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The HIRHAM Regional Climate Model

Version 5 (β)

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Colophon

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Content:

Abstract

This report describes version 5(β) of the HIRHAM regional climate model. The report is in two parts. The first part discusses the structure and main features of the upgraded version of the model system, while the second part offers a short tutorial on how to install and run the code, e.g. on NEC SX6.

Resumé

Denne rapport beskriver version 5(β) af den regionale klimamodel HIRHAM. Rapporten er i to dele. I første del diskuteres strukturen og hovedelementerne i den opgraderede udgave af modelsystemet, mens anden del giver en kort gennemgang af, hvorledes koden installeres og køres, for eksempel på NEC SX6.

Introduction

HIRHAM is a regional atmospheric climate model (RCM) based on a subset of the HIRLAM (Undén et al, 2002) and ECHAM models (Roeckner et al, 2003), combining the dynamics of the former model with the physical parameterization schemes of the latter. The HIRLAM model - High Resolution Limited Area Model - is a numerical short-range weather forecasting system developed by the international HIRLAM Programme (http://hirlam.org) and is used for routine weather forecasting at a number of meteorological institutes, i.e. DMI (Denmark), FMI (Finland), IMS (Iceland), KNMI (The Netherlands), met.no (Norway), INM (Spain), and SMHI (Sweden). The ECHAM global climate model (GCM) is a general atmospheric circulation model developed at the Max Planck Institute of Meteorology (MPI) in collaboration with external partners. The original HIRHAM model was collaboration between DMI, the Royal Netherlands Meteorological Institute (KNMI) and MPI.

The latest running version of the HIRHAM model system, version 4, was released in 1996 (Christensen et al, 1996). An increasing demand for the use of state-of-the-art physical parameterization schemes and higher model resolution, however, recently made it crucial that a major upgrade be performed. Initial work on this upgrade began in 2005 and commenced throughout 2006.

This document describes the beta-test version of HIRHAM version 5, or simply "HIRHAM5", which has been developed in a collaboration between the Danish Climate Centre at DMI (Ole Bøssing Christensen, Martin Drews and Jens Hesselbjerg Christensen) and the Potsdam Research Unit of the Alfred Wegener Institute Foundation for Polar and Marine Research (Klaus Dethloff, Klaus Ketelsen, Ines Hebestadt and Anette Rinke).

HIRHAM5 is based on release 7.0 of the HIRLAM model and release 5.2.02 of the ECHAM model. In the following these two codes will be referred to as HIRLAM7 and ECHAM5.

What is new?

In essence HIRHAM5 is a completely new regional climate model (RCM), combining the most recent versions of HIRLAM and ECHAM. While the general structure of the HIRLAM model has not changed much compared to the underlying version used in HIRHAM4 (Christensen et al, 1996), a semi-lagrangean advection scheme has been introduced and now become the default. The physical parameterization has also greatly been modified, but this is not of relevance for the present development. On the other hand, the ECHAM code has been completely redesigned and rewritten in Fortran 90/95 to take full advantage of state-of-the-art programming techniques. The major changes with respect to the former version, HIRHAM4 (Christensen et al, 1996), are:

- The model dynamics now employs a semi-lagrangean time stepping scheme instead of the traditional Eulerian scheme, which is used in HIRHAM4. It is planned that the Eulerian scheme will be optional in a future release of HIRHAM5. The semi-lagrangean scheme allows for longer time steps and thus makes high-resolution simulations computationally feasible, e.g. on a 5 km x 5 km grid.

- Since the GRIB (GRIdded Binary) data file format used by the World Meteorological Organization is specific to numerical weather prediction centres, output from the model is now also as an option available in the netCDF format (http://www.unidata.ucar.edu/software/netCDF/), allowing for direct access using generally available software tools. Running the model requires the use of a netCDF library offering full 64-bit support, i.e. version 3.6 or newer. The gridded input data, e.g. climatological data, is still in the standard GRIB data format except for the boundary files, which may optionally be provided in netCDF (Ketelsen, 2006b).

- The gridded input data are no longer interpolated *within* the scope of the HIRHAM code; hence all gridded data must be pre-processed if not on the right grid.

It should be noted that HIRHAM4 is based on ECHAM version 4 and HIRLAM version 2.

Structure of HIRHAM5

As mentioned above HIRHAM5 is based on a subset of the HIRLAM7 model, where the physical package has been replaced with the more elaborate physical parameterizations of ECHAM5. The implementation strategy has been to keep the changes in either code to a minimum, i.e. ideally there would be no changes to the source codes. Hence, in the current model the HIRLAM7 environment and the ECHAM5 environment is connected only through a general interface subroutine (see the description below), which takes care of initialization and parameter passing, while the data structures in either model constituent remain the same. By adopting this approach means future versions of HIRLAM may – in principle - easily be combined with newer versions of ECHAM to provide updated versions of the RCM. While in the current instance the ECHAM5 code has been left largely untouched, the HIRLAM code has been modified at a few points to accommodate the requirements of the combined model system. Moreover, since HIRLAM is a forecast model a number of extensions that are essential for a climate model have been added, most notably related to IO, forcing data and restart functionality. These add-ons are generally written in Fortran 90/95 and form a number of *modules*, which are called from within the HIRLAM code. Again, this is done in order to make it easy to implement the required changes in an updated version of HIRLAM.

About this report

This technical report summarizes the main features of the new HIRHAM5 RCM. In the following sections the main parts of the model is discussed in more detail, i.e. HIRLAM, ECHAM and the HIRLAM-ECHAM interface. The installation of the model system is described, and finally we discuss how to run the model, showing the output from an example run.

