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.

- A new formulation of the dependence of surface fluxes of heat and moisture on wind speed has been introduced; over the oceans, sensible and latent heat fluxes are reduced at higher wind speeds. This damps the tendency of GME for overdevelopments of oceanic cyclones (October 2001).
- The upper air GME analysis is now performed completely in the triangular model grid. Before, an interpolation of the first guess fields to a regular geographical grid resulted in some (unwanted) smoothing. Also, the data assimilation cycle of GME has been reduced from 6 hours to 3 hours with a 1.5 hour observation window. Additional observations, especially from satellite and aircraft, can now be used. This led to an improved analysis in quite a number of cases during the parallel trials (April 2002).
- The calculation of the roughness length over water has been modified again for unstable conditions to yield a better match to available observations of temperature and wind speed during cold air outbreaks. Also, the 'climatological' temperature at a depth of 36 cm in the ground is no longer prescribed as a climatological value, but is taken from the corresponding ECMWF analysis once a day. The use of this new lower boundary condition in the soil model reduced the bias of the 2m-temperature. (April 2002).
- The global analysis of the sea surface temperature (SST) now uses the 0.5°x0.5° SST analysis of NCEP as a background field instead of the coarser 1°x1° NCEP analysis (August 2002).
- A Rayleigh friction has been introduced in the uppermost stratospheric layers to reduce the wind speed of the polar night jet in the southern hemisphere in cases of Courant numbers close to 1, i.e. for a wind speed greater than 170 m/s. This allows to use the same time step throughout the year without the risk of a model blow up. The artificial reduction of the wind speed at the model top showed no adverse impact on the forecast scores (September 2002).

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 2 of the LM software library lm_f90 was introduced in August 2000. The new version resulted from a basic redesign of the code and has a strongly increased modularity. This allows for faster compilation of the code. Also, due to the reduced interdependency of the modules, the simultaneous work on the code by different groups has become much more easy.

During 2002, there have been a number of correction updates of LM. But also a few more significant changes to the model code have been introduced, mainly the implementation of a new multi-layer soil model, the Kain-Fritsch convection scheme, the SLEVE vertical coordinate, frames as lateral boundary conditions, and a scheme for prognostic treatment of the precipitation phases for optional use. Also, a number of improvements have been introduced in other physics and dynamics routines, e.g the 2-timelevel integration scheme, the TKE-based turbulence scheme and the cloud ice scheme. Moreover, the diagnostic output of the model has been extended and revised (snowfall limit, convective wind gusts, cloud cover).

Within the nudging module, a large number of both technical and scientific updates have been introduced, focusing on the use of wind-profiler data and VAD radar winds, and a revised formulation of the nudging of surface pressure data.

Notes on lm_f90 Version 2.13

This version was created on 18 January 2002. It includes several changes to the data assimilation and a few bug corrections in the dynamics.

- Nudging: Introduction of an option to assimilate Wind Profiler / RASS reports.
- Nudging: Adjustment of the treatment of humidity observations in case of the cloud ice scheme option.
- Nudging: Adaptions for default use of 32-bit integers, e.g. by re-organizing station characteristics and main flag words (VOF format revised).
- Nudging: All 'data' statements replaced by direct assignment, to allow for IBM compiler option 'hot'.
- Nudging: Adaptation for IBM: Array elements replaced by reals for intent-in subroutine arguments.
- Surface analysis: Adaptation for IBM: sorting routine replaced (M. Buchhold).
- Dynamics: Array dimensions of the local fields `za1t` and `za2t` in subroutine `slow_tendencies.f90` have been corrected.
- Initialization: Small bug correction in data exchange for the cloud ice scheme.
- Dynamics: Small bug correction for runs without physics.
- General: Correction of error code messaging.

There is no direct meteorological impact, except for model runs using the cloud ice scheme or a large number of vertical levels.

Notes on lm_f90 Version 2.14

This version was created on 15 February 2002. It includes changes related to the cloud ice scheme, introduces the option to use the SLEVE vertical coordinate, and adds the height of snowfall limit as a new diagnostic output variable.

- Changes to the cloud ice scheme
  The coefficient for autoconversion of cloud water to rain has been reduced from 0.0007

to 0.0004 (this value is also used in GME). Also, the interpretation of sub-grid scale cloud water and cloud-ice content was modified (only in case of the cloud-ice scheme switched on) to improve the cloud-radiation interaction.

