

20 Years a Model

The COSMO Story Behind the Scenery

Ulrich Schättler

Department for Numerical Modeling (FE1)

Deutscher Wetterdienst, Germany

With contributions from many colleagues!

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Dawn of the COSMO-Model

First Plans for a Non-Hydrostatic Regional Model

- In the 90ies DWD had two operational NWP models:
 - GM: a global model based on IFS from ECMWF.
 - EM/DM: regional hydrostatic grid point model.

- Soon after the operationalization of the high-resolution „Deutschland-Modell“, several workshops were organized with participation from different modeling groups (universities, research institutes) to define requirements for a new non-hydrostatic regional NWP model.

**Workshop zur Entwicklung eines nichthydrostatischen Modells
beim DWD
21./22.03.1994 Offenbach am Main**

PROGRAMM

Montag, 21. März 1994		
Diskussionsleitung: E. Müller		
11.00 - 11.30	Begrüßung, Ziele des WS Vorgaben für das LM	Müller DWD
11.30 - 12.15	Übersicht über die Modelle	Schlünzen UNI Hamburg
12.15 - 13.00	Übersicht über die Anwendungen	Groß UNI Hannover, Pflüger DWD
13.00 - 14.00	MITTAGSPAUSE	
Diskussionsleitung: M. Claußen		
14.00 - 14.30	Modellgleichungen und ihre Vereinfachungen	Groß UNI Hannover
14.30 - 15.00	Numerische Struktur der Modelle	Eppel GKSS Geesthacht
15.00 - 15.30	Anfangszustand und Randbedingungen	Adrian KfK Karlsruhe
15.30 - 16.00	KAFFEEPAUSE	
Diskussionsleitung: G. Groß		
16.00 - 16.30	Erdoberflächenprozesse	Claußen MPI Hamburg
16.30 - 17.00	Atmosphärenphysik	Bott UNI Mainz
17.00 - 17.15	PAUSE	
Diskussionsleitung: D. Eppel		
17.15 - 17.45	Erste Ansätze beim DWD	Steppeler DWD
17.45 - 18.15	Schnittstelle DM/mesoskalige Modelle, Datenabgabe	Frühwald DWD
	Konstituierung der Arbeitsgruppen	
19.00	Gemeinsames Abendessen	

Development of the „Lokal-Modell“

- The decision was taken to develop a non-hydrostatic model using the **full compressible basic equations** with a dynamical time stepping according to Skamarock and Klemp (1994) (similar to MM5).
- (Some of the) Basic Requirements:
 - Regional NWP model for central Europe (but global re-locatable).
 - Research Model for resolutions from 1 m to 10 km.
 - Urban climate model with resolution < 50 m.
- Programming Requirements:
 - To run LM as NWP model, a computer with about 0.2 TFlop/s is needed.
 - Most probably with **massive parallel processors** (MPP) and **distributed memory**.
 - Use **standard** FORTRAN (90) as far as possible.

The First Working Version (1995/96)

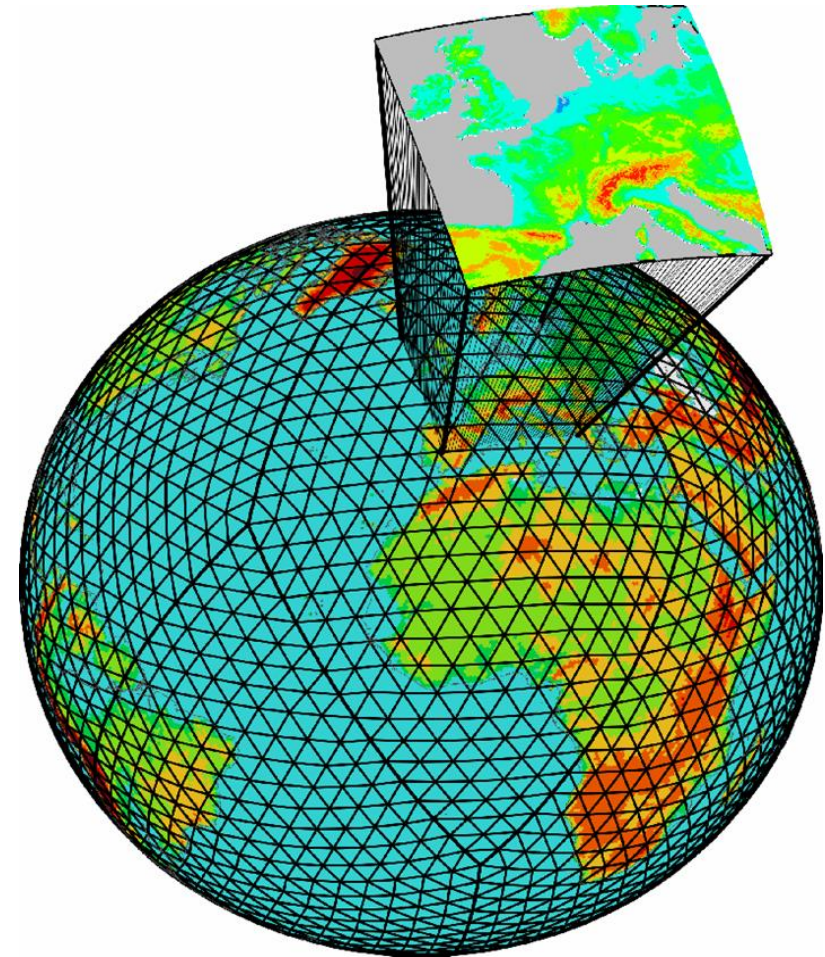
- A first prototype was based on the hydrostatic EM/DM System.
- The hydrostatic dynamical core of EM/DM was replaced by the split-explicit time stepping for the full compressible equations.
- In the beginning, the physical parameterizations from the EM/DM were used.
- Programming Environment:
 - Cray YMP with 4 processors and shared memory.
 - Cray Fortran 77 (already with dynamic memory management, but no standard).
 - Code was vectorized for YMP (inherited from EM/DM).
- Although it had a similar dynamical core, **it was NOT a copy of the MM5!**



