4 Operational Applications

The LM is operated in five centres of the COSMO members. Following a 1-year preoperational trial from October 1998 to November 1999, the model became operational at DWD in December 1999. At MeteoSwiss the LM was integrated in a preoperational mode two times a day since July 2000. The model became fully operational in February 2001. In Italy the model runs operational twice a day at ARPA-SMR. The HNMS in Greece integrates the LM once a day in parallel to their old operational system. IMGW integrated the LM twice a day since October 2001 in a preoperational mode and switched to an operational schedule when they officially joined the COSMO group in July 2002. Figure 5 shows the integration domains of the model runs at the COSMO meteorological centres.

All five centres use interpolated boundary conditions from forecasts of the global model GME of DWD. Only a subset of GME data covering the respective LM-domain of a COSMO meteorological centre are transmitted from DWD via the Internet. ARPA-SMR, HNMS and IMGW start the LM from interpolated GME analyses, followed by an initialization using the digital filtering scheme of Lynch et al. (1997). At DWD, a comprehensive data assimilation system for LM has been installed (see Section 3.2), comprising the LM nudging analysis for atmospheric fields, a sea surface temperature (SST) analysis, a snow depth analysis and the soil moisture analysis according to Hess (2001). Since November 2001, MeteoSwiss also runs a data assimilation system based on the LM nudging scheme.

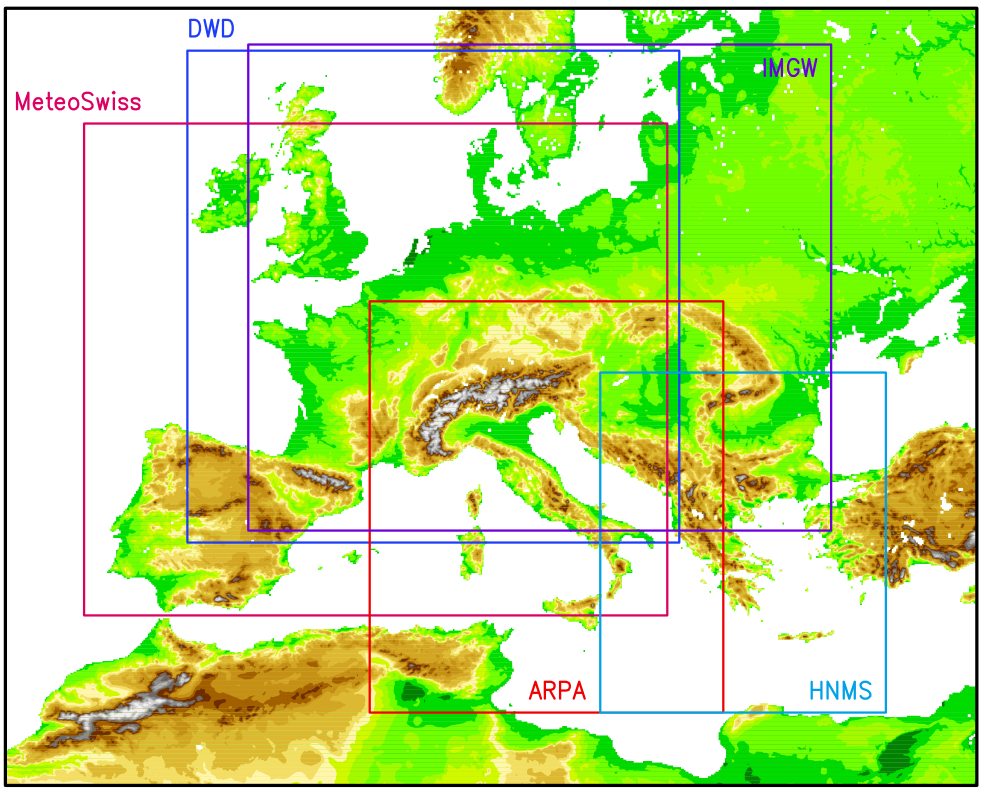

Figure 5: LM integration domains at DWD, MeteoSwiss, ARPA-SMR, HNMS and IMGW

The following sections give a brief overview on the configurations of the operational LM systems in the COSMO meteorological centres. MeteoSwiss, ARPA-SMR and UGM have renamed the model within their services: the LM application in Switzerland is called ***aLMo*** (Alpine Model), the LM application in Italy is called ***LAMI*** (Limited Area Model Italy).

4.1 ARPA-SMR (Bologna)

Basic Set-Up of LM

The regional meteorological service ARPA-SMR in Bologna operates the LM (as LAMI) at 7 km grid spacing. The rotated lat-lon coordinates of the lower left and the upper right corner of the integration domain are ($\lambda = -5°, \varphi = -24.0°$) and ($\lambda = 9.5625°, \varphi = -7.0625°$), respectively. See Figure 5 for this model domain. The main features of the model set-up are summarized in Table 7.