- SLEVE vertical coordinate
  A hybrid version of the Smooth Level Vertical coordinate (SLEVE) was introduced as a third option for choosing a specific terrain following coordinate. It is activated by setting the global coordinate type parameter `ivctype` to 3. Three additional global parameters have been introduced to define the SLEVE coordinate.

  – `svc1` specifies the vertical decay rate for the large-scale part of the topography (in m, the default value is 8000m).
  – `svc1` specifies the vertical decay rate for the small-scale part of the topography (in m, the default value is 5000m).
  – `nfltvc` specifies the number of digital filter operations to split the topography into a large-scale and a small-scale part (the default value is 100).

  These parameters (including the type parameter `ivctype`) are NAMELIST input of GME2LM and are coded in the grid description section of the LM initial and boundary data GRIB files, from where they are read. In case of user-defined initial and boundary data for idealized cases, the SLEVE parameters must be explicitly specified in the subroutine `src_artifdata.f90`.

- Height of snowfall limit
  The hight of the snowfall limit has been introduced as a new diagnostic output field. In a first step the wet bulb temperature is calculated, and in a second step, the snowfall limit is evaluated as the height where the wet bulb temperature has the value of +1.3°C. GRIB output of this field is achieved by specifying the variable name `SNOWLMT` in the variable list `yvarml` within the input group `/gribout/`.

Besides these changes, some bugs have been corrected and in a routine from the nudging scheme, NEC compiler directives for better vector performance have been inserted.

There is only a small meteorological impact due to bug corrections. In case of running the cloud ice scheme, a slightly larger cloud water content and differences in the cloud-radiation interactions is to be expected.

Notes on lm_f90 Version 2.15

This version was created on 20 March 2002. It includes changes to new TKE-scheme for vertical diffusion and the new surface layer scheme. Besides, a bug related to the check of the input-data grid structure was corrected.

- Changes in subroutine `turbtran.incf`
  Reformulation of the diagnosis of the 10m wind vector according to a different definition using a roughness length `z0m_dia` belonging to a typical SYNOP station. This leads to much larger values at gridpoints with large over all roughness length `z0m`, where according to the previous definition very small inner canopy wind vectors were calculated, which did not match with the measurements at SYNOP stations.
  Also, the roughness length `z0m` is now multiplied by a laminar correction factor which was excluded so far by a command sign. This is more consistent, but has a minor feedback to the model.

- Changes in subroutine `turbdiff.incf`
  Some formal modifications have been introduced in order to make the code more efficient for vector machines. Also, a bug in the calculation of the flux conversion from the system of conserved variables to that of the model variables has been corrected. This flux conversion is used for the explicit correction in the calculation of the heat flux, and has a marginal effect only.

The modifications in the new surface layer transfer scheme has a significant impact on the diagnosed values of 10-m wind. A much better agreement with SYNOP observations in regions with high roughness length (orography, cities) is expected.

Notes on lm_f90 Version 2.16

This version was created on 28 March 2002. It is a pure correction update for version 2.15, as the actual formulation of the momentum fluxes with the roughness length multiplicated by a laminar correction factor became unstable during a test assimilation run. Now, the laminar limit is introduced without touching the value of `z0m`.

Notes on lm_f90 Version 2.17

This version was created on 8 May 2002. It includes a number of code optimizations and a few bug corrections, and introduces two new parameterization schemes, which can optionally be switched on.

- Optimizations to the I/O:
  The communications necessary for distributing and gathering the fields to and from the processors are now done in the format of the irealgrib-KIND, which normally is single precision – instead of double precision. Thus the amount of data send is reduced.

- The new multi-layer soil model:
  The module `src_soil_multlay.f90` has been added to the LM library, which contains the source code for the new multi-layer soil model (see COSMO TR No.2 by R. Schrodin and E. Heise). To switch to the new model, the following NAMELIST variables have been introduced in the input group `/phyctl/`.

Parameter	Definition / Purpose	Default value
`lmulti_layer`	To switch on (off) the new multi-layer soil model	`.FALSE.`
`lmelt`	To switch on (off) the freezing of soil layers	`.FALSE.`
`lmelt_var`	If `.TRUE.`, the soil freezing temperature is dependent on the water content	`.FALSE.`
`ke_soil`	Number of soil layers in the new soil model	7
`czhl_soil`	Array for the depth (m) of the bottom level of each soil layer	0.01, 0.04, 0.10, 0.22 0.46, 0.94, 1.90

- The Kain-Fritsch convection scheme:
  As an alternative scheme to parameterize moist convection, the Kain-Fritsch convection scheme has been implemented. The source code of the scheme and the interface program to the LM is available in the new source-code module `src_conv_kainfri.f90`.