Cray YMP at DWD in the 90ies
Peak Performance: 1.2 GFlop/s

Towards Operational Forecasting

- Parallel to the COSMO-Model, a new global model was developed at DWD, the **GME**: based on the dynamics and physics of EM/DM, but working on an **icosahedral grid**.
- Start of operational forecasts of GME and LM on **December, 1st, 1999**, on a Cray T3E.



Cray T3E at DWD end of the 90ies
Peak Performance: 979 GFlop/s

A Strategic Goal: Cooperation

„Key Priority at DWD“

(Prof. Sarah Jones in her Welcome Address for ICCARUS 2021)

First Contacts

- For the development of the LM we asked for national and international cooperations to share know-how and expertise.
- Participation to the first workshops by Universities of Bonn, Hamburg, Hannover, Karlsruhe, Köln, Leipzig, Mainz, AWI Bremerhaven, DLR Oberpfaffenhofen, HZG (former GKSS) Geesthacht, KIT (former IMK) Karlsruhe, PIK Potsdam, Tropos (former IfT) Leipzig, GeoPhys, MCH (former SMA) Zürich.
- Cooperations could be started with some institutes.
- The University of Bonn was the first institute to install a prototype of the „standard“ LM in 1998.
- At the same time first considerations for a climate version already exist.

Consortium for Small scale MOdeling

- ➔ Based on the collaboration of DWD and MCH, Italy (ARPA Bologna) and Greece were interested in further usage and development of the LM.
- ➔ This was the beginning of COSMO.
- ➔ A first „General Meeting“ was held in Bologna from 23-25 September 1999, which consisted of „Work Package Reports“ and „Plenum Discussions“.
- ➔ About 10 years later LM has been renamed COSMO-Model.