Table 7: Configuration of the LAMI at ARPA-SMR

Domain Size	234 x 272 gridpoints
Horizontal Grid Spacing	0.0625° ($\sim$ 7 km)
Number of Layers	35, base-state pressure based hybrid
Time Step and Integration Scheme	40 sec, 3 time-level split-explicit
Forecast Range	72 h
Initial Time of Model Runs	00 UTC and 12 UTC
Lateral Boundary Conditions	Interpolated from GME at 1-h intervals
Initial State	Interpolated from GME, initialized by DFI scheme
External Analyses	None
Special Features	Use of filtered topography, new TKE scheme, new surface-layer scheme
Model Version Running	lm_f90 3.1
Hardware	IBM SP pwr4 (using 32 of 512 processors)

Changes in the last year

Due to the replacement of the IBM SP3 system with more powerful p690 power4 nodes at CINECA, ARPA-SMR could extend the forecast range to 3 days, which takes approximately 1 hour 40 minutes on 32 processors. Since then also the new TKE scheme and the new surface layer scheme are enabled. Figure 6 gives a screenshot from CINECA web pages for the Italian LM users.

After the main operational suite also an experimental assimilation suite now runs with two 12-h cycles and a daily forecast starting at 00 UTC up to 3 days. The AOF (analysis observation file) is provided by UGM Rome with SYNOPs, AIREPs, TEMPs and PILOTs used. The configuration is the same as for the main run; for the assimilation mainly the default values of the namelist parameters are used.

4.2 DWD (Offenbach)

Basic Set-Up of LM

The LM runs operationally at DWD using a 7 km grid spacing and 35 vertical levels. The rotated lat-lon coordinates of the lower left and the upper right corner of the integration domain are ($\lambda = -12.5°, \varphi = -17.0°$) and ($\lambda = 7.75°, \varphi = 3.25°$), respectively. See Figure 5 for this model domain. The main features of the model set-up are summarized in Table 8.