The former module `src_convection`, which contains the Tiedtke-scheme for the convection, has been renamed to `src_conv_tiedtke.f90`. If convection is enabled by setting `lconv = .TRUE`, two new switches have been defined to choose between these two parameterizations in input group `/phyctl/`.

Parameter	Definition / Purpose	Default value
`lkainfri`	To switch on (off) the Kain-Fritsch convection scheme	`.FALSE.`
`ltiedtke`	To switch on (off) the Tiedtke convection scheme	`.TRUE.`

The Kain-Fritsch scheme is switched off by default. At present it is not recommended to use the scheme for operational application, as it requires further evaluation in test experiments.

- Further optimizations and changes:
  In the soil model and radiation scheme, the definition of the land fraction covered by snow and water has been adapted to the GME formulation. Further optimizations for better vectorization have been introduced in the new turbulence scheme.

- Bug corrections:
  Some minor bug corrections have been done in the nudging code, in the new cloud ice scheme and in the dynamics.

Notes on lm_f90 Version 2.18

This version was created on 16 July 2002. It contains new options for the LM – prognostic precipitation and the use of ECMWF frames as boundary conditions – and some already existing optional parts have been modified. Again, some bugs have been corrected.

- Prognostic precipitation:
  An option to predict the specific water contents q_r and q_s of rain and snow by using full 3-d budget equations has been introduced. For horizontal and vertical advection, the same routines as for cloud ice q_i are applied. Due to stability problem in case of precipitation falling through thin model layers, a special treatment of precipitation fallout has been introduced. The variables q_r and q_s (and their sum, q_{rs}) have also been introduced in the GRIB tables to allow for GRIB output. This is achieved by specifying the names `QR`, `QS` or `QRS` in the variable list `yvarml` within the input group `/gribout/`. The full prognostic precipitation schemes can be chosen by setting the NAMELIST input variable `itype_gscp` within input group `/phyctl`. The following table summarizes the current options to parameterize grid-scale precipitation.

Parameter	Definition / Purpose
lgsp	Enable (=.TRUE.) or disable (=.FALSE.) the parameterization of grid-scale precipitation
itype_gscp = 1	Warm rain parameterization scheme kessler; prognostic: q_v, q_c, diagnostic: q_r.
itype_gscp = 2	Parameterization hydor (default); prognostic: q_v, q_c, diagnostic: q_r, q_s.
itype_gscp = 3	Cloud ice scheme scheme hydci; prognostic: q_v, q_c, q_i, diagnostic: q_r, q_s.
itype_gscp = 4	Prognostic parameterization hydorprog; prognostic: q_v, q_c, q_r, q_s.
itype_gscp = 5	Prognostic cloud ice scheme hydciprog; prognostic: q_v, q_c, q_i , q_r, q_s.

- Use of frames:
  The technical possibility to work with boundary data defined not on the full model domain but only on lateral frames (as e.g. provided by ECMWF) has been introduced. To use this new option, two new NAMELIST input variables have been defined. `lbd_frame` enables the use of frame boundary data, and `npstrframe` defines the width (in number of gridpoints) of the strip around the lateral boundary frame. Both input variable are within the NAMELIST input group `/gribin/`.

- Modified options:
  The two time-level scheme based on second order Runge-Kutta time integration and 3rd-order horizontal advection has been changed. Also, the new multi-layer soil model has been improved.

- Bug corrections:
  The wind rotations from and to geographical into rotated coordinates in module `utilities.f90` were not correct on the southern hemisphere. These routines and their vector counterparts – `uv2uvrot(_vec)` and `uvrot2uv(_vec)` – have been modified. Also, a multiplication had to be changed to a division in subroutine `hydor` within the module `src_gscp.f90`.

- Surface evaporation over sea:
  Some test runs over tropical ocean revealed that the surface evaporation seems to be overestimated, resulting in very intense convection. Within the default diagnostic surface layer scheme `parturs`, the calculation of roughness length for scalar quantities over sea has been changed to follow the surface parameterization of ECMWF formulation. Also, the Charnock constant for the dynamic roughness length z_0 was increased from 0.0123 to 0.0150.