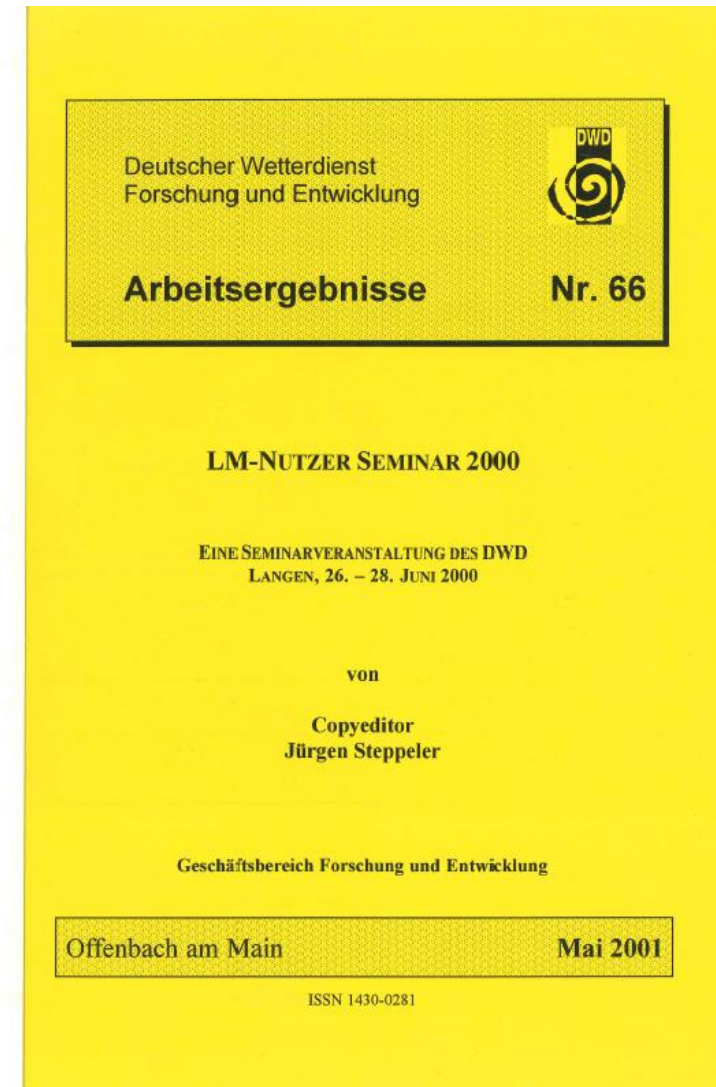


Reference Version and Implementation

Work Pack. No.	D	CH	I	GR	Activities (and Deliverables)	Status / Milestone
c: commitment for work i: interest, but only marginal resources D: Germany , CH: Switzerland , I: Italy , GR: Greece						
6.1	c	c	c		Preparations of topographical data sets (GRIB1) Domains I to V, 28, 21, 14, 7, 2.8 km	complete by 26/02/99
6.2					Work at SMI	
6.2.1	i	c			Installation of SM on Cray SV1 at ETH	start at 01/99
6.2.2	i	c			Installation of GME2HM/GME2LM on SV1 at ETH	start at 04/99
6.2.3	i	i			Installation of LM_S on SV1 using MPI	start at 09/99
6.2.4	i	c			Transmission of GME data to SMI	start at 09/99
6.3					Work at ITAV	
6.3.1	i		i		Installation of IM on DEC Alpha 8200	start at 07/99
6.3.2	i	c			Installation of GME2HM/GME2LM/HM2LM on DEC Alpha	start at 03/99
6.3.3	i	c			Installation of LM_I on DEC Alpha 8200	start at 07/99
6.3.4	i	c			Transmission of GME data to ITAV (via ECMWF?)	start at 03/99
6.3.5	i	c			Creation of AOF file from IMS data base	start at 04/99
6.4					Work at SMR-ARPA	
6.4.1	i	c			Installation of LM_I on Cray T3E (Bologna)	start at 02/99
6.4.2	i	c			Installation of GME2LM/HM2LM on Cray T3E	start at 03/99
6.4.3	i	i			Transmission of GME data to SMR-ARPA via ITAV	start at ?
6.4.4	i		i		Transmission of IM data to SMR-ARPA from ITAV	start at ?
6.4.5	i		i		Creation of AOF file from ARPA data base for LM_I	start at 09/99
6.4.6	i		i		Quasi-operational use of LM_I at SMR-ARPA	start at ?
6.5					Work at HNMS	
6.5.1	i		i		Installation of LM_G on Convex (Athens)	start at ?
6.5.2	i		i		Installation of GME2LM on Convex (Athens)	start at ?
6.5.3	i		i		Transmission of GME data to HNMS	start at ?
6.5.4	i		i		Creation of AOF file from HNMS data base for LM_G	start at ?
6.5.5	i		i		Quasi-operational use of LM_G at HNMS	start at ?
6.6	i	c			Programming and testing of LM2LM	start at 06/99
6.7	c				Reference version of LM packages (LM, GME2LM, LM2LM)	
6.7.1	i				Set up new mailing list of "operational" LM users	02/99
6.7.2	i				Provide direct access to master libraries (ftp)	02/99
6.7.3	i	c	i	i	Define procedure for updating the reference version	04/99
6.7.4	i	c	i	i	Regular update of reference version	start at 04/99
6.8	c				Set-up of common plotting package based on METVIEW	start at 04/99

Workshops and Seminars

- In the European SRNWP framework, DWD became the „Lead Center for Non-Hydrostatic Modelling“ and started a series of workshops in March 1996.
- As a visiting lecturer at the University of Bonn, Jürgen Steppeler organized a first „LM Nutzer Seminar“ in Langen in June 2000.
- This became a yearly tradition now known as ICCARUS.
- Contributions in the first seminar were mainly by „experienced scientists“, but soon the majority of contributions were by students.



NWP Training

→ After the User Seminar in 2002, the first practical training was organized.