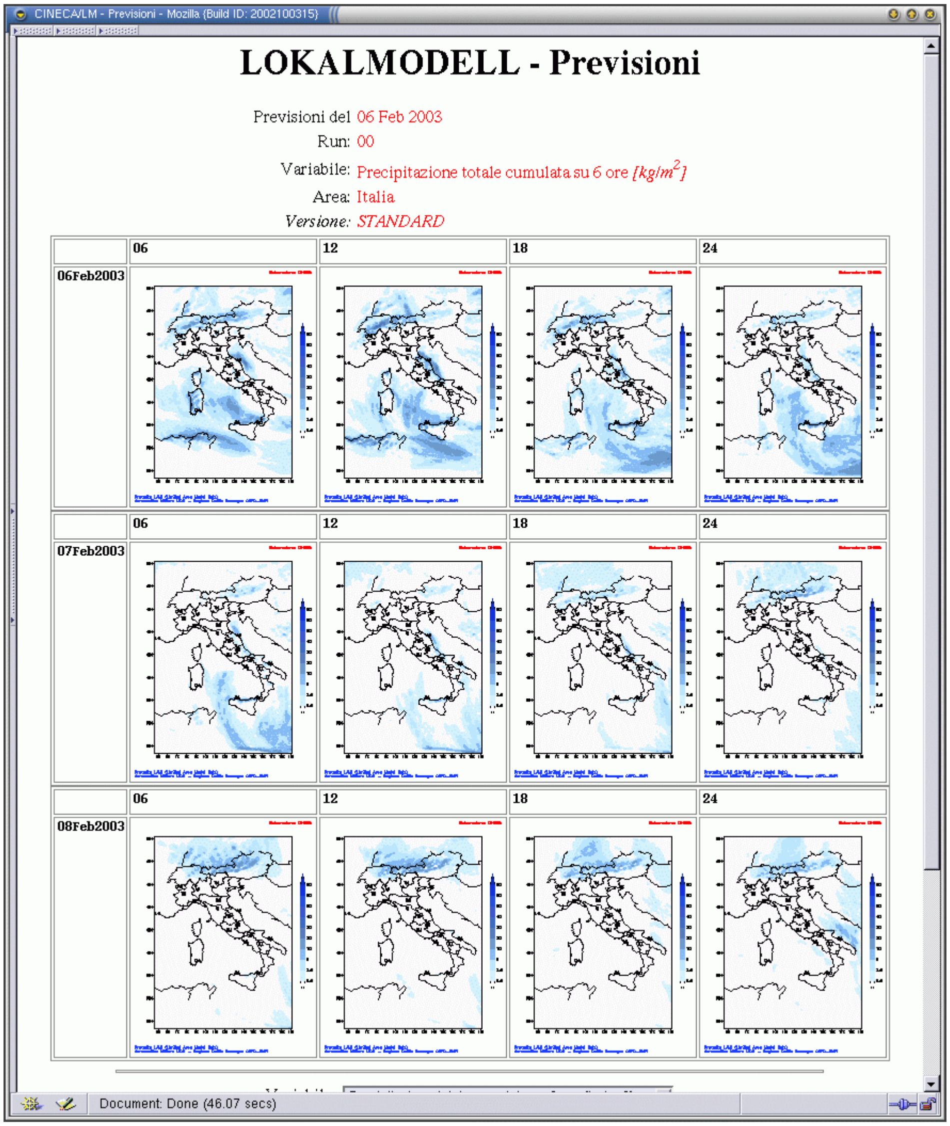

Figure 6: Total precipitation predicted by LAMI

Data Assimilation

At DWD, a comprehensive data assimilation system for LM has been installed. Besides the analysis by observational nudging, three external analyses are run: a sea surface temperature (SST) analysis (00 UTC), a snow depth analysis (00, 06, 12 and 18 UTC) and a variational soil moisture analysis (00 UTC).

The data assimilations for the models GME and LM proceed as parallel streams which are coupled only via the boundary data. (see Fig. 7). The GME analysis is based on a 3-D multivariate optimum interpolation (OI) of deviations of observations from 3-h forecasts (first guess), generating an intermittent assimilation cycle with 3-h analysis frequency. All observations within a time window of ± 1.5 hours are considered as instantaneous, i.e. to be valid at analysis time.

Table 8: **Configuration of the LM at DWD**

Domain Size	325 x 325 gridpoints
Horizontal Grid Spacing	0.0625° (~ 7 km)
Number of Layers	35, base-state pressure based hybrid
Time Step and Integration Scheme	40 sec, 3 time-level split-explicit
Forecast Range	48 h
Initial Time of Model Runs	00 UTC, 12 UTC, 18 UTC
Lateral Boundary Conditions	Interpolated from GME at 1-h intervals
Initial State	Nudging data assimilation cycle, no initialization
External Analyses	Sea surface temperature (00 UTC) Snow depth (00, 06, 12, 18 UTC) Variational soil moisture analysis (00 UTC)
Special Features	Use of filtered topography, new TKE-scheme new surface-layer scheme
Model Version Running	lm_f90 3.1
Hardware	IBM SP3 (using 165 of 1280 processors)

The 3-h GME forecasts to produce the first guess are used to generate boundary data at 1-h intervals for the LM assimilation cycle. The nudging scheme produces a continuous analysis stream, where data are assimilated at the time they are observed - but using a time-weighting function to spread the information in time. For practical reasons, 3-hour LM assimilation runs are done. LM analysis files are written every hour.

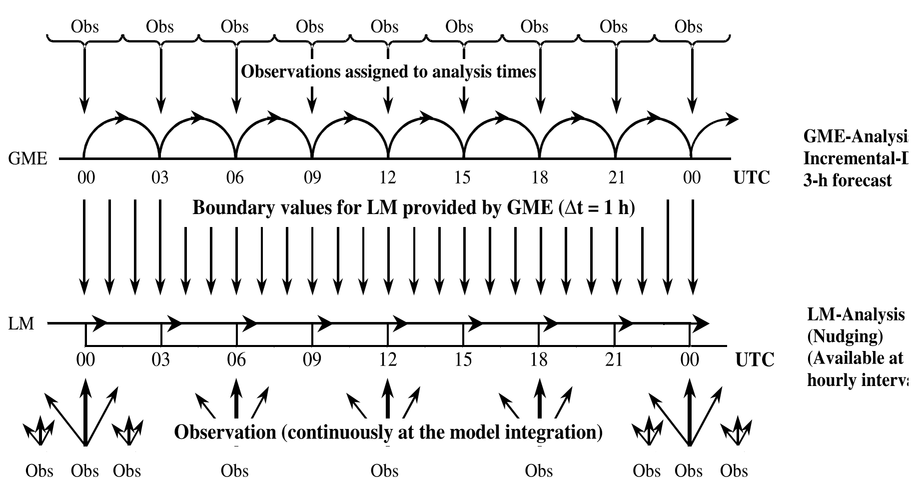

Figure 7: 4-D data assimilation for GME and LM

Operational Schedule

The operational schedule is structured by data assimilation for GME and LM every three hours, i.e. for 00, 03, 06, 09, 12, 15, 18 and 21 UTC. The data cut-off time for the 00 UTC and 12 UTC model runs of both GME and LM is 2 h 14 min. Based on this analyses, GME performs a 174-h forecast, and LM performs a 48-h forecast. Another 48-h prediction of both models is performed starting at 18 UTC with a data cut-off time of 4 hours. Besides the forecast models, a wave prediction suite comprising a global and a local sea state model (GSM and LSM) is run operationally.

