LMK: A Very Short Range Forecasting System

Goals and Methods
Structure of the project ‘LMK’
Development Work
LMK Testsuite
Final Remarks

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LMK - (LM-Kürzestfrist)
‘Aktionsprogramm 2003’ of DWD

Goals
• Development of a model-based NWP system for very short range forecasts (2-18 h) of severe weather events on the meso-γ scale, especially those related to
  – deep moist convection
    (super- and multi-cell thunderstorms, squall-lines, MCCs, rainbands,...)
  – interactions with fine-scale topography
    (severe downslope winds, Föhn-storms, flash floodings, fog, ...)

Method

• Application of the LM at a grid-spacing < 3km (currently 2.8 km)
  with about 50 layers
  -> direct simulation of deep convection (!?)
• 18-h forecasts every 3-hours from a rapid-update data assimilation cycle
  -> ensemble of forecasts
• Continuous data assimilation based on nudging, short cut-off (< 1h)
• Use of all available data, especially radar reflectivities and winds.
Potential benefits from an explicit representation of convection

- no drawbacks from the use of parameterized convection (artificial closure conditions, stationarity, ...)
- time evolution (life-cycle) of convective cells is simulated
- transport of convective cells with the wind field (impact of shear)
- formation of new cells along gust-fronts (long-lasting cells, super- and multi-cells development)
- more detailed representation of cloud-microphysics
- thermodynamic interaction between updraft und downdraft
- scale-interaction and organization (Squall-Lines)

Related projects:
AROME, UK MetOffice, HIRLAM, WRF (BAMEX)
Deep moist convection

Schematic model from a Colorado storm case study (Raymer Hailstorm)

from: R. A. Houze, Jr.: Cloud Dynamics
International Geophysics Series Vol. 53
with convective parameterization

Δ = 7km

without convective parameterization

Δ = 7km

Δ = 2km

Min: 1.73816  Max: 17.63
Min: 1.92288  Max: 31.85
Min: 2.1937   Max: 39.70

vmax and obs. wind gusts (m/s)  2 June 1999 00UTC +17h
LMK Assimilation and forecast cycle (LAF-Ensemble)

LMK: new forecast every 3 hours
LMK will require not only adjustments of existing schemes but also the development of new components

- Further developments in the method to assimilate radar data (Latent heat nudging, LHN)
- 5-min radar composites (DX-data) including quality control
- Development of an efficient time-integration scheme allowing for high-order spatial discretization
  - modified metrics, new ‘symmetric’ thermodynamics, BCs, cov. metrics
- Full 3-d budget equations for precipitating hydrometeors
- Development of new physics schemes for kilometer-scale simulations (graupel and hail microphysics, 3-d turbulence, shallow convection)
- Development of new tools for model validation and verification using remote-sensing data
  - pseudo-satellite and pseudo-radar products, Lidar, cloud-radar products
- Development of products and methods to interpret model results from deterministic forecasts (on stochastic scales) and to estimate the predictability (probabilistic products)
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<td>Michael Buchhold (FE 12)</td>
<td>- Quality control of 5-min DX-data</td>
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<td>Kathleen Helmert</td>
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<td>- Assimilation of radar winds</td>
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<td>Christoph Schraff (FE 12)</td>
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<td>Klaus Stephan</td>
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<td><strong>M9: LM 2.8 km &amp; explicit convection</strong></td>
<td>Michael Baldauf (FE 13)</td>
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<td>Jochen Förstner</td>
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<td>- Lateral and upper boundaries</td>
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<td><strong>M10: Verifikation and Validation</strong></td>
<td>Uli Damrath (FE 15)</td>
<td>- Traditional verifikation (Syn/Temp)</td>
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<td>Claus-Jürgen Lenz</td>
<td>- Use of pseudo-satellite and pseudo-radar tools</td>
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<td>- New methods (pattern recognition, upscaling, ...)</td>
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Plus ~ 10 permanent staff members at 10 -20 %
Current Activities

• **Radar Data**
  • Generation of a DX composite for the DWD network
  • Quality control
  • Clutter corrections

• **Latent Heat Nudging (LHN)**
  • Diagnostic studies -> Reasons for the short memory time of LHN?
  • Use of DX data
  • Code transfer to LM
  • LHN <---> prognostic precipitation ? problem: different basic assumptions
Current Activities (2)

• Dynamics, Numerics, Boundary Data
  - New ‘symmetric thermodynamics’ within the RK3 solver
  - Lateral boundary conditions: ‘pressure drop’ (solved)
  - LBC’s for prognostic precipitation
  - Update of LM2LM (SLEVE coordinate, ex. Param for data assimilation)
  - Idealized cases