Training Course for using the LM Package

- The LM Package - Overview
- Scheme of the NWP-System using the LM
- The LM Package - GME2LM
- The LM Package - LM
- The System at DWD
- Available Products
- New Developments
- Technical Issues
- Practical Exercises

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Introduction into the Use of LM: Practical Exercises
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Instructions for installing and running the LM-Package

1. Introduction:
-----

This guide gives some information for installing the LM-Package during
your training at DWD on the IBM SP of DWD.

The files and data needed can be found in the following places:

List of the tar-files / data needed:

Name                Description                directory
-----
Tar-Files:
- grrib1.tar         GRIB-library                /uhome/for2sch/TRAINING
- gme2lm_yymmdd_x.y.tar.Z  GME2LM source code        /uhome/for2sch/TRAINING
- lm_yymmdd_x.y.tar.Z    LM source code              /uhome/for2sch/TRAINING
- reference_data.tar(.gz)  reference data set         /uhome/for2sch/TRAINING

Data:
- lm_gn_rrrrr_iiixjjj.g1  external data               /rhome/routfor/routfox/lm/const
- giff00000000 ...      GME Data                    /uwork0/for2sch/GME_DATA/GME...
  gfff02000000

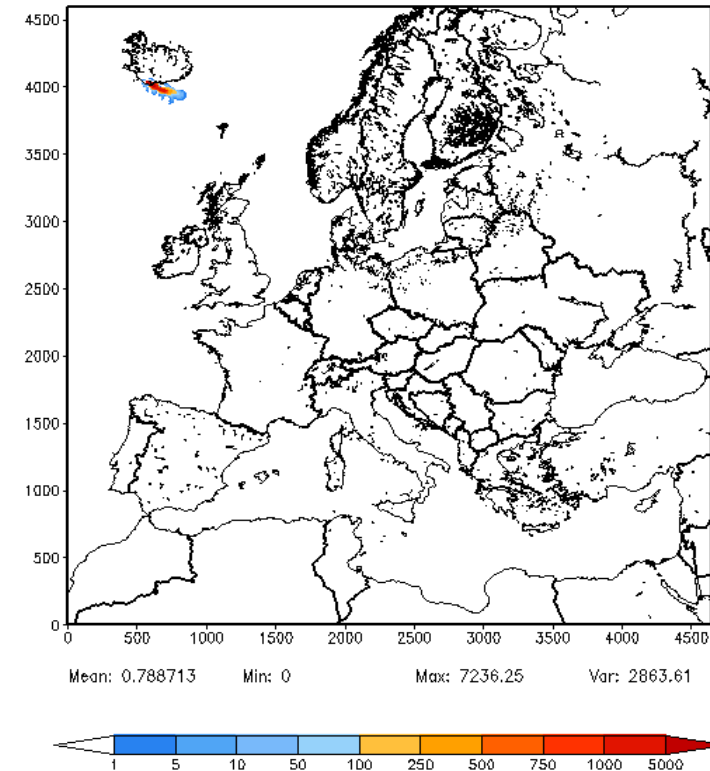
The tar-files you should copy to the $HOME-directory of your training
accounts, the data you can access from the directories listed above.
The data you create with your tests should be written to the $WORK-directory
(/uwork0/fegastx).

```

COSMO-ART

- Over several years KIT Karlsruhe developed ART, the „Aerosol and Reactive Trace gases“.
- Initially, ART was online coupled to KAMM, but later the COSMO-Model has been used (as development for KAMM was stopped).
- COSMO-ART has been established as a widely used tool to treat secondary aerosols, directly emitted components like soot, mineral dust, sea salt and biological material as pollen.
- It is available since COSMO-Model version 4.9 (June 2009).

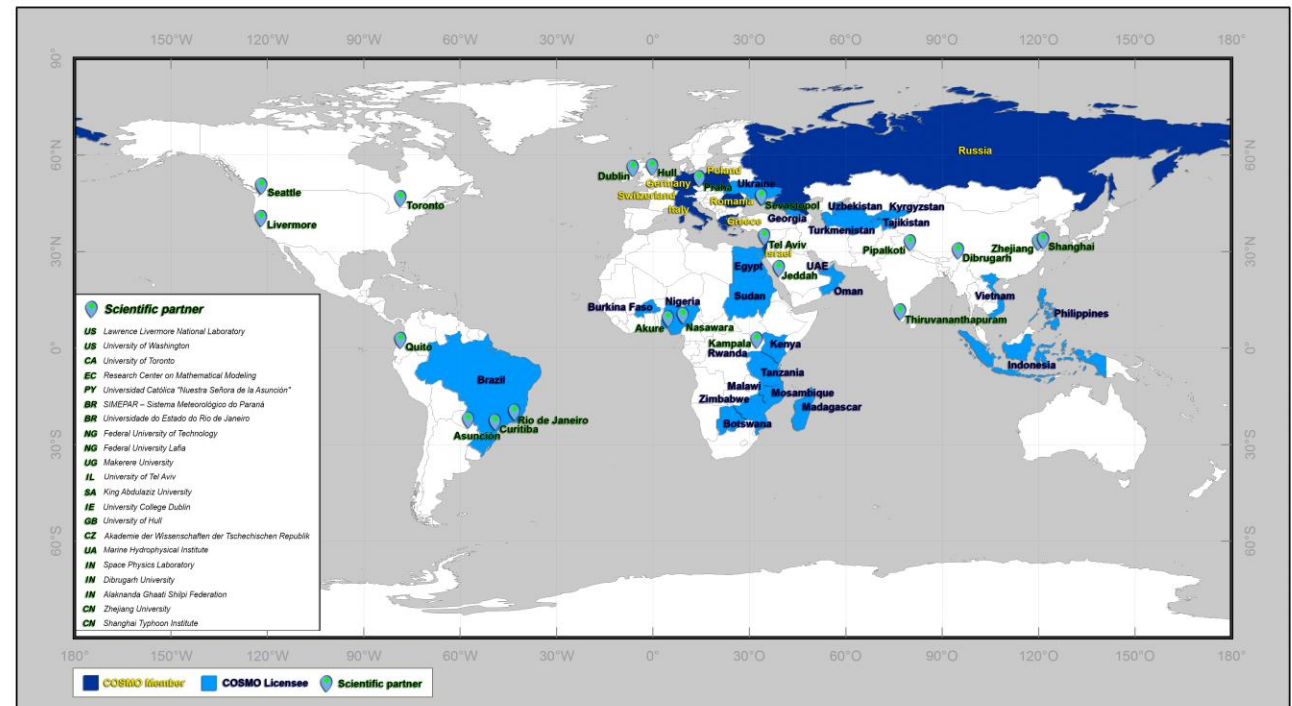
2010041412 - 15 m⁻⁶ - vv=000 - ca. 800 m



Eruption of the unpronounceable volcano in Island.
COSMO-ART simulation

COSMO Licensees

- ➔ About 20 years ago the „Workstation Version“ of the EM/DM system has been provided as HRM to several national weather services.
- ➔ Between 2010 and 2014 these partners migrated to the COSMO-Model.



Necessary Condition for Cooperations

- The original LM development team started a major work to write comprehensive scientific documentations and user guides.