New Computer System
In April last year the operational suite started to run on the new IBM supercomputer. This is a RS/6000 SP3 system consisting of 80 Nighthawk II nodes with 16 processors each. Every processor is equipped with a 375 MHz CPU capable of doing two floating point multiply-adds in parallel. The peak performance per processor therefore is 1.5 GFlop/s. The peak performance of the total 80-node system (1280 processors) thus adds up to nearly 2 Teraflop/s. The sustained performance for typical NWP codes is about 3.5 to 5 times larger than the performance of the former Cray T3E 1200 system.

A SGI Origin 2000 system with 2 x 16 processors, 16.4 GByte memory and 2337 GByte disk space (configured as fail-save RAID system) is used as data server (DAS1 and DAS2). All observations (BUFR code) and model results (GRIB1 code) are stored in huge *ORACLE* data bases. For example, one GME forecast run up to 174 h produces more than 12 GByte of data, and one LM forecast up to 48 h about 5 GByte. The daily NWP production exceeds 40 GByte of data. Archiving of the NWP data is based on *AMASS* (Archival Management and Storage System) with about 75 TByte of data on REDWOOD cassettes. Most pre- and post-processing, like observation decoding and graphics, is performed on so-called 'operational servers', a *SGI Origin 2000* system with 8 + 14 processors and 6.1 + 7.9 GByte of memory (RUS1 and RUS2).

4.3 HNMS (Athens)

(E. Avgoustoglou, HNMS)

Basic Set-Up of LM
The national meteorological service of Greece, HNMS in Athens, operates the LM in a pre-operational mode at 14 km grid spacing. The rotated lat-lon coordinates of the lower left and of the upper right corner of the integration domain are ($\lambda = 4.5°, \varphi = -24.0°$) and ($\lambda = 16.25°, \varphi = -10.0°$), respectively. See Figure 5 for this model domain. The main features of the model set-up are summarized in Table 9.

Table 9: **Configuration of the LM at HNMS**

Domain Size	95 x 113 gridpoints
Horizontal Grid Spacing	0.1250° (~ 14 km)
Number of Layers	35, base-state pressure based hybrid
Time Step and Integration Scheme	80 sec, 3 time-level split-explicit
Forecast Range	48 h
Initial Time of Model Runs	00 UTC
Lateral Boundary Conditions	Interpolated from GME at 1-h intervals
Initial State	Interpolated from GME, initialized by DFI scheme
External Analyses	None
Special Features	Default model version
Model Version Running	lm_f90 1.9
Hardware	CONVEX (using 14 of 16 processors)

Since August 2002, HNMS has utilized its computational resources at ECMWF and operates the LM at the Fujitsu VPP5000 on a daily basis. The domain is the same as in the one used for the local operation but the grid spacing has been reduced to 7 km. In addition to their regular operational use at the National Meteorological Center, the results were used for the partial support of the first Olympic test event that was held in August 2002 at the Saronic Gulf, South of the Athens Metropolitan area. Figure 8 shows the results for 10 meter winds for a sample of dates where strong winds were prevailing over almost all of Greece and in particular over the sea area. Table 10 shows the main features of the model set-up for the runs at ECMWF.

Table 10: **Configuration of the LM at HNMS (operation at ECMWF)**

Domain Size	189 x 225 gridpoints
Horizontal Grid Spacing	0.06250° (∼ 7 km)
Number of Layers	35, base-state pressure based hybrid
Time Step and Integration Scheme	30 sec, 3 time-level split-explicit
Forecast Range	48 h
Initial Time of Model Runs	00 UTC
Lateral Boundary Conditions	Interpolated from GME at 1-h intervals
Initial State	Interpolated from GME, initialized by DFI scheme
External Analyses	None
Special Features	Use of filtered topography
Model Version Running	lm_f90 2.16
Hardware	Fujitsu VPP5000 (4 out of 100 processors)