HIRLAM 7

A detailed description of the HIRLAM model may be found in (Undén et al, 2002). In HIRHAM we only use a subset of the complete forecast system, i.e. the *hlprog* executable, which is the time integration module for prediction of the key meteorological variables. The overall algorithm can roughly be described as a giant time-loop (src/grdy/GEMINI.f) that based on various input computes prognostic values such as the horizontal wind components U and V, temperature, specific humidity, cloud water, turbulent kinetic energy, and the surface pressure in each grid point. The inherent physics implementation works on vertical "columns", i.e. there is no connection between neighbouring grid points in the horizontal direction. The application has been parallelized using the MPI – Message Passing Interface (Gropp et al, 1999). In parallel mode the column data is local to each of the MPI processes.

In the present project we use a special "cleaned up" and self-contained version of the HIRLAM 7.0 reference version, which was prepared by Jacob Weisman Poulsen, DMI, for the "DMI-HIRLAM benchmark project". For more information about this project see its home page: http://benchmark.dmi.dk.

Within HIRLAM the physics is called from the subroutine src/phys/PHCALL.f, cf. Figure 1. Use of the ECHAM5 physics is enabled via the pre-processor directive *#ifdef ECHAM5_PHYS*, which calls the interface routines rather than native routines (see below). In the current release of HIRHAM5 it is not possible to run the model with HIRLAM physics, hence this directive must always be enabled.
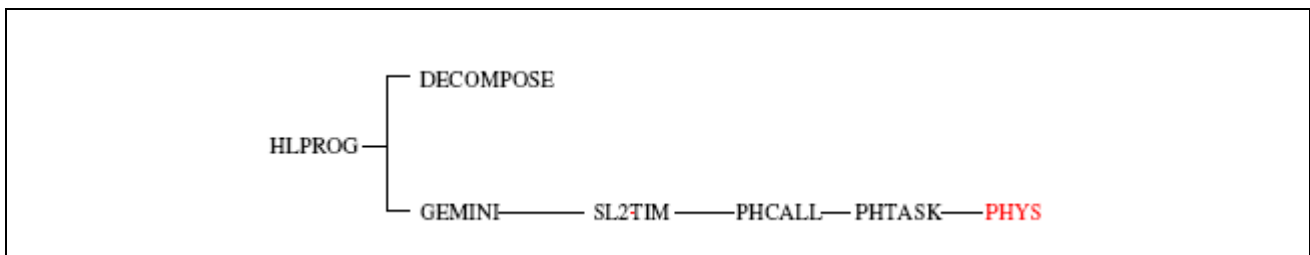

Figure 1: Schematic calling sequence of the HIRLAM physics

32/64 bit mode

As discussed in Ketelsen (2006a) it proves necessary to compile HIRLAM in a 32/64 bit version in order to avoid conflicts with ECHAM, i.e. with 32-bit integers and 64-bit floating point values. This is, however, not immediately possible in the HIRLAM 7.0 reference version due to the implementation of encoding and decoding of GRIB values. To get a 32/64 bit version we therefore established a workaround, where the original HIRLAM routines were combined into a new Fortran 90/95 module (src/gcod/grib_coding.f), which may explicitly be compiled in 32/32 bit mode, while the rest of the model is compiled in the required 32/64 bit mode. A detailed discussion of this may be found in Ketelsen (2006a). Note that later releases of HIRLAM7 are not expected to have this problem, i.e. due to recent work by Jacob Weisman Poulsen, DMI.

Input files

HIRHAM5 requires three sets of input files:

- Boundary files

- Climatology files

- Sea surface temperature (SST) files

In HIRLAM, file input is governed by the subroutines GETDAT and GETGRB. In HIRHAM5 these subroutines are converted and replaced by module procedures in the *mo_GETDAT* (src/grdy/GETDAT.f) and *mo_input_hirlam* (src/prpo/mo_input_hirlam.f90) modules. The code has been modified to read the three sets of input files specified above in the GRIB format with ASI-MOF headers, i.e. as in the HIRLAM7 reference version. Optionally, it is possible to read the boundary files in netCDF (.nc) format as described in Ketelsen (2006b). In the current release the following file names are assumed at run-time (Y = year, e.g. 2057; M = month, e.g. 01; D = day, e.g. 01; H = hour, e.g. 06):

- Boundary files: "d" + YYYY + MM + DD + HH

- Climatology files: "fort.40" (January) to "fort.52" (December)

- SST files: "sst" + YYYY + MM + DD + HH

As mentioned above HIRLAM no longer performs imbedded grid interpolation, and hence all input data are now assumed to be on the right grid.

Output files

In HIRHAM5 the prognostic output is directed to netCDF files, where floating point values are written in 64-bit precision. A dedicated FORTRAN 90/95 module *NetCDF_IO* (src/grdy/NETCDF_IO.f90) handles netCDF IO in the "HIRLAM context". A detailed description of this module is given in Ketelsen (2006b).

Similarly, diagnostic IO is written to netCDF files using the *mo_put_NetCDF* module (src/grdy/mo_put_NetCDF.f90). Optionally, the diagnostic data may also be written in GRIB format using the inherent HIRLAM subroutine PUTDAT (src/grdy/PUTDAT.f). To enable GRIB output the pre-processor directive *#ifdef DIAG_GRIB* must be activated.

In either case diagnostic output is written in 32-bit precision in order to save disc space.

Restart

Since HIRLAM is a forecast model it does not require "restart" functionality. To use the existing control flow for climate model runs, a number of modifications were therefore introduced into the main time loop (src/grdy/GEMINI.f):

- A new name list now passes information from the run script to the executable at run-time, e.g. the name of the current restart file, the time step increment for restart, and the current restart time step.

- Branching between "cold start" and restart of the model.