- Also the ongoing work is documented now in form of Newsletters and Technical Reports.
- We also made efforts to document the ongoing development work.
 - <http://www.cosmo-model.org/content/model/releases/developments.htm>
- But we realize that there is much room for improvement!

Documentation

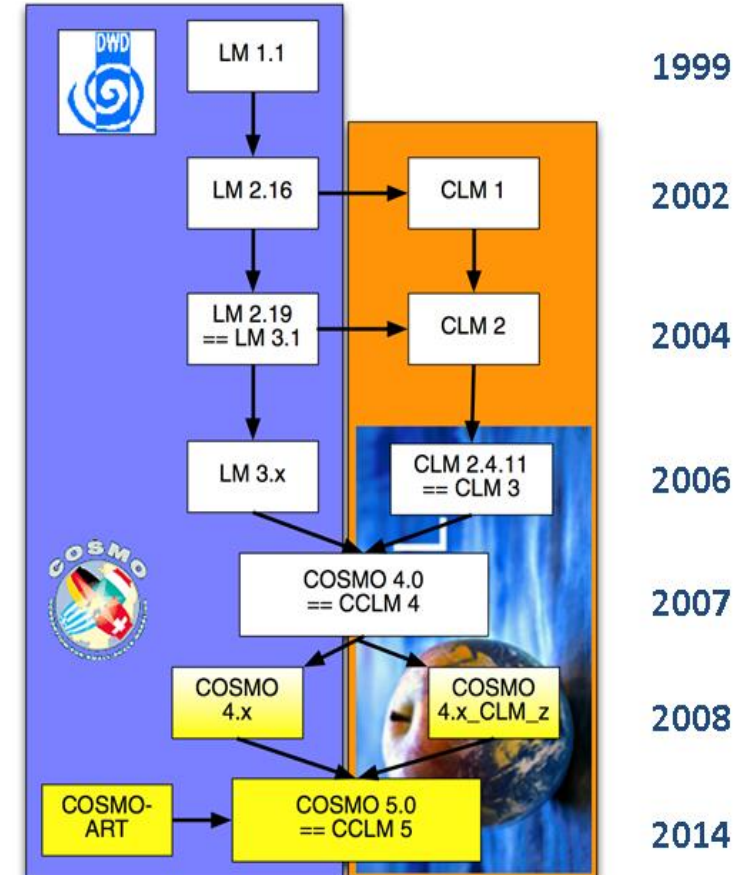


Günther Doms: † 20.06.2004
Father of the COSMO-Model
and its documentation.

Towards a Regional Climate Model

At a Glance

„The history of the CLM Community started in 2004, when colleagues from PIK, GKSS and BTU Cottbus presented the first version of the Climate Local Model (CLM) and invited all scientists to build a network aiming to develop the CLM systematically, to coordinate their activities and to use the computational resources effectively. The CLM-community was born.“



From: „History of the CLM-Community“
<https://wiki.coast.hzg.de/clmcom/history-119570580.html>

Where It All Began

- ➔ Potsdam, October 1998: Expert Discussions on LM.
- ➔ At PIK Potsdam and Meteorological Observatory Potsdam.
- ➔ No more records available.



Glienicker Bridge, Potsdam

Antrag auf Genehmigung einer Inlanddienstreise
 (gilt auch für "kleinen Grenzverkehr")

des/für *) WISS. ANG. ULRICH SCHÄTTLER Dienststelle: CB FE
(Amtsbezeichnung und Name in Druckschrift oder Schreibmaschine) Abt./Ref. od. Dez.: FE 13

1. Beginn der Dienstreise: 19.10.98 Uhrzeit: 16.00 Ende der Dienstreise: 21.10. Uhrzeit: 22.00

2. Reiseziel: Potsdam

3. Mitfahrer: Franker Doms

4. Zwecke der Dienstreise (Erläuterungen der Dienstgeschäfte):
Fachprüfung begl. LM bei PIK Potsdam und am MOP Potsdam

5. Beförderungsmittel (entsprechendes Kästchen ankreuzen)

- a) Dienst-Kfz
- b) Deutsche Bahnen, ohne ICE
- c) Anderes Beförderungsmittel (auch ICE) mit Bahncard 2, Klasse
 wenn ja, welches

Wenn Reisekosten höher als bei Nutzung der Deutschen Bahnen (ohne ICE) anfallen:
 Wird Anspruch auf eine ggf. höhere Reisekostenvergütung geltend gemacht?
 nein
 ja, "triftige Gründe" aufführen auf der Rückseite des Antrages

6. Vertreter: /

7. In Eilfällen erreichbar: /

8. Benötigter Abschlag: /

9. Voraussichtliche Reisekostenvergütung: ca. 450,-

Kosten trägt: DWD Kapitel: 1214 Titel: 52701

nur bei Kapitel 1214, Titel 527 01: Objektkontonummer: 0,2,1,2,6,6,6,6

Workshops on Next Generation Regional Models

Protokoll des Workshop über die nächste Generation Regionalmodell

am 2. 5. 2001, 11:00-15:00, Seminarraum Schlump 58, in **Hamburg**

→ Ambitioned plans for next generation model

→ Replacing REMO with LM?

In den darauf folgenden 2-3 Jahren soll das LM angepasst werden. Schon jetzt absehbare Schritte dorthin sind:

Nr.	Aufgabe	Aufwand (Personen- monate)	Partnerinstitute
1	Einbau der Massenerhaltung in LM	24	DWD, PIK
2	Umwandlung der ECHAM-Physik in LM „software engineering mode“ incl. Fortran90, Modularisierung,, Einbau der Physik	24	PIK, GKSS, MPI
3	Tunen der ECHAM und LM Physik für Klimaanwendung, Validierung	12	BTU, GKSS, MPI, PIK
4	Einbau zusätzlicher Felder als Tracer	3	DWD, GKSS
5	Anpassen von 3d- Randbedingungs-Feldern und Vorbereitung der Ankopplung von Modellen der Klimasubsysteme (u. a. Ozean, Eis, Biosphäre, Chemie) .	6	GKSS, MPI, PIK
Summe		69	

Workshops on Next Generation Regional Models


- First mention of „CLM“.
- Only one participant from MPI-M Hamburg.
- No more reference to ECHAM physics.
- Planning of longer simulation runs.


Tagesordnung	
Workshop zur Entwicklung einer LM-Klimamodell-Version	
Potsdam, 12.12.2001	
<u>Dienstag, 11.12.2001</u>	
- ca. 18 ⁰⁰	individuelle Anreise
19 ⁰⁰ - ca. 21 ⁰⁰	gemeinsames Abendessen in der Gaststätte "Pancho Villa" (argentinisch/mexikanisch, auch deutsche Küche) Treffpunkt: Potsdam-Hauptbahnhof, Ausgang Busbahnhof
<u>Mittwoch, 12.12.2001</u>	
09 ⁰⁰ - 09 ¹⁵	Begrüßung, Vorstellung, Änderungswünsche und Annahme Tagesordnung
Vorstellung und Diskussion der konzeptionellen Ideen zur Entwicklung des CLM	
09 ¹⁵ - 10 ⁰⁰	<i>U. Böhm/K. Keuler</i> physikalische Parametrisierungen und Validierung
10 ⁰⁰ - 10 ⁴⁵	<i>R. Klein/N. Botta</i> Numerik
10 ⁴⁵ - 11 ⁰⁰	Kaffeepause
11 ⁰⁰ - 11 ⁴⁵	<i>R. Klein/J. Steppeler</i> Software Engineering
11 ⁴⁵ - 12 ⁰⁰	Generelle Diskussion, ggf. Formulierung von Anforderungen an den WLA
12 ⁰⁰ - 13 ⁰⁰	Mittag
13 ⁰⁰ - 15 ³⁰	Vorstellung und Diskussion des aktuellen Standes der Entwicklungsarbeiten in den beteiligten Gruppen (die Themen sind als Vorschläge aufzufassen)
	BTU (Modell-Setup, Validierung)
	DWD (Numerik, Massenerhaltung, Eigenschaften Version 2.12)
	GKSS (Web-Präsentation, Standards NetCDF, Erfahrungen mit LM für Grönland)
	M&D (Vorstellungen zur Implementierung)
	PIK (aktueller Stand Implementierungen Version 2.12, Vorbereitung, Ausführung 10-Jahres-Lauf, Bedarf an Bodenfeldern, Erfahrungen Brasilien, externer Zugriff, Numerik-Entwicklungen)
	Uni Bonn (Parametrisierungen - Konvektion in den Tropen)
15 ³⁰ - 16 ⁰⁰	Kaffeepause
16 ⁰⁰ - 17 ⁰⁰	Generelle Diskussion offener Probleme
	Anregungen:
	● wo wird ab wann die Standard-Version vorgehalten,
	● wie wird verwaltet [SCCS?],
	● Bearbeitungsschwerpunkte der einzelnen Gruppen,
	● Kontrolle der Programmier-Standards,
	● Implementierung der Zuarbeiten der einzelnen Gruppen in das CLM,
	● welche Anforderungen sollte CLM erfüllen [NWP-COSMO/Klima]