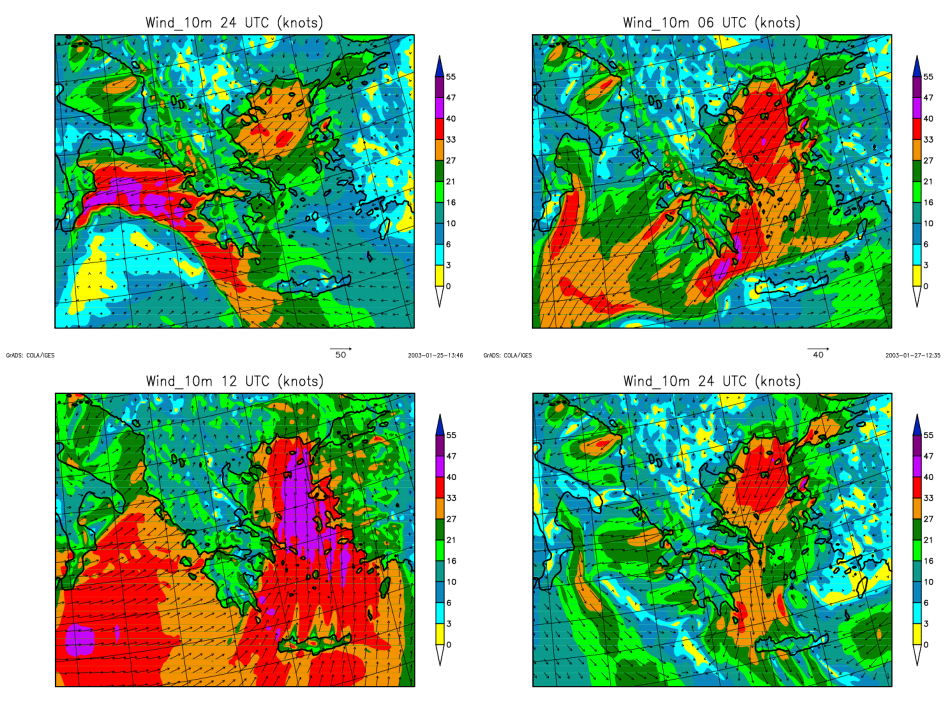

Figure 8: Forecast products used at HNMS, Athens

4.4 IMGW (Warsaw)

(J. Parfiniewicz et.al., IMGW)

Basic Set-Up of LM

The national meteorological service of Poland, IMGW in Warsaw, operates the LM in an operational mode at 14 km grid spacing twice a day (00 UTC and 12 UTC). The rotated lat-lon coordinates of the lower left and of the upper right corner of the integration domain are ($\lambda = -10.0°, \varphi = -16.5°$) and ($\lambda = 14.0°, \varphi = 3.5°$), respectively. See Figure 5 for this model domain. The main features of the model set-up are summarized in Table 11.

Table 11: **Configuration of the LM at IGMW**

Domain Size	193 x 161 gridpoints
Horizontal Grid Spacing	0.1250° ($\sim$ 14 km)
Number of Layers	35, base-state pressure based hybrid
Time Step and Integration Scheme	80 sec, 3 time-level split-explicit
Forecast Range	72 h
Initial Time of Model Runs	00 UTC and 12 UTC
Lateral Boundary Conditions	Interpolated from GME at 1-h intervals
Initial State	Interpolated from GME
External Analyses	None
Special Features	Use of filtered topography, new TKE-scheme new surface-layer scheme
Model Version Running	lm_f90 3.1
Hardware	SGI 3800 (using 88 of 100 processors)

The results of the LM forecasts are provided to the Weather Offices and to the RADAR and HYDRO units of IMGW (also for verification). Figure 9 shows some of these forecast products.

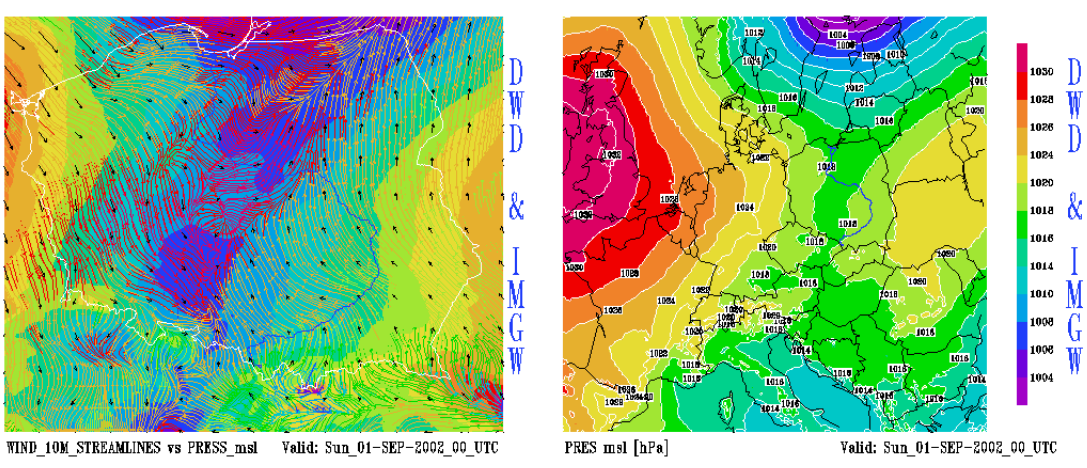

Figure 9: Forecast products used at IMGW, Warsaw

In addition to the operational runs with dx=14 km the LM also runs with a resolution of 7 km, but only for a forecast range of 30 hours.

4.5 MeteoSwiss (Zürich)

(E. Zala, MeteoSwiss)

The Lokal-Modell (named as aLMo at MeteoSwiss) runs on a NEC SX5 placed at the Swiss Centre for Scientific Computing (CSCS) in Manno. During the operational forecasting slots the SX5 enters dedicated mode: 12 CPUs are then reserved for the model integration, 1 for the interpolation of the initial and lateral boundary fields provided by DWD. The operational suite is controlled by the LM Package. This is a set of scripts running on SUN workstations.