- The required (time dependent) initialization routines are called.

- Model time variables, e.g. IYEAR, are set to the current restart time.

- The arrays corresponding to the boundary data for both time steps are checked, i.e. making sure that they are intact.

- Data from the restart file is input, in netCDF format.

- Data is written to a restart file, in netCDF format.

- "End of job" is output.

All restart IO is carried out by a dedicated FORTRAN module, *hirham5_restart* (src/grdy/hirham5_restart.f90), which is called from the GEMINI subroutine. As mentioned previously the netCDF data is stored in 64-bit floating point precision. In the present model setup all restart data is taken from the *hirlam_data_module* (src/grdy/hirlam_data_module.f), however, this

could change in future releases.

Time control

The overall time control mechanism in HIRLAM has effectively been switched off. It is replaced by an "ECHAM-conformable" method (interface/src/time_control.f90), e.g. which is used to administer the names of input and output files.

No digital filter initialization

The HIRLAM option of digital filter initialization (DFI) is not used in HIRHAM5 and thus should be switched off in the HIRLAM name list file (`ldfi=.f., lnmi=.t.`).

ECHAM 5

As mentioned above the fifth generation of the ECHAM global atmospheric circulation model was completely rewritten in Fortran 90/95 and hence in the current version data is stored in modules. A substantial number of changes have been introduced both in the physics and the numerics of the model compared to previous versions. A complete description of these changes can be found in Roeckner et al (2003).
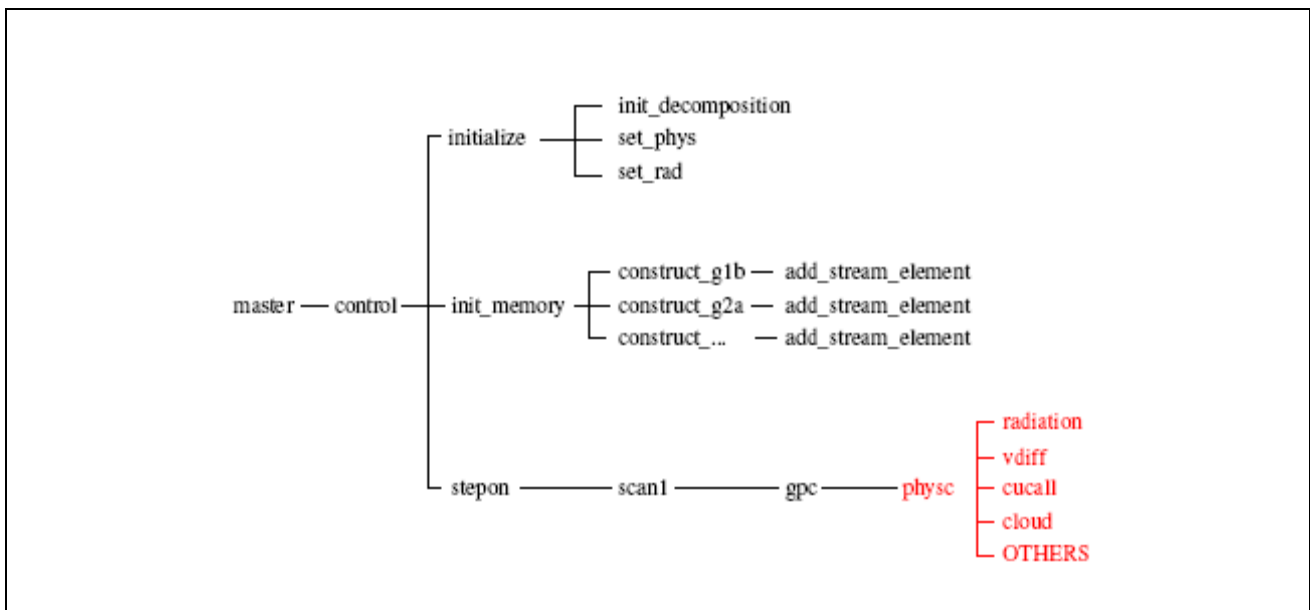
Figure 2: Schematic ECHAM5 calling sequence

Figure 2 shows a schematic overview of the ECHAM5 calling sequence, listing only the significant subroutines. The interface to the ECHAM5 physics is the subroutine *physc*, which in the HIRHAM5 context replaces the HIRLAM equivalent, cf. Figure 1. Like HIRLAM the physics works on column data, however, the ECHAM5 reference version supports only three <u>fixed</u> sets of vertical levels: 19, 31 and 60 levels. Assuming that the number of vertical levels used in the combined

model system conforms to this, virtually no changes are needed in the reference version save for a few bug fixes and modifications to argument lists (Ketelsen, 2006a). In the case of a different number of vertical levels the modules *mo_cumulus_flux.f90* and *mo_cloud.f90* must be modified.

ECHAM5 has been parallelized using MPI in a similar manner to HIRLAM, e.g. column data is local to the MPI processes. In order to avoid conflicts in the MPI setup of the two models, however, we use ECHAM5 only in serial mode, since the physics of the ECHAM5 model does not actually need MPI communication. Thus, when running the combined HIRHAM5 model system in parallel, every "HIRLAM" MPI-process will use ECHAM5 as a serial model on its own sub-domain, i.e. there is a global ECHAM5 domain on every MPI process.

The HIRLAM-ECHAM interface

Ideally, the HIRLAM-ECHAM interface should allow for a "clean" interchange of the *PHYS* subroutine in HIRLAM with the *physc* subroutine in ECHAM5. To make this feasible the interface layer simulates the full ECHAM5 environment, i.e. minimizing the number of changes needed in either of the reference codes.

