3. Special topic: World-wide Local Weather Forecasts by Meteo-GRID Computing

3.1 Introduction

There is an increasing demand for reliable high resolution short range (up to 48 hours) weather forecasts for government, industry, traffic and media [1]. These local forecasts are most valuable in cases of high impact weather, that is for weather systems such as typhoons or violent extra tropical storms which may result in loss of life and property due to wide-spread flooding and gale force winds. Many national weather services as the Deutscher Wetterdienst (DWD) run regional (local) numerical weather prediction models (NWP models) with a mesh size of 10 km or less up to four times a day to provide the necessary forecast products for the general public. The execution of such an NWP model is computationally very demanding: A 48 hour forecast for a typical model domain of 300 x 300 grid points and 40 layers in the vertical requires up to 60 x 10^{12} floating point operations (flop) and creates about 20 GByte of forecast data at hourly output. Moreover, short range weather prediction is a time critical task which has to be completed in less than two hours. Thus only **h**igh **p**erformance **c**omputer (HPC) centers are able to execute such forecasts.

3.2 EUROGRID and Meteo-GRID

The European Union project EUROGRID (Application Testbed for European GRID computing, IST-1999-20247; funding period: Nov. 2000 until Oct. 2003, http://www.eurogrid.org) provides the required infrastructure, namely the HPC Research GRID and UNICORE software [6], [7], [8]. The HPC GRID consists of the following HPC centers: CSCS Manno in Switzerland, FZ Jülich in Germany, ICM at the University of Warsaw in Poland, CNRS-IDRIS Paris in France, University of Bergen in Norway, and University of Manchester in the United Kingdom. Meteo-GRID is one of the three application GRID projects of EUROGRID, the other two are Bio-GRID (GRID for biomolecular simulations developed by ICM, Warsaw, Poland) and CAE-GRID (Coupled simulations of aircraft developed by EADS, Toulouse, France).

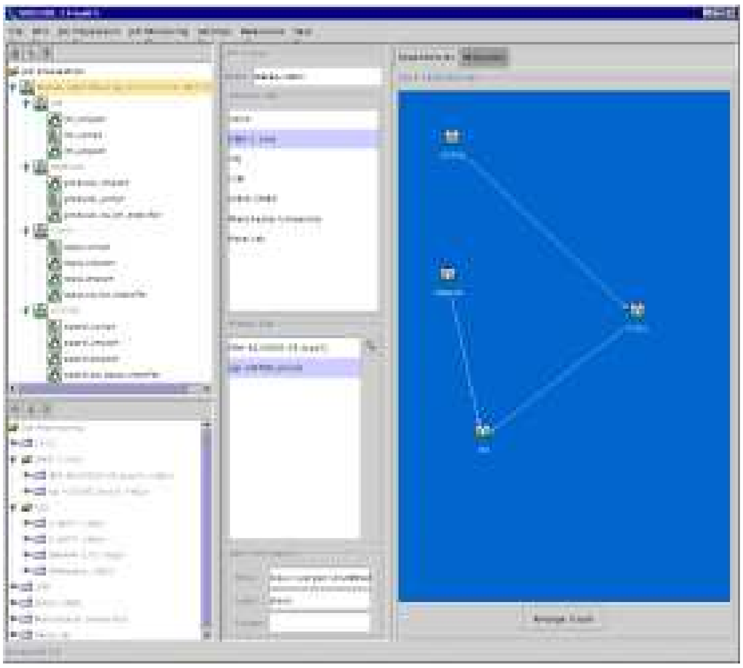

Fig. 3.2.1 Graphical User Interface (GUI) of the UNICORE software Client, the user tier of the UNICORE software.

3.3 Local weather prediction from computational point of view

The main goal of Meteo-GRID is the development of an ASP (Application Service Provider) solution which allows virtually anyone to run a high resolution numerical weather prediction model on demand. The NWP model used is based on the nonhydrostatic Lokal-Modell LM of DWD [2], [3] and [4]. LM is a large, fully portable code of about 100,000 lines of FORTRAN95 and parallelised for distributed memory MPP computer systems based on the MPI (message passing interface). In operational application at DWD, LM is executed on 160 processors of the IBM RS/6000 SP to produce a 48 hour forecast for a model domain of 325 x 325 grid points and 35 layers in less than one hour. The further scientific development of LM is coordinated in the Consortium for Small scale Modelling (COSMO; http://www.cosmo-model.org) with DWD's partners Greece, Italy, Poland and Switzerland.