Basic Set-Up of aLMo

The aLMo domain extends from 35.11 N -9.33 E (lower left) to 57.03 N 23.41 E (upper right). This domain is covered by a grid of 385x325 points with a horizontal resolution of 7 km (see Figure 5). The borders are placed prevalently over sea in order to reduce negative interferences generated at the transition zone of the orographies of the driving model (GME) and aLMo. The main features of the model set-up are summarized in Table 12.

Table 12: **Configuration of the aLMo at MeteoSwiss**

Domain Size	385 x 325 gridpoints
Horizontal Grid Spacing	0.0625° ($\sim$ 7 km)
Number of Layers	45, base-state pressure based hybrid
Time Step and Integration Scheme	40 sec, 3 time-level split-explicit
Forecast Range	48 h
Initial Time of Model Runs	00 UTC and 12 UTC
Lateral Boundary Conditions	Interpolated from GME at 1-h intervals
Initial State	Nudging data assimilation cycle, no initialization
External Analyses	Merging of LM-DWD snow analysis
Special Features	Use of filtered topography
Model Version Running	lm_f90 3.1
Hardware	NEC SX5 (using 12 of 16 processors)

Vertical Coordinates

In operational mode the model runs with 45 levels vertically distributed as shown in Fig. 10.

Hardware and Communications

The computational work of the aLMo suite is managed by 3 systems:

- SUN Enterprise 3000	at Meteo Swiss	(dissemination)
- SGI Origin 3000	at CSCS	(conduct, postprocessing)
- NEC SX5	at CSCS	(GME2LM, aLMo, LPDM)

Figure 11 shows the present configuration of hardware and communication used for the operational application of aLMo.