The interface is implemented in the *mo_echam5_phys* module (interface/src/mo_echam5_phys.f90) and its schematic structure is shown in Figure 3.

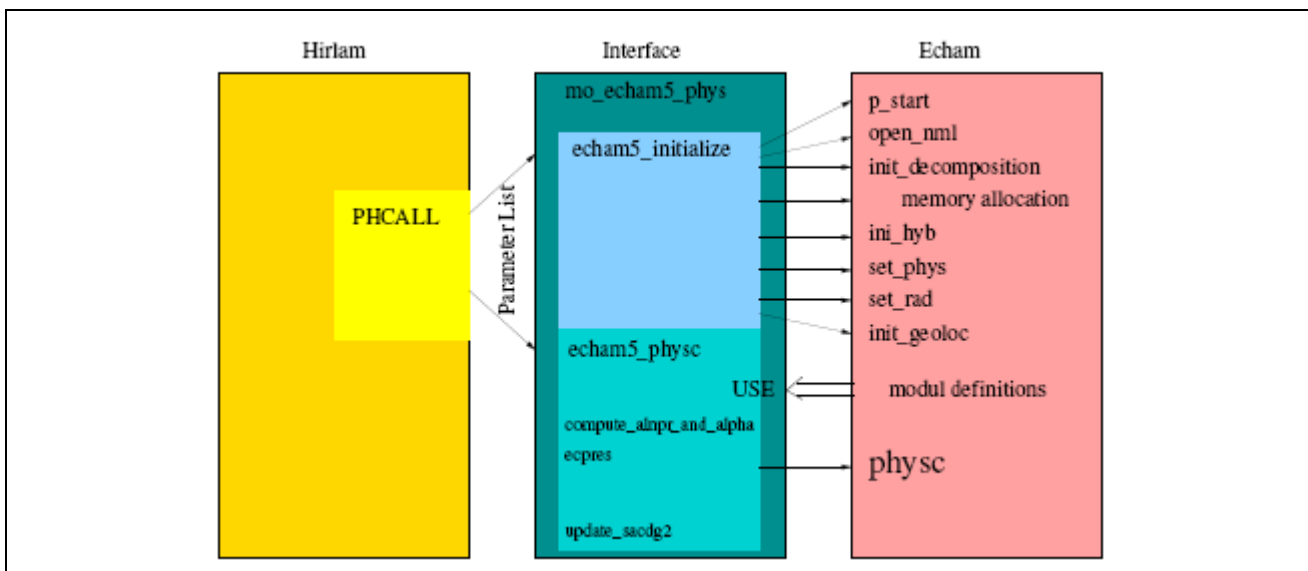Figure 3: HIRLAM-ECHAM interface scheme

The interface module consists of two subroutines, *echam5_initialize* and *echam5_physc*, which effectively replace the call to the PHCALL subroutine in the HIRLAM context. The former sets up the ECHAM5 environment and is called only when the model is started:

- General information about the model setup e.g. size and domain decomposition is copied to ECHAM5 modules.

- Setup and initialization routines required by ECHAM5 physics are called.

- Memory initialization routines required by ECHAM5 are called.

The *echam5_phys* subroutine, i.e. the front end of *physc*, is called at every time step and collects the required parameters from the HIRLAM environment. These parameters are then copied to the appropriate ECHAM5 data modules before the call to *physc*. Finally, the physics output data are copied back into the HIRLAM environment.

Installing the model

This section describes how to install and build HIRHAM5. Presently, the model runs on the NEC SX6 system, where the executable is built using the *sxmpif90* and *sxc++* cross compilers and the *sxmake* utility. To build the executable requires a full netCDF library, version 3.6 or newer.

Directory structure

The layout of the source code of the HIRHAM5 model is shown schematically in Figure 4. The content of the ECHAM directory is identical to that of the reference version of the ECHAM5 model and will not be discussed here.

/hirham5	/echam5.2.02	Makefile … /include /lib /modules /source /…	
	/hirlam_7.0	/include	… Makefile *hlprog** …
		/src	/gcod /grdy /grw1 /phys /port /prpo /tsfs /util /vari
		…	…
	/interface	/lib /src	… Makefile mo_echam5_phys.f90 mo_phys_data.f90 time_control.f90 …

Figure 4: HIRHAM5 directories

The HIRLAM directory contains the stripped down HIRLAM7 source code with the modifications discussed above. The original code is written in Fortran 77, while added code modules are written in Fortran 90/95. The built HIRHAM5 executable, *hlprog*, is located in the /src directory.

The /interface directory contains all the main components of the HIRLAM-ECHAM interface, e.g. initialization, parameter passing between the two environments and time control.

Compiling

Assuming that the HIRHAM5 source code has been installed as shown above, the following procedure is used to build the executable, i.e. *hlprog*.

1. First build the ECHAM5 library. This is done from the command prompt in the /interface/src directory by typing

```
> sxmake echam_lib
```

The ECHAM5 library <u>must</u> be compiled with the following options: `-Wf,-A idbl4,-DNOMPI`, i.e. with standard 32-bit (integer) variables and 64-bit floating point variables. MPI is deactivated as discussed above. The resulting library, *libecham.a*, is installed in the /interface/lib directory. Note that the ECHAM5 data and subroutines are never referenced directly from HIRLAM but only through the interface.

2. Next, build the interface layer. This is done from the command prompt in the /interface/src directory by typing

```
> sxmake interface
```

During compilation all the ECHAM5 module information must be available (`-I` compiler switch). The object files of the interface layer are subsequently installed in the /interface/src directory.

