
  - PLCOV, LAI, ROOTDP, annual cycle
  - VIO3, HMO3 annual cycle
- Initial fields:
  - Atmosphere: U, V, W, T, PP, QV, QC, QI, QR, QS, QG
  - Soil and surface: T_SNOW, W_SNOW, W_I, QV_S, T_S, T_SO, W_SO, FRESHSNW, RHO_SNOW, (T_M, T_CL, WG_1, WG_2, W_CL)
- Boundary fields:
  - Atmosphere: U, V, W, T, PP, QV, QC, QI, QR, QS, QG
  - Soil and surface: T_SNOW, W_SNOW, QV_S, (T_S, T_M, WG_1, WG_2)

Preprocessor: Int2lm

- INT2LM does the final preprocessing of all input data for the COSMO-Model. Despite the name, this is more than just an interpolation program.
- The constant external parameters are taken as provided.
- The varying external parameters are processed, depending on the day of the year.
- The variables for ozone (vio3, hmo3) are not provided externally, but are computed by INT2LM, depending on the day of the year.

Preprocessor: Int2lm

- All other initial and boundary fields are taken from a coarse grid model and processed for the COSMO-Model domain.
- This involves (mainly) a horizontal interpolation, a vertical interpolation and a special treatment in the boundary layer.
- Running the INT2LM is controlled by several Namelist groups.
- For a complete reference consult the documentation section at: http://www.cosmo-model.org

  "Part V – Preprocessing"

INT2LM: /CONTRL/

Basic control:

`ydate_ini, ydate_bd`	Initial date and time of the forecast and of the forecast from the boundaries
`hstart, hstop, hincbound`	Start and end of the forecast and increment for providing boundaries (in hours)
`lgme2lm, lec2lm, llm2lm, lcm2lm`	To specify the input model that provides (initial and) boundary data
`linitial, lboundaries`	To specify, whether initial and / or boundary data should be computed
`lbdclim`	To provide the boundaries for the climate mode
`lfilter_oro`	To do a filtering of the orography for avoiding numerical problems

INT2LM: /LMGRID/

Definition of model domain (same as in the COSMO-Model):

`startlat_tot, startlon_tot`	Rotated latitude and longitude of lower left grid point
`dlat, dlon`	Resolution (grid spacing) in degrees
`pollat, pollon`	Geographical latitude / longitude of rotated north pole
`ielm_tot, jelm_tot kelm_tot`	Horizontal and vertical grid size (in grid points)

INT2LM: /GRID_IN/

This group specifies the characteristics of the input model:

`ni_gme, i3e_gme`	Resolution and vertical grid size for GME
`ie_in_tot, je_in_tot, ke_in_tot`	Grid specifications for other models than GME
`startlat_in_tot, startlon_in_tot`	
`dlon_in, dlat_in`	
`pollat_in, pollon_in`	

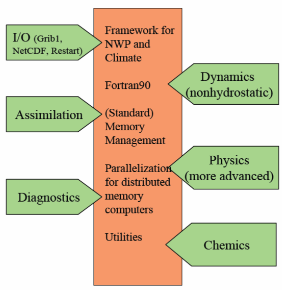
INT2LM: /DATA/

This group controls the input and output:

`ylmext_cat, yinext_cat`	Directories of external fields for COSMO- and input model
`ylmext_lfn, yinext_lfn`	Names of the files for external fields for COSMO- and input model
`ylmext_form_read, yinext_form_read`	To specify the format of these files (`grb1`,`ncdf`)
`ie_ext, je_ext`	Size of the external field for the COSMO-Model (in grid points)
`ylm_cat, yin_cat`	Directories where to write the results and where to read the input data
`yin_form_read ylm_form_write`	To specify the format of input and output files (`grb1`,`ncdf`)

