5 Changes to the Model System

In this section, important changes to the LM-system which have been introduced during the last year are briefly described, and the possible impact on the forecast products are summarized. Of course, changes in the host model GME can also have a significant impact on the LM forecasts. Important changes to GME and its data assimilation are summarized below.

- The global analysis is now using PAOB data to improve the GME analysis and forecast in the southern hemisphere. PAOBs (bogus data of sea surface pressure) are provided by the Australian Met. Service based on surface observations and images of polar orbiting satellites. The data are available for 00 and 12 UTC and consist of about 400 "observations" daily. PAOBs are used by the GME data assimilation scheme over the oceans and in extratropical regions only (December 2002).
- An improved quality check for humidity observations of SATEM data has been introduced in the global data assimilation. Before, almost all observations, even "out-layer" were able to enter the humidity analysis of GME. Flagging those observations which differ from the 3-h first guess by more than 40% improved the global analysis and forecasts by up to 6 hours beyond day 5 (March 2003).
- Some modifications have been introduced to the snow depth analysis and the SST analysis schemes. For the new (planned) prognostic treatment of sea ice in the GME, the SST now allows to modify the predicted values of sea ice cover, ice thickness and ice surface temperature according to analyzed values. The global snow depth analysis now uses the NOAA snow cover analysis once a day to adapt the first-guess snow depth in regions with no measurements. For a more realistic estimate of the snow albedo, a new variable has been introduced, the "fresh snow factor" (September 2003).
- Cloud ice content is introduced as a new prognostic variable (in both GME and LM) allowing for a better description of upper-air atmospheric humidity and of the cloud–radiation feedback (September 2003).
- The operational global data assimilation now uses also MODIS data. These are wind vectors in polar regions which are derived from measurements of the "Moderate Resolution Imaging Spectroradiometer" instrument of the polar orbiting Terra and Aqua satellites. An impact study has shown a neutral impact of these data for the northern hemisphere, but a noticeable positive impact for the southern hemisphere (December 2003).
- Since 17 December 2003, the GME data assimilation runs with Pseudo-Temps derived from ECMWF IFS-fields. Pseudo-Temps are vertical profiles of temperature, wind and humidity, which are calculated over sea (at about 9150 points) and over the antarctic region (350 points) from ECMWF analyses at 00 UTC. The spatial distance of this "observations" is about 190 km, and they are assimilated similar to radiosonde data. In the GME data assimilation cycle, Pseudo-Temps are included once a day in the final 00 UTC analysis to improve the first guess for the main runs. Parallel assimilation experiments for the spring period 2003 and for the autumn/winter period 2002/2003 revealed a significant positive impact on GME forecasts.

For more detailed information on changes to GME and its data assimilation, please refer to the *Quarterly Report of the Operational NWP-Models of the Deutscher Wetterdienst* (available at `www.dwd.de`).

5.1 Major Changes to LM

Cycle 3 of the LM software library lm_f90 was introduced in February 2003. The model version 3.1 was defined as the latest reference version, containing a number of new features and significant changes to the model code as e.g. the implementation of a new multi-layer soil model, the Kain-Fritsch convection scheme, the SLEVE vertical coordinate, frames as lateral boundary conditions, a scheme for prognostic treatment of the precipitation phases for optional use within the 2 time-level integration scheme, and extensions in both the nudging analysis scheme and the model diagnostic output.

During 2003/04 a number of updates have been introduced. The changes up to version 3.7 are described below. The main features are – besides code optimization and bug corrections – a new option to assimilate GPS data, a new version of the multi-layer soil model with modified organization and data handling, the implementation of prognostic precipitation within the Leapfrog time integration scheme, the introduction of a new dynamical core using 3rd-order Runge-Kutta time integration, and the generation of synthetic satellite images using the RTTOV library.

Notes on lm_f90 Version 3.1

This version was created on 3 February 2003. It is formal identical to the version 2.19 from October 2002.

Notes on lm_f90 Version 3.2

This version was created on 7 February 2003. The cloud ice threshold for autoconversion is set to 0 (in subroutine `hydci` of module `src_gscp.f90`), to improve the performance of the cloud ice scheme (analogous to changes made for the global model GME).

Besides, some optimizations have been performed in the communications. The computations for the horizontal diffusion, which are identical in the leapfrog-scheme and the 2timelevel scheme have been put to a new external subroutine `hori_diffusion.f90`.