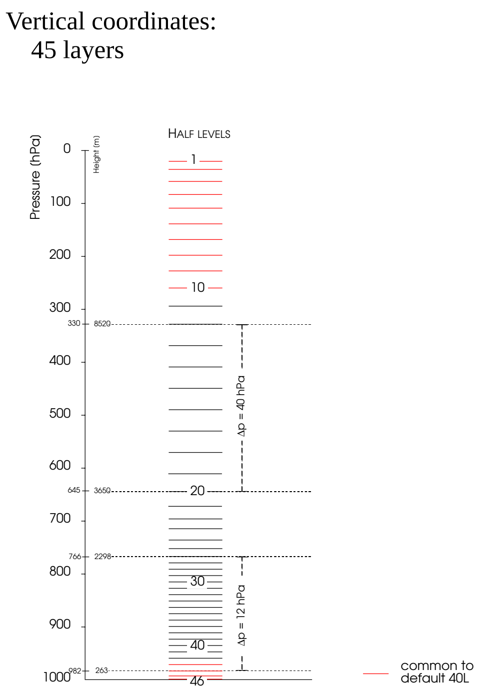

Figure 10: Vertical distribution of levels used at MeteoSwiss

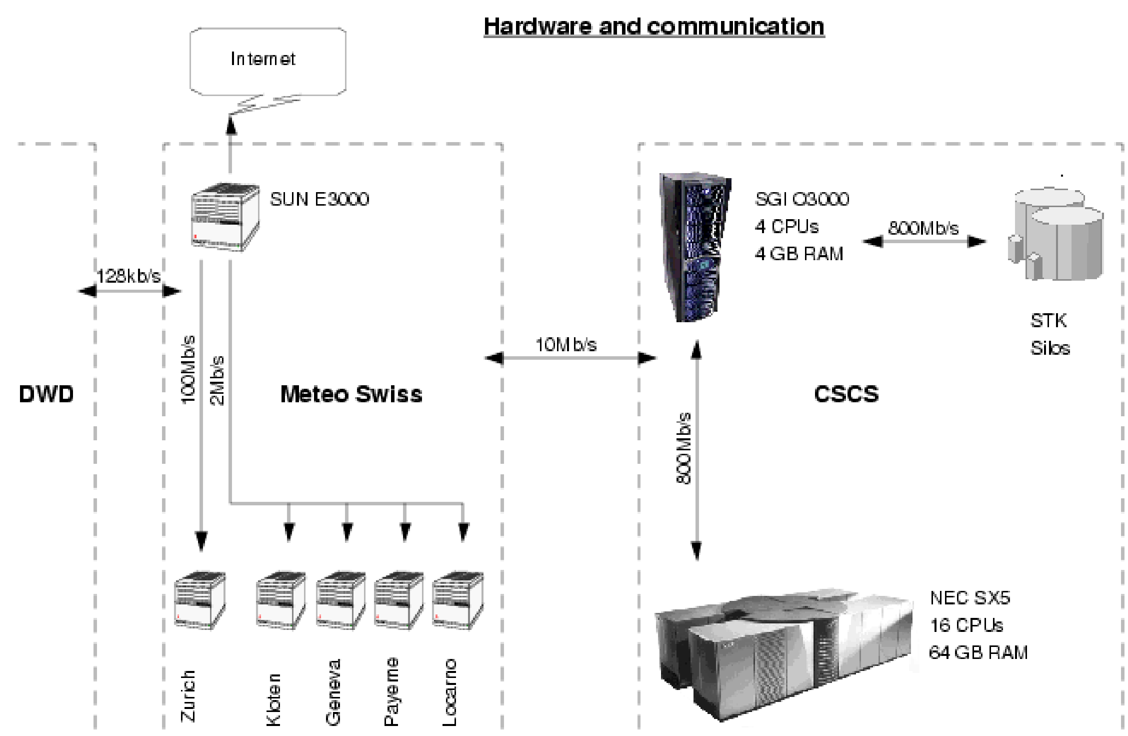

Figure 11: Present configuration of hardware and communications at MeteoSwiss

Data Flow
Figure 12 sketches the dataflow of the operational system.

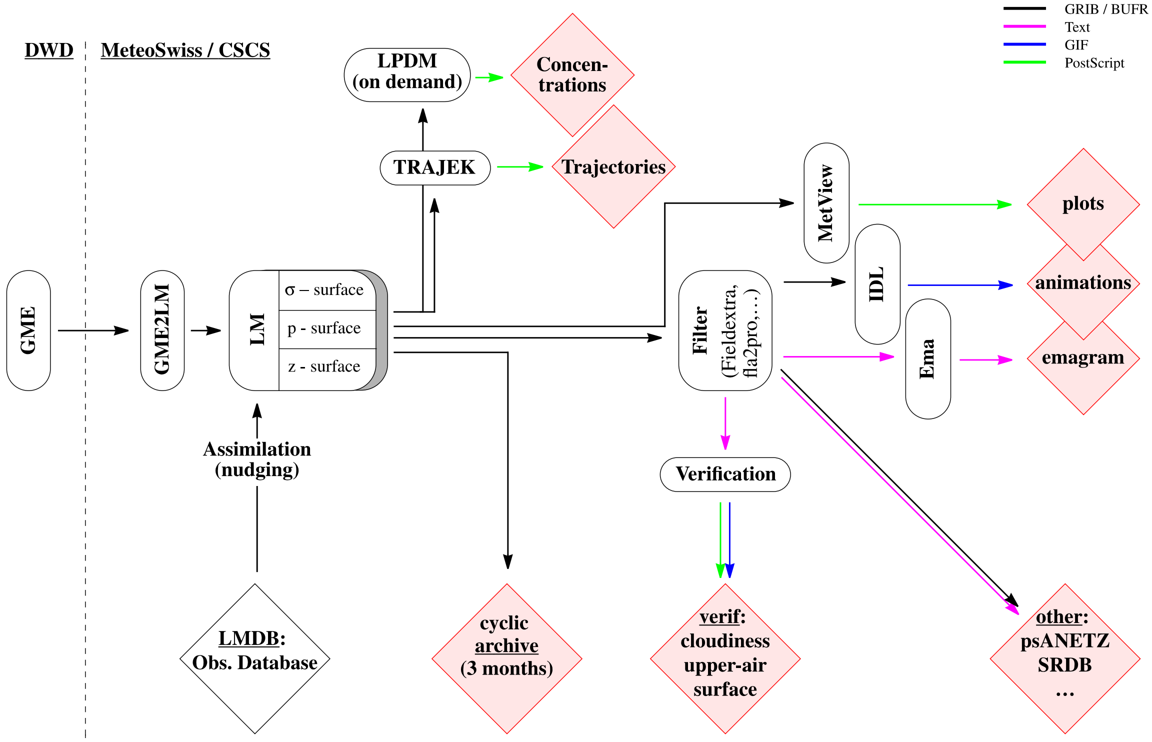

Figure 12: Dataflow of the current operational system at MeteoSwiss

LM Package
The operational suite is driven by "LM Package", a software developed at Meteo Swiss. It has a modular structure and is composed by 50 shell scripts. It can be executed in three different modes: operational, test and personal mode. In operational mode preprocessing, aLMo and postprocessing are running concurrently; warnings and exits are transmitted to operating which has the possibility of manual intervention.

Products
- 2-D plots: produced by MetView every 6 hours
- Animations: Hourly loops produced with IDL
- Tables, extracts of the model output in different formats
- Trajectories
- Concentrations from LPDM module

Assimilation Cycle
The data assimilation at MeteoSwiss is implemented with 3-hour assimilation runs. Cut off time is 5 hours. The observations are taken from the aLMo data base, basically a copy of the ECMWF message/report data base. During the 06-09h and 18-21h assimilation runs the ozone, vegetation and soil parameters are updated from the GME analysis. In a similar way the LM snow analysis from DWD is merged into aLMo initial conditions.