- Other changes:
  Some constants in subroutine `hydor` have been modified. This will change the results slightly. Also, the calculation of the variable `t_g` (in subroutine `tgcom` within the source code module `meteo_utilities.f90`) has been modified, which will change the results slightly. In the subroutine `turbtran.incf` and the module `src_nudging.f90`, additional security tests have been added before performing a division (because of problems on the NEC). In the modules `src_sing_local.f90` and `src_mult_local.f90`, the setup for a run without flat model levels has been corrected.

Notes on lm_f90 Version 2.19

This version was created on 24 October 2002. It contains changes to the data assimilation system, improvements of the new two timelevel scheme, and a new scheme to diagnose the maximal wind gusts. Again, a number of bug corrections have been introduced.

- Analysis of 10m wind speed as part of the surface analysis scheme:
  The method to analyze the observed 10m wind speed is a successive correction procedure as used for the analysis of 2m temperature and 2m relative humidity. The surface analyses are carried out for diagnostic and verification purposes only and are not used in the data assimilation scheme.

- Treatment of frequently measuring observing systems:
  In the nudging analysis scheme, the data from frequently measuring observing systems – such as wind profilers and VAD radar winds – are used in the same way as PILOT observations, but the temporal range of influence of a single report is significantly shortened. Up to now wind profiler data are used in experimental mode only.

- Modified surface pressure analysis and geostrophic correction:
  The nudging coefficient for surface pressure analysis (`gnudg(2)`, `gnudgsu(2)`) has been increased from 0.0006 to 0.0012, and the global geostrophic weight (`qgeo`) has been decreased from 0.5 to 0.3. Also, a revised geostrophic wind correction has been introduced: the global geostrophic weight was made height-dependent (new namelist parameter `qgeotop`).

- New NAMELIST input variables for the data assimilation scheme:
  Several new input parameters have been introduced in context with the changes mentioned above. They are summarized in the following table.

Parameter	Definition / Purpose	Default value
`qgeotop`	Factor to the geostrophic wind increments at ptpstop (parabolic interpolation between 1000hPa and ptpstop)	.FALSE.
`vpblsu(4)`	additional stability-dependent vertical weights for 2m humidity analysis (also for 10m-wind analysis)	4*99.0
`loiqv2m`	Use of 2m humidity observation increments as differences of specific humidity instead of relative humidity	.FALSE.
`lqfqv2m`	Use of a quality factor for 2m humidity observations dependent on T-2m differences	.FALSE.
`lcd137`	Use of pilot code 137 data (Radar VAD)	.FALSE.
`lff10m`	Analysis of 10m wind speed	.FALSE.
`hffa`	Time (hrs) of first 10m wind-analysis since model start	999.0
`hffi`	Time increment (hrs) to next wind analysis	999.0

- Convective wind gusts:
  Up to now, the 10m wind gusts (in the output field `VMAX_10M`) have been diagnosed only in terms of boundary layer turbulence. In order to include the wind gusts generated by subgrid-scale moist convection, a new diagnostic scheme has been developed that derives convective wind gusts from the downdraft properties in the Tiedtke convection scheme.

- 2-timelevel integration scheme and prognostic precipitation:
  A number of modifications have been introduced in the routines related to the new 2-timelevel scheme and the new scheme for the prognostic treatment of precipitation, because several problems were detected.

- Bug corrections and technical changes:
  Some code restructurings related to better vectorization and output organization have been introduced (in the radiation scheme, the new soil model and the Kain-Fritsch scheme). A bug in the Tiedtke convection scheme related to the calculation of entrainment rates was detected and has been corrected. This has a noticeable impact on the convective precipitation amounts.

Planned Releases

Also in 2003, 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
- Modification and updates for the frames boundary files option
- Optimization of the I/O and the dynamical core
- Improvement and tuning of the cloud-ice scheme
- Code re-organization and optimization of the TKE-scheme

5.2 Major Changes to GME2LM

The interpolation program GME2LM has been extended to include a couple of new features, which are mainly related to the introduction of the new SLEVE vertical coordinate, the new multi-layer soil model and the interpolation of data for the new z-coordinate version of LM. The following release notes summarize the changes.