The user will be able to specify the model domain, grid resolution, initial date, forecast range and selection of products via a JAVA based **G**raphical **U**ser **I**nterface (GUI). Taking the user specifications into account the following steps are executed:

- Derivation of topographical data for the model domain selected from high resolution (1 km x 1 km) data sets stored in a global geographical information system (GIS) at DWD containing about 7 GByte of data. The high resolution information of orography, land fraction, soil type and vegetation parameters are averaged over the grid boxes specified by the user. The derivation of the topographical data file for the model domain takes about 30 minutes to one hour; the packed data file has a size of 1 to 5 MBytes depending on the size of the selected model domain (Fig. 3.3.1)

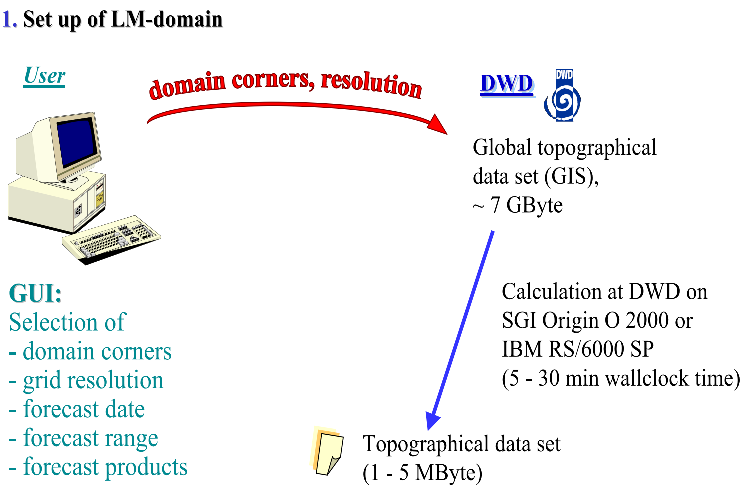

Fig. 3.3.1 Schematic illustration of the information and data flow within Meteo-GRID (1).

- Preparation of initial and lateral boundary data sets for the LM. These data are derived from analyses and forecasts of DWD's Global-Modell GME [5], [9]. The GME data are stored on the icosahedral-hexagonal model grid (about 164,000 grid points per layer for a global field) in an ORACLE data base at DWD. To reduce the amount of data to be transferred only those GME grid points which cover the user's domain of interest will be taken from the data base and stored in the initial and (at hourly intervals) lateral boundary data files. The packed data files have a total size of about 50 MByte depending on the size of the domain specified by the user (Fig. 3.3.2).

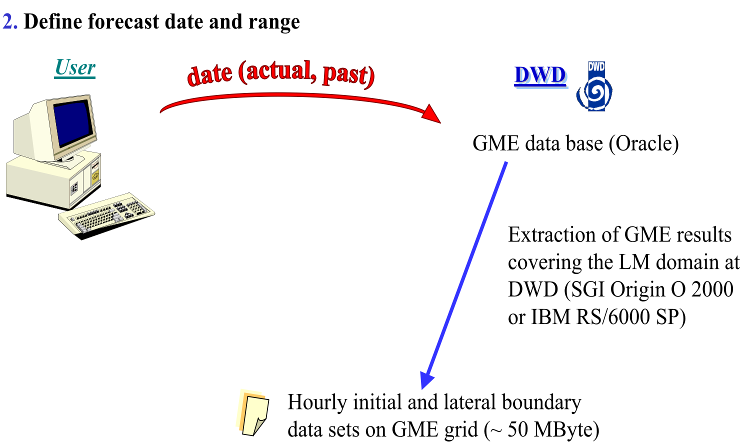

Fig. 3.3.2 Schematic illustration of the information and data flow within Meteo-GRID (2).

- Transfer of the topographical data and the GME data extracted before from the ORACLE data base to one of the HPC centers available in the HPC GRID (Fig. 3.3.3).