3. Finally build the HIRHAM5 executable. This is done from the /hirlam_7.0/src directory, where the executable is also installed:

```
> sxmake hlprog
```

The present HIRHAM5 executable is built with the following flags:

```
-Wf, -A idbl4                        -DBLAS
-DNEC                                -DSCOPY=dcopy -Dscopy=dcopy
-USX                                 -DSGEMM=dgemm
-DWORDRECLEN                         -DMPI_SRC
-DPREC32                             -DGC
-DFLP_64B                            -DMPI_REAL=MPI_DOUBLE_PRECISION
-DINIPHY=iniphy_h                    -DECHAM5_PHYS
```

The following run-time libraries are linked: BLAS, LAPACK, ECHAM5, and netCDF. Note that the BLAS library is likely to be obsolete in a future release of HIRHAM5.

Running the model

In the following we describe briefly how to run the HIRHAM5 executable, i.e. on a NEC SX6 system.

Input

In order to run the model, the following files with forcing data must be prepared in the correct format and on the correct grid:

-    Climatology files (GRIB/ASIMOF): "cl00010000" ... "cl00120000" (12 files).

-    Sea surface temperature files (GRIB/ASIMOF): "sstYYYYMMDDHH" (e.g. daily values).

-    Boundary files (GRIB/ASIMOF or netCDF): "dYYYYMMDDHH" (e.g. 6 hourly values).

-    RRTA data (ASCII; coefficients required by ECHAM5): "rrtadata".

In addition a number of input name lists are needed. These are generated by a run script.

Run script

The HIRHAM5 run script always contains at least four parts as exemplified by Figures 5(a-d). In the following the directory containing the HIRHAM5 source code, e.g. /hirham5, is assumed to be the root directory ($HOME). Comments are shown in red, while the tag <FIXME> is used to designate user defined input.

The first part of the run script, cf. Figure 5a, sets up the environment for running the simulation. All the data files, e.g. boundary files, are symbolically linked in the working directory, so they are referred to by the file names assumed by HIRHAM5, i.e. as listed above. The number of processors

used for the run and the size of the model region is also set here. Finally, directives for submitting the run to NEC SX6 are defined.

The second part, cf. Figure 5b, prepares the HIRHAM5 (time control) name list, defining the start date of the simulation.

The last two parts initialize the HIRLAM and ECHAM environments in the context of a climate model run, i.e. as shown on Figures 5c and 5d. A comprehensive discussion of this will be deterred for a later publication.

```
# *** Shell ***
#!/bin/bash

# *** Prepare for submitting run to NEC SX6 ***
#PBS <FIXME>
…

# *** Environment ***
export NPROC=1                      # Single processor run
export MPIPROGINF=YES

# *** Define size of model region ***
NLON=110                            # Horizontal grid points = NLON * NLAT
NLAT=115
NLEV=19                             # Vertical levels = NLEV

# *** Directories ***
HOME=<FIXME>/hirham5                # HIRHAM5 root
BINARIES=$HOME/hirlam_7.0/src       # Location of HIRHAM5 executable
RUNDIR=$HOME/run                    # Run directory
WORK=$RUNDIR/work                   # Working directory
DATADIR=$RUNDIR/data                # Output directory
RRTADIR=$RUNDIR/data                # Input directories
SSTDIR=$RUNDIR/sst
BNDDIR=$RUNDIR/boundary
CLIMDIR=$RUNDIR/climate
HOST=`hostname 2>/dev/null`         # Host

# *** Clean working directory ***
rm -rf $WORK
mkdir -p $WORK
cd $WORK

# *** Create symbolic links to SST files (GRIB/ASIMOF) ***
ln -s $SSTDIR/<FIXME> sst<FIXME>
…

# *** Create symbolic links to climatology files (GRIB/ASIMOF) ***
ln -s $CLIMDIR/cl00010000 fort.41
ln -s $CLIMDIR/cl00020000 fort.42
ln -s $CLIMDIR/cl00030000 fort.43
ln -s $CLIMDIR/cl00040000 fort.44
ln -s $CLIMDIR/cl00050000 fort.45
ln -s $CLIMDIR/cl00060000 fort.46
ln -s $CLIMDIR/cl00070000 fort.47
ln -s $CLIMDIR/cl00080000 fort.48
ln -s $CLIMDIR/cl00090000 fort.49
ln -s $CLIMDIR/cl00100000 fort.50
ln -s $CLIMDIR/cl00110000 fort.51
ln -s $CLIMDIR/cl00120000 fort.52

# *** Create symbolic links to boundary files (here: GRIB/ASIMOF; could also be netCDF) ***
ln -s $BNDDIR/<FIXME> d<FIXME>
…

# *** Copy RRTA data file to the working directory ***
cp $RRTADIR/rrtadata .

# *** HIRLAM internal files (REQUIRED) ***
( cd $WORK && ln -s fort.97 ts )
( cd $WORK && echo " $WORK" > fort.99 )
```

Figure 5a: HIRHAM5 run script, part 1. Environment and data files.

```
# *** Prepare HIRHAM5 name list (hirham5.nml) ***
cat > hirham5.nml << EOF
&TimeControl
  start%year=<FIXME>,
  start%month=<FIXME>,
  start%day=<FIXME>,
  start%hour=<FIXME>,
/
EOF
```