• Physical Parameterization
  - Implementation of 3-d turbulence for the RK3 solver
  - Test and evaluation of the new Graupel-Scheme
  - Development of a shallow convection scheme
  - Sensitivity tests for radiation update frequency

• Verification and Validation
  - Synop Verification of LMK testsuites
  - Pseudo-satellite and pseudo-radar products
Full 3-d budget equations connect microphysics to flow field
- horizontal and vertical transport of precipitation is important

The current LM (Class-5) scheme is designed for stratiform clouds

Application to convective clouds requires adjustments and extension to include graupel (hail):
- Formulation of a Class-6 scheme

Implementation of a double moment ice scheme for research and benchmark (A.Seifert, NCAR)
New microphysical processes related to graupel are formulated and parameterized.

Full 3-d budget equation:
- advection with the 3-d wind
- sedimentation and source/sinks are treated with a quasi-implicit predictor-corrector method

Prototype version:
- tests and evaluation
- adjustments of parameters
- completeness
LMK test-simulation with the new graupel scheme

10. June 2003 12 UTC + 9 h

West-east vertical cross section through a deep convective cell (equidistant in level space) (mixing ratio in g/kg)

- light blue: cloud water
- yellow: cloud ice
- dark blue: rain water
- red: snow
- green: graupel

Ongoing sensitivity tests for both convective and stratiform cases
**Testsuite 1**

- LMK-Domain, dx=2.8 km, 50 layers, dt=16 sec.
- Leapfrog-time-integration
- horizontal advection with centered differences 2. order
- diagnostic precipitation scheme with cloud ice (itype_gscp=3)
- prognostic TKE-Vertical diffusion (itype_turb=3, itype_tran=2)
- without convection parametrization
- period: Dez. 2003 - Feb. 2004
Testsuite 1

Tentative Model Domain of LMK

- 2.8 km grid spacing
- 421 x 461 grid points
- 50 layers

Mode configuration as LM, but:
- convection scheme switched off
- no data assimilation
Deutscher Wetterdienst
Aktionsprogramm 2003

Testsuite 1

LMK 2.8 km (exp.: 673 – Leapfrog)
initial: 13 JAN 2004 02 UTC
valid: 13 JAN 2004 15 UTC
(1) 3h PRECIPITATION (>0.1mm) (2) PWSL

LM 7 km (routine)
initial: 13 JAN 2004 02 UTC
valid: 13 JAN 2004 15 UTC
(1) 3h PRECIPITATION (>0.1mm) (2) PWSL

AP 2003: Projekt LMK
Testsuite 1

LMK 2.8 km (exp.: 673 – Leapfrog)

- initial: 13 JAN 2004 00 UTC
- valid: 13 JAN 2004 12 UTC

1. iuv (blue) 2. iwater−iuv (red)

LM 7 km (routine)

- initial: 13 JAN 2004 00 UTC
- valid: 13 JAN 2004 12 UTC

1. iuv (blue) 2. iwater−iuv (red)
Deutscher Wetterdienst
Aktionsprogramm 2003

Testsuite 1

LMK 2.8 km (exp.: 673 – Leapfrog)
init: 21 FEB 2004 00 UTC
valid: 21 FEB 2004 18 UTC
(1) CLCL (2) PMSL

LM 7 km (routine)
init: 21 FEB 2004 00 UTC
valid: 21 FEB 2004 18 UTC
(1) CLCL (2) PMSL
Deutscher Wetterdienst
Aktionsprogramm 2003

Testsuite 1

LMK 2.8 km (exp.: 673 – Leapfrog)
Init: 27 FEB 2004 00 UTC
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LM 7 km (routine)
Init: 27 FEB 2004 00 UTC
Valid: 27 FEB 2004 18 UTC
(1) CLCL (2) PMSL

AP 2003: Projekt LMK
Testsuite 1

“Simple” shallow convection

LMK 2.8 km

Initial: 27 FEB 2004 00 UTC
Valid: 27 FEB 2004 18 UTC

(1) CLCL (2) PWSL

LM 7 km (routine)

Initial: 27 FEB 2004 00 UTC
Valid: 27 FEB 2004 18 UTC

(1) CLCL (2) PWSL
Testsuite 2

- LM-Domain, dx=7km, 35 layers
- RK3-TVD time integration, 5th-order advection, dt=72 sec
- new metrics
- diagnostic turbulence
- GME initial conditions
- period: Dez. 2003

Goals:
- test of the new dynamic core
Testsuite 2: LM Routine \(\text{<-->}\) LM RK3-TVD (19. Dec 2003 +48h)