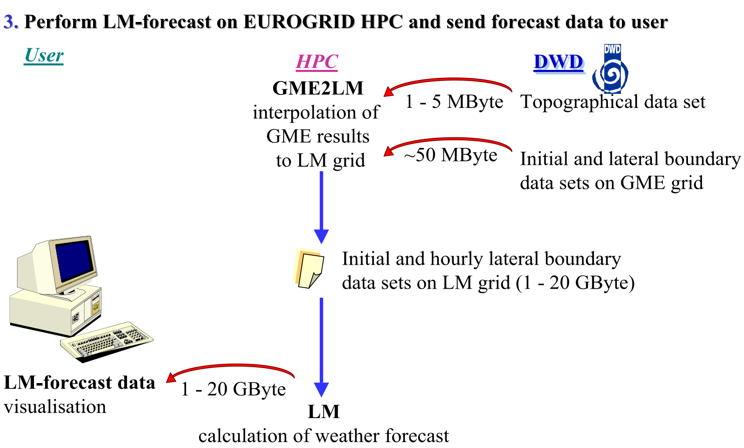

Fig. 3.3.3 Schematic illustration of the information and data flow within Meteo-GRID (3).

- Execution of the LM forecast run on any supercomputer available at this HPC center with highest priority available. The job consists of two separate tasks which run in parallel, namely an interpolation program (GME2LM) which interpolates the GME data to the LM grid and the NWP model itself (LM) which uses the interpolated data as initial and lateral boundary data. Both programs communicate via files in the temporary working space. Depending on the user's specification, one LM forecast up to 48 hours produces about 20 GByte of packed forecast data in GRIB1 format (Gridded Binary; this is a standard data format specified by the World Meteorological Organization, WMO, a suborganisation of the United Nations) (Fig. 3.3.3).

- Dissemination of the LM forecast data to the user's computer via the Internet; because of the large amount of data (up to 20 GByte for a 48 hour forecast) the transfer of the LM data to the user site will be concurrent to the LM forecast run at the HPC center. Thus for example the 1 hour forecast data file will be transferred as soon as this forecast step has been completed (Fig. 3.3.3).

- Visualization of the LM forecast data at the user site based on public domain packages (as GrADS or VIS5D) for 1 to 5 dimensional graphics.

The control structure and job submission of this complex task will be based on the UNICORE software (http://www.unicore.de) which provides the middleware necessary for Meteo-GRID with main emphasis on efficient data transfer, resource brokerage, ASP processes, application coupling and interactive access.

3.4 Outlook

During the year 2001 the work in Meteo-GRID concentrated on the design of the application, definition of **G**raphical **U**ser **I**nterface (GUI), and optimization and first tests of the program which computes the topographical data file of LM for any region on the globe. During 2002 most efforts will be devoted to the design of the GUI and the plugins (will be done by Meteo-GRID partner CSCS in Manno, Switzerland) as well as the implementation of the full LM system on all HPC centers of EUROGRID and the usage of UNICORE for the complex job submission and control. Finally, LM forecasts will be verified for all regions on the earth against the local high resolution observational data available.

3.6 Acknowledgements

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3.7 Abbreviations

ASP	application service provider
CAE	computer aided engineering
CNRS	Centre Nationale de la Recherche Scientifique
COSMO	Consortium for Small Scale Modelling
CSCS	Centro Svizzero di Calcolo Scientifico
DWD	Deutscher Wetterdienst
EADS	European Aeronautic Defence and Space Company
EUROGRID	Application Testbed for European GRID Computing
FZ	Forschungszentrum
GIS	geographical information system
GME	the global model of the Deutscher Wetterdienst
GME2LM	program for the interpolation of results of the global model of the Deutscher Wetterdienst to the model grid of the Lokal Modell
GRIB	gridded binary
GUI	graphical user interface
HPC	high performance computer
ICM	Interdyscyplinarne Centrum Modelowania Matematycznego i Komputerowego
IDRIS	Institut du développement et des resources en informatique scientifique
IST	information society technologies

LM	Lokal Modell
MPI	message passing interface
MPP	massively parallel processors
NWP	numerical weather prediction
UNICORE	Uniform Interface to Computing Resources
WMO	World Meteorological Organization

3.8 References

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