Also, it is now possible to work with boundary data defined on frames and with Rayleigh damping. For that, a new NAMELIST variable `ilevbotnoframe` has been introduced. For the first `ilevbotnoframe` levels, the boundary data has to be specified for the full grid. (These changes are based on the work of Lucio Torrisi, UGM Rome).

Notes on lm_f90 Version 3.3

This version was created on 22 April 2003. It introduces the option to assimilate GPS data, the possibility to use bias-corrected radiosonde humidity, and a bug correction on output fields used for operational postprocessing.

- Nudging of GPS data:
  Introduction of an option to assimilate integrated water vapour (TQV) from ground-based GPS data. The GPS observations are read from a dedicated ASCII file named 'gps' in COST 716 format. 'Observed' humidity profiles derived from TQV by scaling model humidity profiles are nudged like radiosonde humidity profiles. (The horizontal correlation scale is set to a fixed value of 0.45 of that used for radiosondes.) The following new NAMELIST variable have been defined.

Parameter	Definition / Purpose
`gnudggp`	Nudging coefficient for GPS data
`maxgpo`	Maximum number of GPS data
`lgps`	Data of observation type GPS used in exclusion area
`lcd096`	Data of code type GPS used in exclusion area
`lgpsbias`	Bias correction applied to GPS data

Note that the NAMELIST of previous versions does not need to be changed as long as GPS data are not used.

- Nudging:
  Additional code number in instrument specification for reports with bias-corrected (Vaisala RS80) radiosonde humidity. The bias correction itself is done in MAKEAOF / BUFR2AOF.

- Bug corrections:
  An error in the routine `calclmod` of module `pp_utilities` to calculate a modified cloud cover being used for operational graphical presentations was corrected.

Notes on lm_f90 Version 3.4

This version was created on 25 June 2003. It contains small changes in the Tiedtke convection scheme (`src_conv_tiedtke.f90`) to suppress "convective drizzle". A minimum moisture convergence and a minimum grid-scale lifting are now used to initiate moist convection and the formulation of precipitation formation in the updraft has been changed.

Notes on lm_f90 Version 3.5

This version was created on 2 September 2003. It contains changes to the interpretation of cloud cover and to the model diagnostics, an implementation of the total zenith delay (for GPS assimilation) and a number of optimizations for the communications.

- Interpretation of cloudiness:
  A modification in the radiation scheme related to the interpretation of cloud cover when running with the cloud ice scheme has been introduced. The formulation has also been adapted to the global model GME.

- Restructuring of the diagnostics (the YU* files):
  The modules `src_diagnosis.f90` and `src_differences.f90` have been eliminated from the source code, because the corresponding options have not been applied by most of the users. Note:
  All NAMELIST variables for these routines have to be removed from the NAMELIST group `/DIACTL/`. These are `ldia`, `n0dia`, `h0dia`, `nincdia`, `hincdia`, `istartdia_tot`, `jstartdia_tot`, `ienddia_tot`, `jenddia_tot`, `ldiffdia`, `n0diffdia`, `h0diffdia`, `nincdiffdia`, and `hincdiffdia`.

- Gridpoint output:
  The grid point output (long and short form) has been adapted to include cloud ice and to use new (English) variable names. Note that the format of the short and long grid point output forms has also been changed.

- Implementation of zenith total delay:
  A routine `calztd` has been added to the module `pp_utilities.f90` to compute the total (ZTD), the wet (ZWD) and the hydrostatic (ZHD) zenith delay for the GPS signal through the atmosphere (ZTD = ZWD + ZHD). All 3 variables can be chosen as additional GRIB output fields. They are implemented in the DWD GRIB table 202 as element numbers
  121: ZTD, 122: ZWD, 123: ZHD
  with level type = 1 (two-dimensional fields).

- Optimizations for the communications:

  – The global communication in the radiation scheme for computing the maximum of `zmaxmu0` has been eliminated by computing `zmaxmu0` for a whole latitude in every processor.

  – The two global communications in routine `org_leapfrog` have been combined into one call.

  – The boundary exchange for the surface pressure in the main program `lmorg.f90` and in routine `dfi_initialization.f90` has been eliminated. The surface pressure is now computed in routine `near_surface.f90` for the whole domain (before it was computed in `src_relaxation.f90` for the interior domain).

  – In routine `dfi_initialization`, a bug has been corrected for the communication of variables for the convection scheme.