17 ⁰⁰ - 18 ⁰⁰	Formulierung der nächsten Schritte und Abschluß des Workshops


„Arbeitstreffen“ September 2005: „Versionsabgleich“


- ➔ Workshop to plan a version unification 4.0 (LM 3.16 and CLM 2.4.1).
- ➔ First meeting of Andreas Will and Uli Schättler.
- ➔ Among other things: Who is interested to take part in the LM Tutorials?
- ➔ No more participation from MPI-M Hamburg.


CLM-Community w3.gkss.de/CLM











Arbeitstreffen: „Versionsabgleich LM-CLM“

Potsdam, 29-30.9.2005

Ergebnisprotokoll

Anwesend: Uwe Böhm (PIK Potsdam), Dodo Gunawan (Inst.Bioklimatologie, Univ. Göttingen), Detlef Hauffe (PIK Potsdam), Martin Küken (PIK, Potsdam), Cathrine Meißner (IMK Karlsruhe), Ulrich Schättler (DWD Offenbach), Gerhard Smiatek (IMK-IFU Garmisch Partenkirchen), Andreas Will (Umweltmeteorologie, BTU Cottbus)

Grundsätzlich waren alle mit den Ergebnissen des Treffens zufrieden. Wenn es gelingen sollte, die getroffenen Vereinbarungen umzusetzen, dann wäre eine solide Grundlage für die weitere Zusammenarbeit geschaffen. Hierfür braucht Ulrich Schättler jede nur mögliche Unterstützung. Sehr positiv ist auch zu bemerken, daß einige der anstehenden Aufgaben innerhalb der Community auf mehrere Schultern verteilt werden konnten.

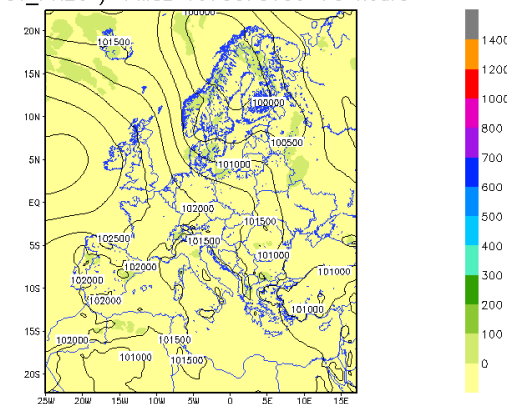
Vereinbarungen Im Verlauf des Treffens wurden mehrere Vereinbarungen von den Anwesenden getroffen. Sie betreffen zum überwiegenden Teil die Anwesenden selbst. Zum kleinen Teil aber auch nicht anwesende CLM-User. Es wird darum gebeten, daß die nicht beim Treffen anwesenden Nutzerinnen und Nutzer dieses Protokoll gründlich durchlesen und sich zu den sie betreffenden Punkten äußern und sich an diese Vereinbarungen halten.

- Versionsabgleich
 - Der Versionsabgleich wird von Ulrich Schättler vorgenommen.
 - Die gemeinsame Version soll im ersten Quartal 2006 freigegeben werden. Eine Testversion soll bis zum 1.1.2006 fertiggestellt sein.
 - Die gemeinsame Version wird die Versionsnummer 4.0 bekommen, d.h. LM 4.0 und CLM 4.0. Der nächste Versionsabgleich soll in etwa einem Jahr stattfinden und mit der Einführung neuer Hauptversionen zusammenfallen, d.h. 5.0, 6.0 usw.
 - Die Unterschiedliche Namensgebung wird beibehalten, um die verschiedenen Anwendungsgebiete zu verdeutlichen.
 - Grundsätzlich wird ein Abgleich der aktuellen Versionen des LM (derzeit 3.16) und des CLM (2.4.1) vorgenommen. Praktisch werden die im CLM 2.4.1 implementierten Modifikationen des LM 3.1 in die aktuelle Version des LM eingearbeitet. Redundante oder offensichtlich nicht nötige Modifikationen werden nicht