Notes on GME2LM Version 1.14

This version of GME2LM was created on 19 February 2002. In includes the new option to use the SLEVE (Smooth LEvel VErtical) coordinate. Runs with this coordinate can be specified with the (existing) NAMELIST variable `ivctype` (which must be set to 3 for SLEVE) and the new NAMELIST variables `svc1`, `svc2`, `nfltvc`. For their definition, see Section 5.1, LM Version 2.14.

Besides, more bugs have been corrected. For computing LM initial fields, it is now also possible to read GME data from a forecast file gfff00000000. All longitude values, that are specified in the Grid Description Section of the Grib Code, have been limited to the range $-180.0 \cdots + 180.0$ to avoid errors from transformation routines. The computation of the pressure deviation `pp_lm` has been modified, if fields are computed for the new z-coordinate version of LM.

Notes on GME2LM Version 1.15

This version of GME2LM was created on 28 March 2002. It contains adaptations to perform the communications for Input and Output in the standard real format used by the GRIB library. Some more bugs have been corrected for running GME2LM on the southern hemisphere. In the routine `org_interpol`, the possibility was added to compute the GME geopotential on a control level, if it could not be read from the GME files.

Notes on GME2LM Version 1.16

This version of GME2LM was created on 16 July 2002. It includes a correction for the rotation of the wind components between the geographical and the rotated system on the southern hemisphere, in accordance with LM Version 2.18. In routine `src_read_ext`, which reads the external parameters, an additional check for validating the correct rotated pole has been added.

Notes on GME2LM Versions 1.17

This version, created on 24 October, corrects two bugs related to the initialization of temperatures and water contents for the new multi-layer soil model, and to the sequential execution of the program.

5.3 Changes to Model Configurations at COSMO Centres

Since winter 2000/2001 all meteorological centres running the LM at 7-km grid spacing have switched to use a weakly filtered orography (by applying a 10th-order Raymond filter with filter parameter $\epsilon = 0.1$, see the contribution of A. Gassmann in Newsletter No.1). Changes to the model configurations during 2002 are summarized below.

DWD
No significant changes.

MeteoSwiss
No significant changes.

HNMS
No significant changes.

ARPA-SMR
Since November 2002, the new TKE turbulence scheme and the new surface layer scheme are used. Also, the LAMI forcast range has been extended from 48 to 72 hours.

IMGW
During 2002, the LM has been run in the phase of a 1-year pre-operational trial. The operational use is planned to start in the beginning of 2003. Two model configurations are integrated, using a 14-km and a 7-km grid spacing covering the same domain (see Section 4.4 for details). IMGW has also switched on the new TKE turbulence scheme and the new surface layer scheme.

5.4 COSMO Limited-Area Ensemble Prediction System

The COSMO limited area ensemble prediction system (COSMO-LEPS) based on LM and ECMWF ensemble forecasts has been installed at ECMWF by our colleagues at ARPA-SMR in Bologna (see the contribution *Operational Implementation of Ensemble Forecasts using Lokal-Modell* by A. Montani et al. in Section 9). The system is ready for a quasi-operational trial since November 2002, using 120-h forecasts of 5 LM runs (10 km grid spacing, 32 levels, with cloud ice and TKE schemes) starting at 12 UTC. on initial and boundary conditions for 5 representative members of an ECMWF-EPS superensemble. Supervision and scheduling of the suite is done by ARPA-SMR. Up to now, the system runs stable and LM-based probability products (derived and processed by the group in Bologna) are ready at about 7.30 GMT. The dissemination to COSMO centres is by GRIB-files. At present, the following products are available.

- Probability of 24-h precipitation amount exceeding 20, 50, 100 and 150 mm thresholds.
- Probability of 72-h precipitation amount exceeding 50, 100, 150 and 250 mm thresholds.
- Probability of maximum 2m-temperature above 20, 30, 35 and 40 Celsius thresholds.
- Probability of minimum 2m-temperature below 5, 0, -5 and -10 Celsius thresholds.
- Probability of maximum 10m wind speed above 10, 15, 20 and 25 m/s thresholds.
- Mean sea level pressure and accumulated precipitation from 5 deterministic LM runs (every 24 hours).
- Geopotential at 700 hPa and temperature at 850 hPa from 5 deterministic LM runs (every 24 hours).

A documentation guide on COSMO-LEPS products is in preparation. During 2003, a subjective evaluation and an objective verification of the products will be done at COSMO centres.