- Optimizations for the boundary exchange:
  Several kinds of performing the communication for the processor boundary data exchange have been implemented.

  – Up to now only an explicit buffering of the data to a sending buffer (`sendbuf`: using routines `putbuf` and `getbuf`) and an immediate send (MPI_Isend) together with a blocking receive (MPI_Recv) has been realized.

    Now there is the choice of the explicit buffering or an implicit buffering by using MPI-datatypes. For every boundary exchange an MPI-datatype is defined and the buffering can then be done implicitly by the system (and at least on the IBM more efficiently).

    The buffering can be chosen with the new NAMELIST parameter `ldatatypes` in the group `/RUNCTL/`:

Parameter	Value	Definition / Purpose
`ldatatypes`	.TRUE.	implicit buffering
	.FALSE.	explicit buffering (this is the default)

  – The exchange can then be done using one of the three kinds:
    1) immediate send, blocking receive and wait on the sender side
    2) immediate receive, blocking send and wait on the receiver side
    3) using MPI_Sendrecv
    The type of communication for the boundary exchange can be chosen by the new NAMELIST parameter `ncomm_type` in the group `/RUNCTL/`, which can be 1, 2 or 3. The default is `ncomm_type` = 1.

  – In addition, most barriers for the time-measurement can now be switched off by setting the new NAMELIST parameter `ltime_barrier` to .FALSE. The default is `ltime_barrier` = .TRUE. (as it was up to now).

The defaults of the three new NAMELIST parameters are set in a way that the boundary exchange is done in the same way as before:
(ldatatypes = .FALSE., ltime_barrier = .TRUE. and ncomm_type = 1).

The new options can be tested on every machine to check if a gain in runtime performance can be achieved. On the IBM we see a gain in forecast mode of up to 10 percent by setting
ldatatypes = .TRUE., ltime_barrier = .FALSE., ncomm_type = 3.

Notes on lm_f90 Version 3.6

This version was created on 11 December 2003. It contains changes to the new soil model, the digital filtering algorithm, the data assimilation and a number of optimizations for vector computers.

- New multi-layer soil model:
  Besides an updated version of `src_soil_multlay.f90`, the whole organization and data handling for the new multi-layer soil model has been changed.
  - The new variables `T_SO`, `W_SO` and `W_ICE` are coded with leveltyp 111 and octet(8) of the product definition section (is pds(10)) gives the depth of the layer in centimeters.
    NOTE: At DWD the first layer is chosen to be in the depth of 0.5 cm. This cannot be coded correctly, so it will be coded with 1 cm.
  - The multi-layer soil model can be switched on by setting the following NAMELIST variables (in group /PHYCTL/):
    lmulti_layer =.TRUE.,
    ke_soil = 7,
    czml_soil = 0.005, 0.02, 0.06, 0.18, 0.54, 1.62, 4.86, 14.58.
    The values for ke_soil and czml_soil are the default values chosen for the global model GME at DWD. The LM must run with the same layers, because there is no vertical interpolation of soil layers yet.
    NOTE: The values for czml_soil are given in meters!
- Digital filtering:
  Some bug corrections in routine `dfi_initialization.f90` have been done. When setting the boundary values for the adiabatic backward integration, there was no check, whether the moisture variables (qv, qc, qi) remain positive definite. With cloud ice (qi) switched on, it could happen that negative values of qi occurred. This is avoided now.

  Also, the possibility to use frames for the boundary values has now been introduced.
- Changes in the data assimilation:
  A new option to assimilate single SATOB winds similarly to aircraft winds has been introduced. Also, modifications to assimilation of GPS-derived Integrated Water Vapour (TQV) have been implemented:
  - new NAMELIST variable rhfgps for horizontal correlation scale,
  - extrapolation below orography for determination of TQV increments,
  - revised ice-to-water correction of TQV (for model version without cloud ice),
  - revised GPS observation error flag in the VOF.

Additionally, some minor bug corrections and modifications within the nudging scheme have been done:

- no further bias correction of Vaisala RS80 bias-corrected humidity data,
- default for NAMELIST variable `tconbox` doubled,
- improved general, statistical, warning, and error messages (and ensuring the printing of error messages at calls of routine `model_abort`).