Components of the COSMO Model

Components of the COSMO-Model



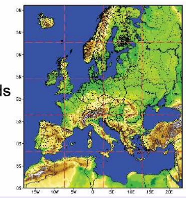
- Basic Framework
- Data Input / Output
- Dynamics
- Physical Parameterizations
- Diagnostics
- Assimilation
- Aerosol and Reactive Tracers (ART)

Components of the COSMO-Model

- In the following, we will give an overview on the important components
- Some **basic** namelist variables
- For a complete reference consult the documentation section at http://www.cosmo-model.org *"Part VII - User's Guide"*

Components: Basic Framework

- The basic organization of the COSMO-Model is done in the main program `lmorg.F90`. The first task is the setup, to define the configuration (`CALL organize_setup` in module `src_setup.f90`)
  - namelist input for the setup
  - definition of the model domain
  - memory management
  - parallelization
  - computation of basic constants and fields
- The relevant namelist groups are
  - `/LMGRID/`
  - `/RUNCTL/`



Components Basic Framework /LMGRID/

Definition of model domain:

`startlat_tot, startlon_tot`	Rotated latitude and longitude of lower left grid point
`dlat, dlon`	Resolution (grid spacing) in degrees
`pollat, pollon`	Geographical latitude / longitude of rotated north pole
`ie_tot, je_tot`	Horizontal grid size (in grid points)
`ke_tot`	Number of vertical levels

Components Basic Framework /RUNCTL/

Initial date and forecast range

`ydate_ini`	Initial date and time of the forecast in the form `2009030212`
`ydate_end`	End date of the total forecast in the form `2009030612` (optional; necessary for long term simulations that are cut into periods)
`ydate_bd`	Start date and time of the forecast, from which the boundary fields are used
`hstart, hstop`	Start and end of the actual forecast period (in hours)
`dt`	Time step (depending on the resolution

Components Basic Framework /RUNCTL/

With the following switches you can turn on (`.TRUE.`) and off (`.FALSE.`) components:

`lphys`	Physical parameterizations
`ldiagnos`	Diagnostics
`luseobs`	Assimilation
`luse_rttov`	Synthetic satellite images
`l_cosmo_art`	Aerosols and Chemistry
`l_pollen`	Pollen
`lartif_data`	To switch off input and generate artificial data instead

Components Basic Framework /RUNCTL/

Parallel Execution:

`nprocx, nprocy,`	Number of processors in east-west and south-north
`nprocio`	Number of additional IO processors (usually `0`)
`nboundlines`	`=2` for Leapfrog dynamics `=3` for Runge-Kutta dynamics
`lreproduce`	Ensures computation of reproducible results, but needs more communication

Components
INPUT-OUTPUT /IOCTL/

This group defines the most important parameters for I/O

`ngribout`	To specify, how many output groups are used
`yform_read`	To specify the format of input files (`grb1`, `ncdf`)
`yform_write`	To specify the format of output files (`grb1`, `ncdf`)
`lbdclim`	To switch on the climate mode and read additional boundary fields for long term runs
`ydir_restart`	Directory, where to write the restart files
`nhour_restart`	Triplet to specify start, stop and increment of writing restart files (values are given in hours)

Components
INPUT-OUTPUT /GRIBIN/

This group defines parameters for input (not only GRIB!)

`ydirini`, `ydirbd`	Directories of the files with initial and boundary data, resp.
`lchkini`, `lchkbd`	To write check values of data read to the file `YUCHKDAT`
`lana_qi`, `llb_qi`	To specify, whether cloud ice `qi` is in the initial (ana) field and / or in the lateral boundary field
`lana_qr_qs`, `llb_qr_qs`	The same for rain `qr` and snow `qs`
`lana_qg`, `llb_qg`	The same for graupel `qg`

Components
INPUT-OUTPUT /GRIBOUT/

This group defines parameters for output (not only GRIB!)
This group can occur several times, to specify different kind of output for different model times.