A Special Meeting on LM / CLM Dynamics: August 2006

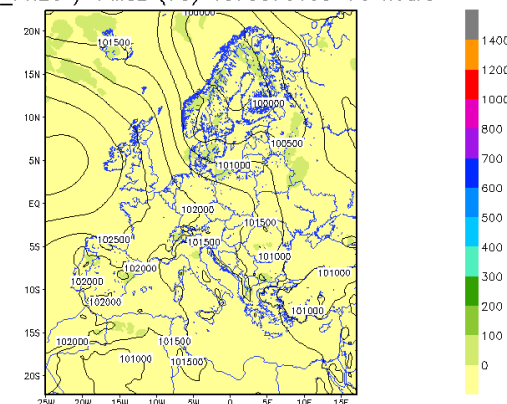
- ➔ CLM simulations showed a dependence on short and long time step for Leapfrog.
- ➔ CLM colleagues were very imaginative to describe the situations:
 - ➔ dt=90s: The Shower (self explanatory)
 - ➔ dt=75s: The day after tomorrow („we successfully simulated the day after tomorrow for dts=18s. An inbreak of cold upper tropospheric air ... is followed by cyclogenesis and strong precipitation.“)
- ➔ To convince DWD colleagues that these problems are not due to special CLM settings, I could show similar problems with standard DWD setup (animations on the right).
- ➔ As far as I remember, this problem could not be solved. All dynamical time stepping methods have a certain „area of instability“.

TOT_PREC / PMSL 1979070100 +0 hours



GRADS: OOLA/RES

TOT_PREC / PMSL (75) 1979070100 +0 hours



GRADS: OOLA/RES

CLM Community

„Independence Day“

- In 2006 the „Community Agreement“ was formulated and CLM could distribute the model code without further DWD acceptance.
- With that, the CLM Community got an administrative independence and had „grown up“.

CLM Assemblies

- CLM scientists already took part in the early DWD User Seminars in Langen.
- On 09./10. March 2006, they hold the first Assembly just after the User Seminar.
- From 2009 on, the Assemblies were organized as extra Meetings (first one in Karlsruhe).

The COSMO Coordinator

- In 2010 a new position was created at DWD to better support all COSMO partners and the CLM Community.
- Uli Blahak and Daniel Rieger perfectly filled this role.

The Success of COSMO and CLM

A SWOT Analysis for COSMO

Strengths

- Usable community model
- Basic model documentation exists
- Basic support available

Opportunities

- Bring together users and scientists from all over the world

Weaknesses

- Documentation of many details nevertheless is missing
- Many developments took too long
- Feedback mechanism „forecast – model development“ could have been more efficient

Threats

- Better models (ICON)

The Success Story

→ From the CLM Community homepage:

If you want to go fast, go alone. If you want to go far, go together. (African proverb)

→ A former director of SMHI (swedish met service):

Not institutions are working together, but people. (Citation from memory)

→ COSMO and CLM really brought together scientists from all over the world!

→ Going fast is not always desirable.

→ But we have come a long way.

And COSMO could share with CLM ...

The COSMO Spirit





It is difficult
to predict

especially
the future.

And we have
only just begun...