- Checks of the IOSTAT-values:
  Checks of the IOSTAT-values when reading the NAMELIST-groups have been introduced. These values have not been checked before, but the IBM does not abort when errors occur while reading a NAMELIST group. So the IOSTAT-values are now checked and the program is aborted by routine `model_abort` in case of errors.

  NOTE: For that reason the handling of reading the different groups for `/GRIBOUT/` had to changed! To know how many different groups have to be read by the program, a new NAMELIST parameter `ngribout` (number of different groups `/GRIBOUT/` for GRIB output has been introduced in the group `/IOCTL/`. The default is `ngribout` = 1. If you want to have more groups for `/GRIBOUT/`, you have to change this value.

- Optimizations for vector computers:
  There were some suggestions by NEC (Switzerland and Germany) for optimizations of the LM code when running on vector processors.

  - `src_gscp.f90`
    Most of the power-functions (a**b) have been replaced by EXP-LOG calls (since $a^b = \exp(b \ln a)$). This is faster also on the IBM.
  - `src_sing_spread.f90`
    A loop has been splitted into 2 single loops for better vectorization.
  - `turbtran.incf`
    Modification of 2 DO-WHILE loops in order to enable vectorization of DO-loops contained.
  - `coe_so.incf` and `coe_th.incf`
    In both routines all the loops contained are combined into one single loop. This reduces the number of temporary arrays and memory traffic.

Notes on lm_f90 Version 3.7

This version was created on 18 February 2004. It contains three new features and a number of modifications in the existing code.

The three new features are:

- Prognostic treatment of rain and snow in the default 3 timelevel Leapfrog scheme.
- Additional options for the 2 timelevel Runge-Kutta integration scheme.
- Computation of synthetic satellite images (for Meteosat7 and MSG).

And the modified features are:

- Renaming of some GRIB names (important for NAMELIST input and GRIB I/O).

– Adaptations in the TKE-scheme.

– Choice of precipitation scheme (NAMELIST variable itype_gscp).

– Check of humidity variables and setting to zero, if they are too small.

The new NAMELIST input parameters related to these changes are listed in the following table.

Group	Parameter	Default	Definition / Purpose
RUNCTL	luse_rttov	.FALSE.	to switch on/off the synthetic satellite images
PHYCTL	rat_sea	1.0	laminar scaling factor for heat over sea and land
	lprogprec	.FALSE.	prognostic treatment of rain and snow for 3-timelevel and 2-timelevel integration schemes
	ltrans_prec	.TRUE.	to switch on/off the 3-d transport of rain and snow (if prognostic treatment of precipitation is switched on)
DYNCTL	irunge_kutta	0	for choosing the type of Runge-Kutta scheme
	irk_order	2	choosing the order of the scheme
	iadv_order	3	choosing the order for the horizontal advection
	hd_corr_u	1.0	correction factor for horizontal diffusion flux of u,v,w
	xkd	0.1	coefficient for divergence damping
	lvertad_impl	.TRUE.	for switching on/off implicit vertical advection in the Runge-Kutta-scheme

To be consistent with GME and other models, some GRIB variable names have been changed. This affects the NAMELIST Group GRIBOUT.

Old name	New Name	Meaning
GPH	FI	Geopotential height
IWV	TQV	Total column water vapour
IQI	TQI	Total column cloud ice
IQC	TQC	Total column cloud water
IWATER	TWATER	Total column water
IDIV_HUM	TDIV_HUM	Total column humidity convergence
GZ0	Z0	Dynamical roughness length
ALB	ALB_RAD	Surface albedo
PHI	RLAT	Geographical latitude
RLA	RLON	Geographical longitude

Also some internal variable names dealing with values for latitudes and/or longitudes have been changed for the same reason (rla → rlon, phi → rlat, tgphi → tgrlat, cphi → crlat, acphir → acrlat). In the following, we describe the new features and the modifications in more detail.

- Prognostic treatment of rain and snow
  A Prognostic treatment of rain and snow for use in the 3 timelevel Leapfrog scheme has been implemented. The corresponding budget equations are solved by time-splitting: First, 3-d transport with the wind field is done by a semi-Lagrangian advection scheme (over a $2\Delta t$ time interval); a corresponding transport routine has been implemented in the dynamics. In a second step, the transported variables are then updated due to microphysics and fallout; a corresponding precipitation scheme `hydci_pp` has been added in the module `src_gscp.f90`. The time integration for cloud ice has also been changed: To avoid inconsistencies in the thermodynamic feedback, cloud ice is also advected over a $2\Delta t$ interval from time level $n-1$ to $n+1$ by applying the positive advection scheme twice (this replaces the former hybrid integration, where cloud ice is integrated from n to $n+1$).