Figure 5b: HIRHAM5 run script, part 2. HIRHAM5 name list.

```
# *** Prepare HIRLAM name list (input.txt) ***
cat > input.txt << EOF
 &namprc
 npbpts=0,
 iacdg2=16,
 iruns=1,
 nprocx=1, nprocy=$NPROC,
 klon_global=$NLON, klat_global=$NLAT,klev_global=$NLEV,
 NHORPH=511,
 KSVAR=1,
 LSERIAL=.false.,
 nhalo=6,
 /
 &namdev
      lunaml=  5,
      lusfil= 14,
      lundig= 2,
      lubfi1= 14, lubfi2= 16,
      luhfi1= 2,
      luntun=  5,
 /
 &namrun
      nexp= 1,
      nstop= 24,  ndtime=600,  eps= 0,
      ldfi=.f., lnmi=.t.,
      nwtime=0,1,2,3,4,5,6,12,18,24,30,36,42,48,54,60,66,72,
      nbdpts=10,  nltanh=.t.,  nlpwei=.f.,
      nleul=.f.,  nlsimp=.t.,  nlslan=.t.,
      sip0=101320.0,
      nltvir=.t.,  nlhumc=.t.,  nlstat=.t., nlstph2d=.t.,
      nlhdif=.t.,  nltcrf=.t.,  ak4=0.8,
      ak4lev= 40*1.0,40*1.0,40*1.0,40*1.0,40*0.0,
      nslinc= 4,  nslind= 4,  nslpqi= 1,  nslint= 1,2,3,
      noption=1,1,2,2,16*0,
      nlsl3d=.t.,  nslext= 2,
      ndtphys=600, ndtvdif=600, ntimesu=3599,nldynvd=.f.,
      epsg=0.1,  epsn=0.1,
      nldifu=.t.,  ndifu=6,     cdifu=40*1.,
      nldifv=.t.,  ndifv=6,     cdifv=40*1.,
      nldift=.t.,  ndift=6,     cdift=40*1.,
      nldifq=.t.,  ndifq=6,     cdifq=40*1.,
      nldifs=.t.,  ndifs=6,     cdifs=40*1.,
      nldifx=.t.,  ndifx=6,     cdifx=40*1.,
      nwmosv=200,
      nlusug=.f.,
 /
 &nampos
      nppstr=0, lunlis=  5, lundip= 71, lposton=.f.,
      lprint=.f., iprint= 10, jprint= 10, lomega=.t.,
 /
 &namppp
      npplonp=$NLON,  npplatp=$NLAT,  iminppp=1,jminppp=1,
      lunarcp=-1, lunppfp=80, lintypp='L',
      prefixp='fc', sufixp='md',hisnam='fc',
      timeppp=0,10800,21600,43200,64800,86400,108000,129600, 151200,172800,
      ntimepp=10,
      nlevmlp=40,    ltypmlp=109,
      nwmomlp=3,
      iwmomlp=006,039,071,
      nslp=41,
      iwmoslp=001,001,006,
              011,086,011,086,
              011,091,
              011,017,033,034,051,052,
              054,061,062,063,065,066,067,071,076,078,079,
              083,164,168,169,
              112,111,115,117,121,122,124,125,
              113,114,117,
      ltypslp=103,105,105,
              105,105,105,105,
              102,102,
              105,105,105,105,105,105,
              105,105,105,105,105,105,105,105,105,105,105,
              105,105,105,105,
              105,105,105,105,105,105,105,105,
              008,008,008,
```

```
         alevslp= 0., 0., 0.,
                  999.,999.,0., 0.,
                     0., 0.,
                     2., 2.,10.,10., 2., 2.,
                     0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,
                     0., 0., 0., 0.,
                     0., 0., 0., 0., 0., 0., 0., 0.,
                     0., 0., 0.,
 /
 &namppp
      npplonp=$NLON,  npplatp=$NLAT,  iminppp=1,jminppp=1,
      prefixp='fc', hisnam='fc',
      sufixp='ve',
      lunarcp=-1,  lunppfp=90,  lintypp='L',
      ntimepp=3,
      timeppp=0,21600,43200,
      nlevmlp=10,   ltypmlp=100,
      alevmlp= 10000.0,20000.0,25000.0,30000.0,40000.0,50000.0,70000.0,85000.0,92500.0,100000.0,
      nwmomlp=8,
      iwmomlp=006,011,017,039,052,033,034,076,
      nslp=0,
 /
 &namppp
      npplonp=$NLON,  npplatp=$NLAT,  iminppp=1,jminppp=1,
      prefixp='fc', hisnam='fc',
      sufixp='ve',
      lunarcp=-1,  lunppfp=81,  lintypp='L',
      ntimepp=5,
      timeppp=0,10800,21600,32400,43200,
      nlevmlp=0,
      nwmomlp=0,
      nslp=14,
      iwmoslp= 006, 001, 001, 011, 017, 033, 034, 052, 061, 071, 066, 065, 011, 081,
      ltypslp= 105, 103, 105, 105, 105, 105, 105, 105, 105, 105, 105, 105, 105, 105,
      alevslp=  0.,   0.,   0.,   2.,   2.,  10.,  10.,   2.,   0.,   0.,   0.,   0.,   0.,
 /
 &namtsf
      ifreqa = 1, zlona(1) = 5.34, zlata(1) = 52.17
      ifreqb = 1, zlonb(1) = 5.34, zlatb(1) = 52.17
 /
 ,G45'
 &namini
      ndfi=3, nfilt=7,
      nitdfi=1,idfi=.t.,lunfgs=15,
      incmod=1,tspan=7200, taus=10800, dtini=600,
      nbdpts_ini=4, nltanh_ini=.f.,
      nmodes = 4, nitnmi = 3, noption_nmi = 0,1,0,0,16*0,
      nlphys_bwd=.false.,
      noption_bwd=1,0,2,2,16*0,
      noption_fwd=1,1,2,2,16*0,
      nlbrel = .f.,ndfsft = 1,lbdyswap = .t.,
      nldifu_bwd=.f.,  ndifu_bwd=6,     cdifu_bwd=${NLEV}*-1.,
      nldifv_bwd=.f.,  ndifv_bwd=6,     cdifv_bwd=${NLEV}*-1.,
      nldift_bwd=.f.,  ndift_bwd=6,     cdift_bwd=${NLEV}*-1.,
      nldifq_bwd=.f.,  ndifq_bwd=6,     cdifq_bwd=${NLEV}*-1.,
      nldifs_bwd=.f.,  ndifs_bwd=6,     cdifs_bwd=${NLEV}*-1.,
      nldifx_bwd=.f.,  ndifx_bwd=6,     cdifx_bwd=${NLEV}*-1.,
      nldifu_fwd=.t.,  ndifu_fwd=6, cdifu_fwd=${NLEV}*1.,
      nldifv_fwd=.t.,  ndifv_fwd=6, cdifv_fwd=${NLEV}*1.,
      nldift_fwd=.t.,  ndift_fwd=6, cdift_fwd=${NLEV}*1.,
      nldifq_fwd=.t.,  ndifq_fwd=6, cdifq_fwd=${NLEV}*1.,
      nldifs_fwd=.t.,  ndifs_fwd=6, cdifs_fwd=${NLEV}*1.,
      nldifx_fwd=.t.,  ndifx_fwd=6, cdifx_fwd=${NLEV}*1.,
      nlhdif_bwd=.f.,nlhdif_fwd=.f.,
 /
 EOF
```