`ydir`	Directory of the output files
`lcheck`	To write check values to the file `YUCHKDAT`
`yvarml(:)`	List of model level variables for output
`yvarpl(:)`	List of pressure level variables for output
`yvarzl(:)`	List of z-level variables for output
`hcomb(:)`	Triplet to specify start, stop and increment for output
`ydomain`	To write the full (`f`: default) or a sub (´s`) domain
`slon, slat, elon, elat`	Definition of subdomain in rotated coordinates

Components: Dynamics

- COSMO offers two different dynamical cores
  - The Leapfrog-scheme
  - Runge-Kutta (or 2-time level) scheme
- For both schemes there are several variants.
- It is planned to replace the Leapfrog schemes with the RK schemes in the near future.
- The relevant namelist group is /DYNCTL/

Dynamics /DYNCTL/
Leapfrog HE-VI Scheme

- The „horizontal explicit - vertical implicit“ variant of the Leapfrog scheme is the standard scheme (still) used in coarser resolutions (COSMO-EU).
- The basic namelist parameters are
  - `l2tls=.FALSE.` No use of two-time level scheme
  - `lsemi_imp=.FALSE.` No use of semi-implicit scheme
  - `epsass=0.15` filter coefficient for Asselin filter
  - `betasw=0.4` time-weighting for VI calculations

Dynamics /DYNCTL/
Leapfrog Semi Implicit

- The semi-implicit was implemented to overcome stability problems in small-scale applications, where steep slopes of the orography may occur.
- Although a larger time step may be used compared to the HE-VI scheme, the necessary solution of an elliptic differential equation made this scheme too expensive for operational use. It is available in the source code, but not tested any more.
- The basic namelist parameters are
  - `l2tls=.FALSE.` No use of two-time level scheme
  - `lsemi_imp=.TRUE.` Use of semi-implicit scheme

Dynamics /DYNCTL/
Runge-Kutta (2 timelevel)

- Two variants of a two timelevel Runge-Kutta scheme are implemented:
  - 3rd order scheme after Wicker and Skamarock (default used)
  - „Total Variation Diminishing“ (TVD) variant after Liu, Osher and Chan
- The basic namelist parameters are
  - `l2tls=.TRUE.` Use of two-time level scheme
  - `irunge_kutta=1/2` Wicker-Skamarock (1) or TVD (2)
  - `iadv_order=5` Order of horizontal advection scheme
  - `irk_order=3` Order of Runge-Kutta scheme
  - `lsl_adv_qx=.TRUE.` Switch for Semi-Lagrange advection

Physical Parameterizations /PHYCTL/

- **COSMO uses several sub components for the physical parameterizations.**

  –Microphysics
  –Radiation
  –Moist convection
  –Turbulence
  –Soil Processes
  –Lake and sea-ice schemes
  –Subgrid Scale Orography Scheme

See Documentation for Details

Running the COSMO Model

Running the COSMO Model

- COSMO will be setup on ***tyndall*** at UCD
- You will each be provided with a ***username*** and password
- ***ssh username@tyndall.ucd.ie***
- ECMWF coarse data and run scripts to perform an initial test 7km forecast will be provided.

Running the COSMO Model

- To Interpolate the coarse data (run Int2lm):
  - ***cd ~/COSMO-MSC/int2lm***
  - ***./run_int2lm***

- To Run the COSMO forecast:
  - ***cd ~/COSMO-MSC/cosmo***
  - ***./run_cosmo***

Running the COSMO Model

- The output of the COSMO forecast will be stored in:
  - ***~/COSMO-MSC/cosmo/output***
- The files can be viewed using ***ncview*** or ***ncBrowse***
- Post-processing tools such as ***cdo*** can be used to manipulate the data (calculate means, max, min, etc).

Running the COSMO Model

When the user is somewhat familiar with COSMO, he/she can edit the run scripts to perform their own forecasts. For example:

- Change the domain area, resolution, time step...
- Experiment with the different dynamical cores
- Experiment with the Physical Parameterization schemes
- Recompile to assess how optimization may affect speed & accuracy

Thank you for your attention