  The new scheme can be switched on with the new NAMELIST parameter `lprogprec` (in the group `PHYCTL`). The only possible choice for the microphysics scheme is then `itype_gscp = 3` (see below: treatment of `itype_gscp`). Optionally, the 3-d transport can be switched off by setting `ltrans_prec` to `.FALSE`. In this case, only fallout and microphysical sources and sinks are treated prognostically.

- New Runge-Kutta options in the 2-timelevel integration scheme
  In addition to the existing 2-timelevel scheme in the module `src_2timelevel.f90` (by Almut Gassmann), normal Runge-Kutta variants of 2nd- and 3rd-order in time as well as a slightly more sophisticated 3rd-order TVD-Runge-Kutta (total variation diminishing) scheme have been implemented in the new module `src_runge_kutta.f90`. In contrary to the scheme by Almut Gassmann, the Runge-Kutta time-loop contains the effects of the complete slow tendencies (especially the full 3-d advection is computed in each Runge-Kutta-step). The integration of the small time steps is done in the new routine `fast_waves_rk.f90`. The type of scheme is set with the new NAMELIST-Parameter `irunge_kutta`:

  0: Scheme by Almut Gassmann,
  1: Normal Runge-Kutta scheme,
  2: TVD Runge-Kutta scheme.

  In case of the normal Runge-Kutta scheme (i.e. only for `irunge_kutta=1`, the order in time can be chosen from 1st, 2nd and 3rd order by setting the new NAMELIST-Parameter `irk_order` correspondingly (value: 1, 2 or 3). For the TVD-scheme, only the 3rd-order in time variant is possible.

  In addition, the order in space of the operator for the horizontal advection of the variables u, v, w, pp and T can be chosen from 3rd, 4th, 5th and 6th order space discretization by setting the NAMELIST-Parameter `iadv_order` correspondingly (value: 3, 4, 5 or 6).

  At the moment, we recommend the use of the 3rd-order Runge-Kutta TVD-scheme with 5th-order horizontal advection. This scheme is activated by switching the 2-timelevel integration scheme on (with `l2tls=.TRUE.`) and setting `irunge_kutta=2`, `irk_order=3`, `iadv_order=5`.

- Computation of synthetic satellite images (for Meteosat and MSG)
  An interface to the RTTOV7-library (the Radiative Transfer Model) has been introduced into the LM. This interface has been developed at the DLR Institute for Atmospheric Physics in Oberpfaffenhofen. With this interface and the RTTOV7-library it is possible to compute "synthetic" satellite images (brightness temperatures and radiances) derived from model variables for Meteosat5-7 and Meteosat Second Generation. The RTTOV7-library has been developed by UKMO et.al. in the framework

of the ESA NWP-SAF. To use the RTTOV7 library, a license is necessary. To switch on/off the computation of the synthetic satellite images, a new NAMELIST Variable `luse_rttov` has been introduced (in group `RUNCTL`). If `luse_rttov=.TRUE.`, an additional NAMELIST group `SATCTL` is read in, in which additional control variables can be set. For a detailed description of the interface and the NAMELIST parameters, see the User Guide (not yet ready).

Besides these new features, some modifications were introduced in the existing schemes. These are described below.

- A NAMELIST variable `rat_sea` has been introduced to set the ratio of the laminar scaling factor for the heat and moisture surface fluxes over sea and land. Default for this variable is `rat_sea = 1.0`. A factor in the computation of the stability-function "sm" (in the file `stab_funct.incf`) has also been changed.
- The treatment of the NAMELIST variable `itype_gscp` to select a specific parameterization scheme for precipitation formation has been changed. Up to now it was as follows.

itype_gscp	Selection	Subroutine	Valid for integration scheme
1	Warm Rain Scheme (diagnostic rain)	kessler	2 and 3 timelevels
2	Rain/Snow Scheme (diagnostic rain and snow)	hydor	2 and 3 timelevels
3	Cloud Ice Scheme (diagnostic rain and snow)	hydci	2 and 3 timelevels
4	As 2, but with prognostic rain and snow	hydorprog	2 timelevels only
5	As 3, but with prognostic rain and snow	hydciprog	2 timelevels only