Figure 5c: HIRHAM5 run script, part 3. HIRLAM setup.

```
# Prepare namelist for ECHAM5 physics (namelist.echam)
cat > namelist.echam << EOF
&runctl
  out_filetype = 1                 ! 1 - GRIB1, 2 - netCDF
/
&PHYSCTL
  LRAD     = TRUE
  LVDIFF   = TRUE
  LCONV    = TRUE
  LMFPEN   = TRUE
  LCOND    = TRUE
  LGWDRAG  = FALSE
  LSURF    = TRUE
  LICE     = TRUE
  ICONV    = 1
/
&radctl
  io3      = 2                     ! Spectral climatology, as in  ECHAM4
/
EOF
```

Figure 5d: HIRHAM5 run script, part 4. ECHAM5 setup.

Output

HIRHAM5 produces two sets of output files:

-   The forecast data files. These files are preceded by the prefix "fc_" and are in netCDF format
    with 64-bit floating point values.

-   Run diagnostics. These files are using 32-bit floating point values and are in either GRIB or
    netCDF (default) format.

Finally, run-time diagnostics is printed to the "standard out" unit during program execution.

Example run

To validate HIRHAM5 the model was run in a test setup over Europe and compared with an
equivalent simulation performed using HIRHAM4. Figures 6-8 shows the comparison for three
important prognostic meteorological variables: the 2-meter temperature, mean sea level pressure
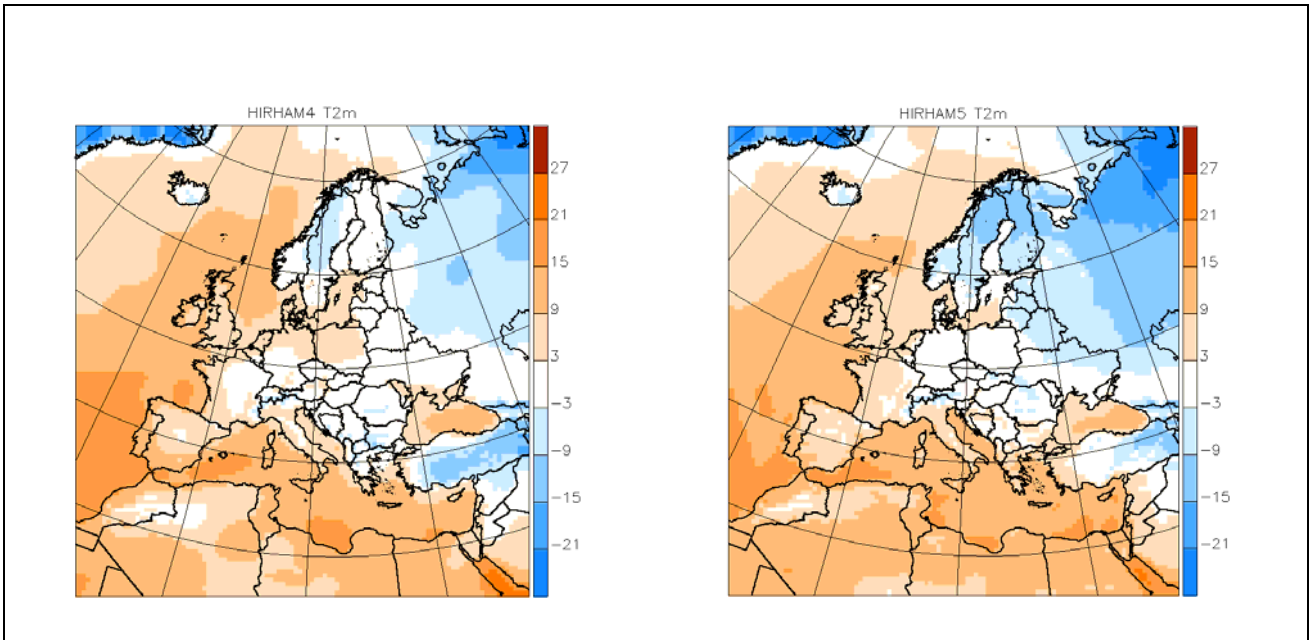and precipitation. In all three cases roughly the same results are obtained as would be hoped for.