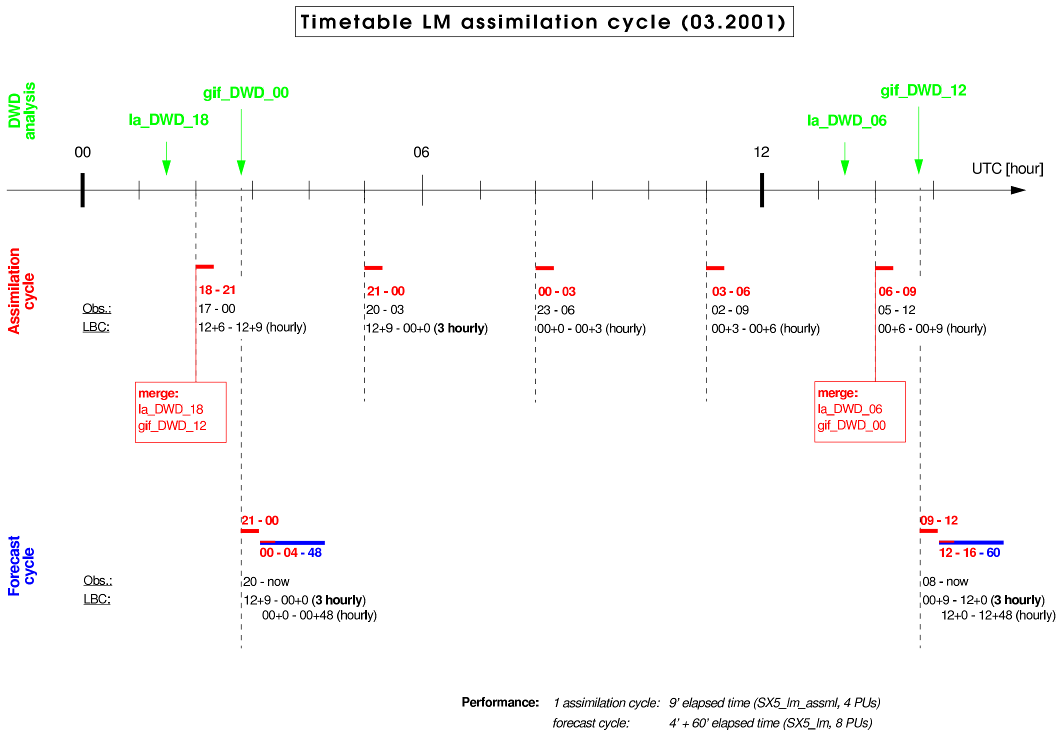

Figure 13: Time table of the aLMo assimilation cycle at MeteoSwiss

Time Table
The analysis used by the main 48h forecasts is produced just ahead of the main runs (lm forecast) with a 3h run of aLMo in assimilation mode (lm assml). During the main forecast runs assimilation continues during the first 4 hours. The postprocessing is divided into a time critical and a non time critical part. During the first part the crucial products for Meteo Swiss internal customers (mainly forecasters) are generated and disseminated. During the second part the remaining products for internal and external customers are created. Archiving and

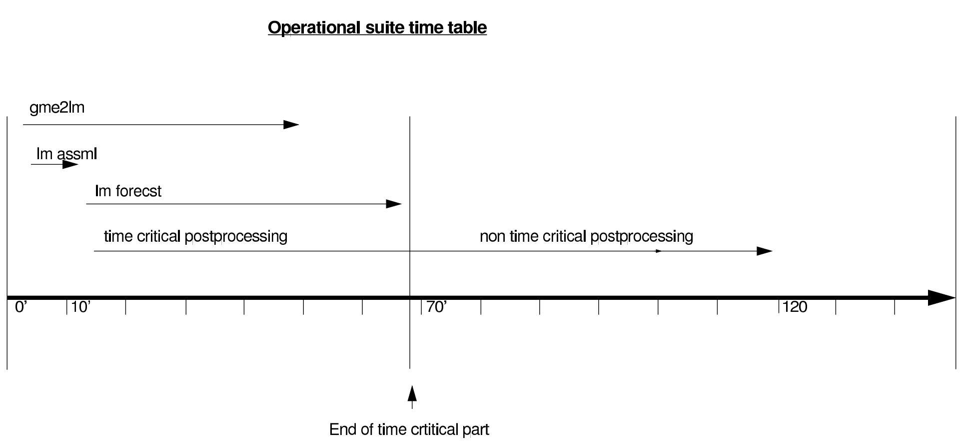

Figure 14: Time table of the operational suite at MeteoSwiss

Verification
The output of the Model undergoes four different types of verification:

- Surface verification: The surface parameters are compared to measurements taken by synoptical and automatic stations.
- Upper air verification: verification of the model against measurements from radiosonde ascents;
- Cloud verification: verification of the model cloudiness based on METEOSAT visible images.
- Radar verification: verification of the precipitation against swiss radar network measurements.