In order to be more flexible later on and to avoid too many numbers for `itype_gscp` applying for different model set-ups, some new parameters have been introduced. Now the treatment is as follows: Valid values for `itype_gscp` are 1, 2 and 3. Prognostic treatment of rain and snow can be switched on/off with the new NAMELIST parameter `lprogprec`. Depending on the value for `l2tls` (to choose between 2- and 3-timelevel integration scheme), `lprogprec` and `itype_gscp`, the following routines are called:

	l2tls = .FALSE.		l2tls = .TRUE.	
lprogprec:	.FALSE.	.TRUE.	.FALSE.	.TRUE.
itype_gscp				
1	kessler	–	kessler	–
2	hydor	–	hydor	hydorprog (if irunge-kutta = 0)
3	hydci	hydci_pp	hydci	hydciprog (if irunge-kutta = 0) hydor_pp (if irunge-kutta > 0)

Depending on `itype_gscp`, an internal logical switch `lprog_qi` is set, with which the LM will determine, whether cloud-ice treatment is switched on or off.

- In the main program `lmorg.f90`, a check of all humidity variables (qv, qc, qi, qr, qs, qrs) has been introduced: if these variables become too small (< 1.0E-15), they are set to zero.

- A new NAMELIST parameter `hd_corr_u` to control the horizontal diffusion of the wind speeds (default 1.0) has been introduced in the group `DYNCTL`.

In addition, some technical changes have been implemented.

- The optimization of the power functions in `src_gscp` (replaced by EXP(... * LOG(..)) had to be modified. This must only be done, if the argument for the LOG-function is not zero.

- The routine for the boundary exchange (`exchg_boundaries`) has been enlarged to exchange up to 24 variables at the same time.

- A consistent treatment of unit-numbers for ASCII-files has been introduced to avoid that the same unit number is used twice in the model. For that purpose, 2 new routines have been introduced in the module `environment.f90`.

`get_free_unit(iunit)`:	returns a unit-number (between 21 and 100), which is not yet used. If `iunit` < 0, no more free unit number is available.
`release_unit(iunit)`:	sets the unit-number free again.

- The routine `model_abort` (in the module `environment.f90`) has been changed, so that now also processors with id $\neq 0$ can write error messages. But still, if an error in processor 0 occurs, this is the first and only processor that will report the error. All processors with id $\neq 0$ first sleep for 30 seconds. Their processes are either killed by processor 0 or they will report their errors then. If processor 0 gets an error, it will close all files with unit numbers determined by the new routine `get_free_unit`.

Planned Releases

Also in 2004, there will be a number of new model versions – not only due to error corrections and optimizations, but also due to the changes in the new physics packages and changes in the model dynamics. By now, the following releases are planned.

- Code modifications (mainly organizational) to run LM in climate mode
- Optimizations for the new RK3 time integration scheme
- Implementation of new physics for the high-resolution LM
- Code re-organization and optimization of the TKE-scheme
- Code re-organization and optimization of the asynchronous I/0.

5.2 Major Changes to GME2LM

The interpolation program GME2LM has been changed only once in 2003 to modify variables related to the new multi-layer soil model, to do some additional security checks and to optimize the data exchange between processors.

Notes on GME2LM Version 1.18

This version of GME2LM was created on 21 October 2003. It contains changes in the calculation of the new multi-layer soil variables. These variables are now defined on the main levels (half levels before).

More checks when reading the NAMELIST variables have been implemented. When the specified file for the LM external parameters cannot be found, the program aborts now (before, the external parameters have then been interpolated from GME external parameters). Only when the specified file name is 'interpolate', and such a file does not exist, the external parameters still are interpolated from GME.

The boundary exchange for the parallel program has been re-written in the same way as in LM version 3.6. There now is the choice between an implicit data buffering using MPI Datatypes (new NAMELIST variable `ldatatypes` =.TRUE.) or the (old) explicit buffering (`ldatatypes`=.FALSE.)

The exchange can then be done using one of the three kinds:
1) immediate send, blocking receive and wait on the sender side
2) immediate receive, blocking send and wait on the receiver side
3) using MPI_Sendrecv

The type of communication for the boundary exchange can be chosen by the new NAMELIST parameter `ncomm_type` in the group `/CONTRL/`, which can be 1, 2 or 3. The default is `ncomm_type` = 1. (see also LM Version 3.5)