Figure 6. The 2-meter temperature (T2m) for Europe, in degrees Celsius for a January situation. The left column shows the result of a HIRHAM4 simulation, the right column the equivalent result for HIRHAM5.
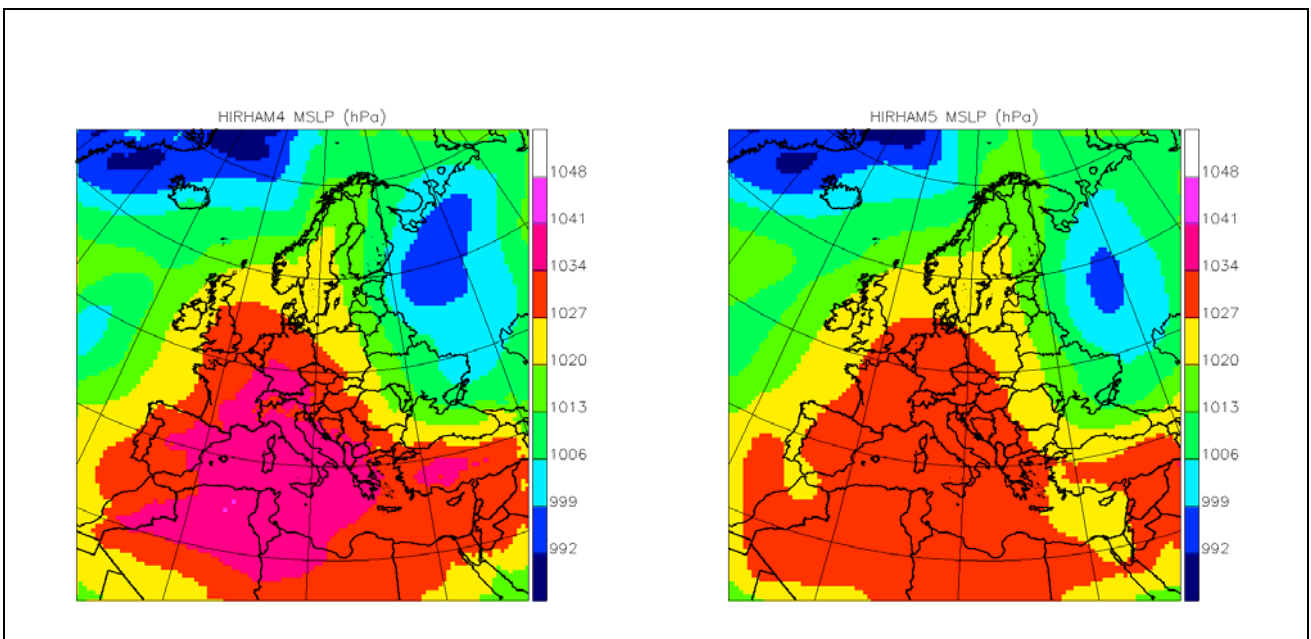

Figure 7. Mean sea level pressure (MSLP) for Europe, in hPa. The figures show results from equivalent HIRHAM4 (left) and HIRHAM5 (right) simulations.
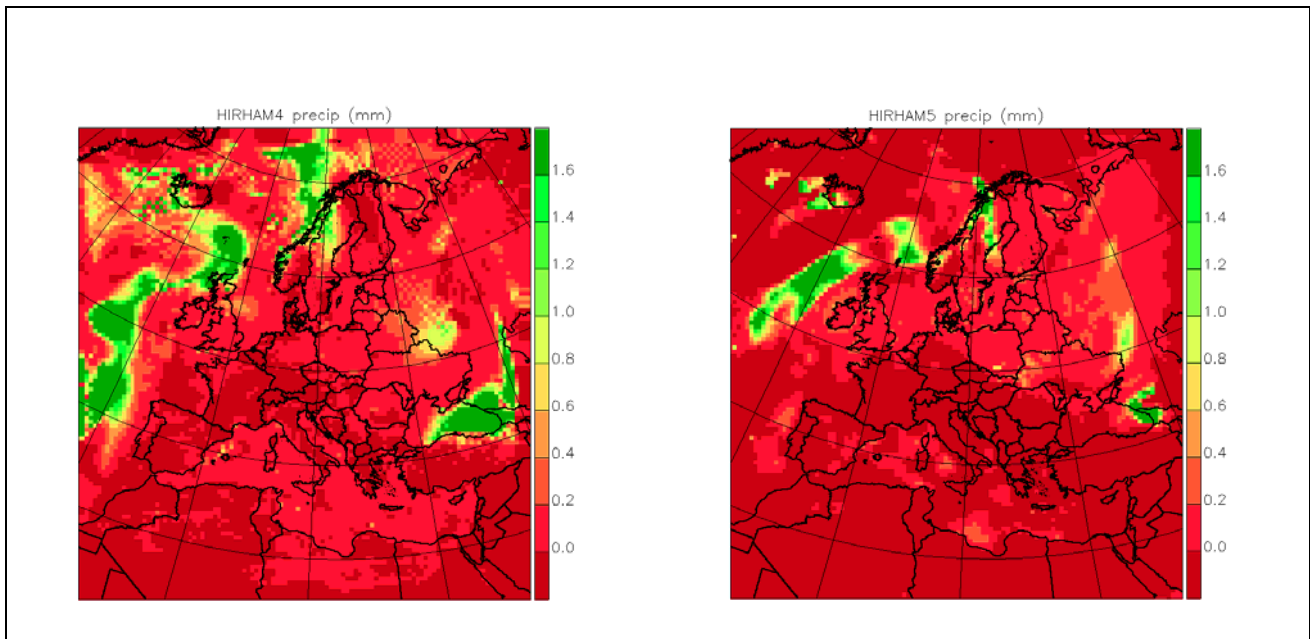
Figure 8. Precipitation for Europe, in mm. The figures show forecasts from equivalent HIRHAM4 (left) and HIRHAM5 (right) simulations.

Acknowledgements

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