LM 7 km (routine)
- initial: 19 Dec 2003 00 UTC
- valid: 21 Dec 2003 00 UTC

LM 7 km (exp.: 4527 – TVD-RK-3rd / UP-5th)
- initial: 19 Dec 2003 00 UTC
- valid: 21 Dec 2003 00 UTC
Testsuite 3

- LMK-Domain, dx=2.8 km, 50 layers
- RK3-TVD time integration, 5th-order advection, dt=30 sec
- new metrics
- with prognostic precipitation (w/o. LBC for rain + snow)
- with prognostic TKE turbulence
- synthetic satellite images
- no data assimilation
- period: Jan. 2004
Testsuite 3: Prognostic precipitation + RK3-TVD

LMK 2.8 km (exp.: 673 - Leapfrog)
initial: 13 JAN 2004 00 UTC
valid: 13 JAN 2004 12 UTC
(1) 3h PRECIPITATION (>0.1mm) (2) PMSL

LMK 2.8 km (exp.: 683 - TVD-RK-3rd / UP-5th)
initial: 13 JAN 2004 08 UTC
valid: 13 JAN 2004 12 UTC
(1) 3h PRECIPITATION (>0.1mm) (2) PMSL
Testsuite 3: Lateral Boundary conditions for rain and snow

LMK 2.8 km (exp.: 683 – TVD-RK–3rd / UP–5th)
Initial: 08 JAN 2004 00 UTC
Valid: 08 JAN 2004 06 UTC

(1) 3h PRECIPITATION (>0.1mm) (2) PMSL

LMK 2.8 km (exp.: 683 – TVD-RK–3rd / UP–5th)
Initial: 08 JAN 2004 00 UTC
Valid: 08 JAN 2004 06 UTC

(1) 3h PRECIPITATION (>0.1mm) (2) PMSL
Testsuite 4

- LMK Domain, dx=2.8 km, 50 layers
- RK3-TVD time integration, 5th-order advection, dt=30 sec
- new metrics
- with prognostic precipitation
- with prognostic TKE-turbulence (1-dim. scheme)
- synthetic satellite images
- ‘symmetric thermodynamics’
- smooth boundary relaxation zone
- period: Jan. 2004
Testsuite 4: Symmetric thermodynamics and smooth boundaries
Testsuite 5

- LMK Domain, dx=2.8 km, 50 layers
- RK3-TVD time integration, 5th-order advection, dt=30 sec
- new metrics
- with prognostic precipitation
- with prognostic TKE-turbulence (1-dim. scheme)
- synthetic satellite images
- ‘non-symmetric thermodynamics’
- period: May-July 2004
Testsuite 5: channeling in rhine valley (7.5.2004, 06 UTC)

(every 2. wind vector in 10 m above ground)

LMK, dx=2.8 km, RK3+upstream 5. order

LM, dx=7 km, Leapfrog
Further planned tests:

- **Idealized test cases**
  - Linear mountain flow (hydrostatic / non-hydrostatic case)
  - cold bubble (Straka et al., 1993)
  - warm bubble in shear flow (Weisman, Klemp, 1982)

- **Test cases especially for turbulence**
  - roughness jump
  - tilted plane
  - checkerboard heating

- **Test cases especially for cloud physics scheme**
  - IMPROVE-2
Project LMK: Milestones

• End 2003:
  First test-suite with LM at high resolution is running.

• Autumn 2004:
  Prototype version of the LMK-System with data assimilation but without LHN running.

• Summer 2005:
  Prototype version of the LMK-System with LHN is running in a quasi-operational mode.
  Further testing and evaluation of new numerical schemes and physical parameterizations.

• Early 2006:
  Start of a pre-operational test-phase.
  Fine-Tuning and final evaluation of all components of the system.

• End 2006:
  Start of the operational application.
Final Remarks and Outlook

• Preliminary test of LM at 2.8km grid-spacing (operational set-up, convection switched off) from Dec 2003 - Feb 2004
  - stable and robust
  - deficiencies from explicit convection -> shallow convection needed
  - sometimes convective structures verify subjectively, sometimes not
  - pressure discontinuity at lateral boundaries is solved now
  - spin-up of about 1 h (also at lateral boundaries)

• Re-run of the testsuite for the same starting from Jan 2004 using
  - RK3-TVD time-split integration with 5th order horizontal advection
    (no horizontal diffusion required)
  - full budget equations for rain and snow (prognostic precipitation)
  - SLEVE (smooth level vertical) coordinate

• Upgrade with new physics / dynamics and data assimilation

• Deterministic and probabilistic products

• Many open questions concerning skill and predictability