Deutscher Wetterdienst

Prognostic Precipitation in the Lokal-Modell (LM)

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COSMO-Meeting, Mailand, 22.09.2004

COSMO, Work Package 2.1.1:

Task:

replacement of the **diagnostic scheme** for rain/snow in LM 3.5
by a **prognostic scheme**
in operational use since 26.04.2004 (LM 3.9)

Aim:

improvement of the precipitation distribution in orographically structured areas
due to horizontal **drifting** of rain/snow (solving the ‚windward-lee-problem')

Conservation equation for humidity variables

current LM: diagnostic scheme for rain/snow

$$0 = -\nabla \cdot \mathbf{P}^x - \nabla \cdot \mathbf{F}^x + S^x$$

‚column-equilibrium‘

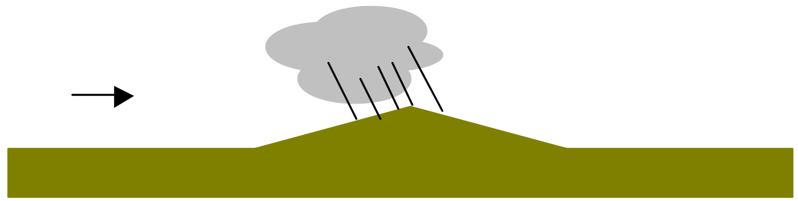
r	[kg/m^3]	density of air
$q^x = r^x/r$	[kg/kg]	specific mass
$\mathbf{P}^x$	[kg/m^2/s]	sedimentation flux of *x* (only *x*=*r*,*s*)
$\mathbf{F}^x$	[kg/m^2/s]	turbulent flux of *x*
S^x	[kg/m^3/s]	sources/sinks of *x* (cloud physics)

x=*v*	water vapour
x=*c*	cloud water
x=*i*	cloud ice
x=*r*	rain drops, $v_{sedim} \approx 5$ m/s
x=*s*	snow, $v_{sedim} \approx 1..2$ m/s

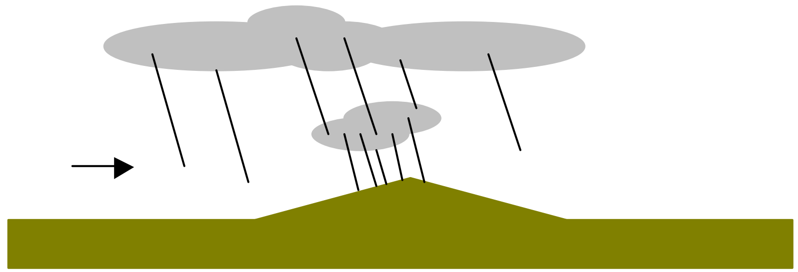
Mechanisms of orographic precipitation generation

(Smith, 1979)

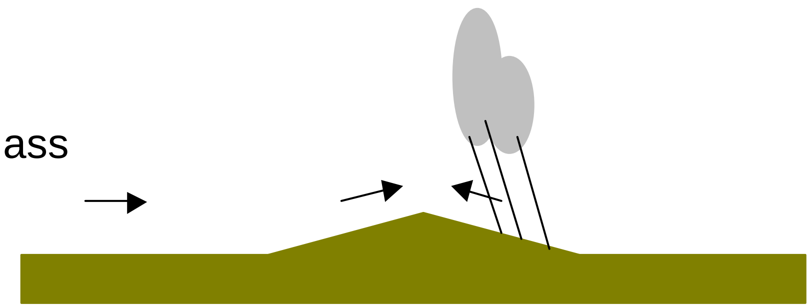
Large-scale upslope precipitation



Seeder-Feeder-mechanism



Cumulonimbus in conditionally unstable airmass



Semi-Lagrange-schemes

Advection-equation (1-dim.)

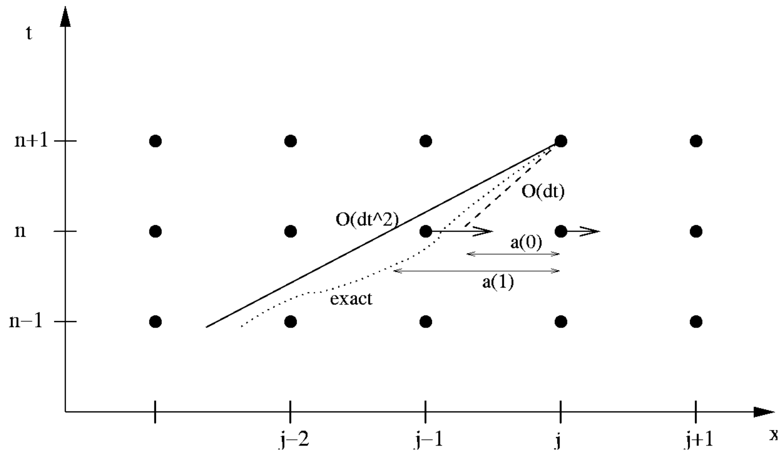
$$\frac{\partial \phi}{\partial t} + u\frac{\partial \phi}{\partial x} = 0$$

or

$$\frac{d\phi}{dt} = 0, \qquad \frac{dx}{dt} = u$$

Numeric formulation

$$\phi(x_j, t^{n+1}) = \phi(\tilde{x}_j^{n-1}, t^{n-1})$$



1.) determine the backtrajectory
2.) interpolate f at the starting point

Properties:

- unconditionally stable (for *u*=const., without source terms)
- simple use in irregular grids
- avoids non-linear instabilities by advection

Lit.: e.g. Staniforth, Côté (1991)

In LM 3.9 used for prognostic precipitation:

Semi-Lagrange Advection

- backtrajectory in 2. order $O(\Delta t^2)$ (about 80% comp. time)
- trilinear interpolation (about 20% comp. time)

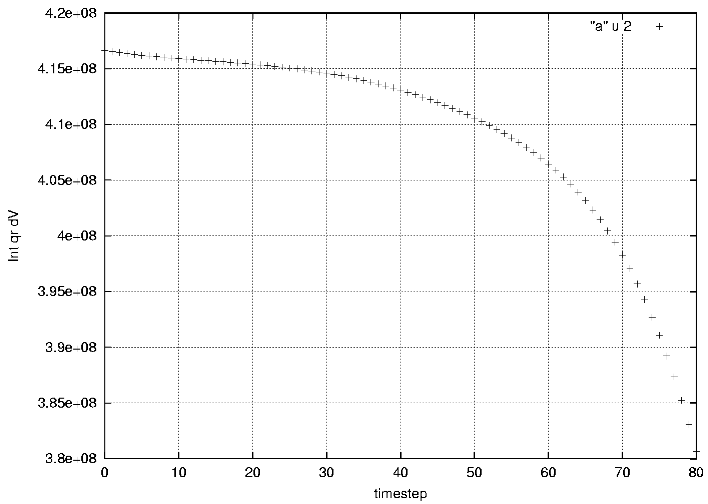
Properties:

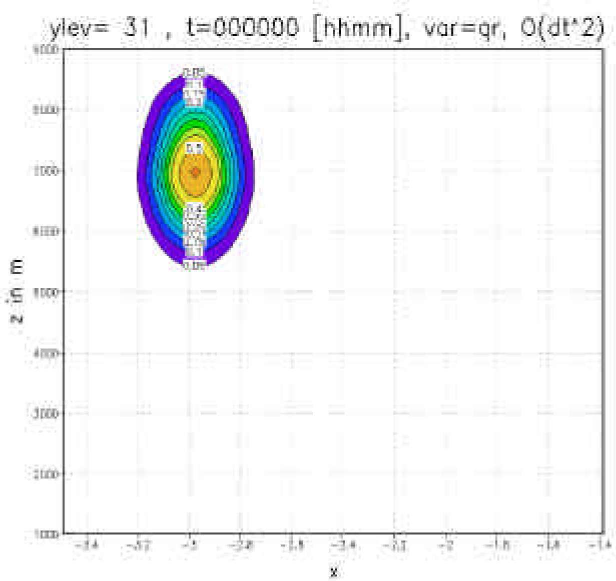
- positive definite
- conservation properties sufficient for rain/snow
- relatively strong numerical diffusion

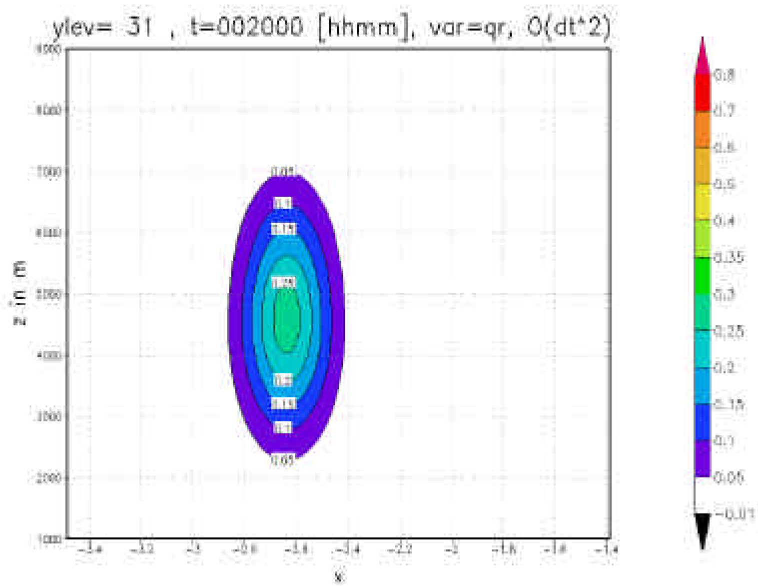
Test of Semi-Lagrange-Adv. in LM

backtrajectory in 2. order $O(\Delta t^2)$,
trilinear interpolation

plane, $(u,v,w) = (30, 0, -2)$ m/s = const.



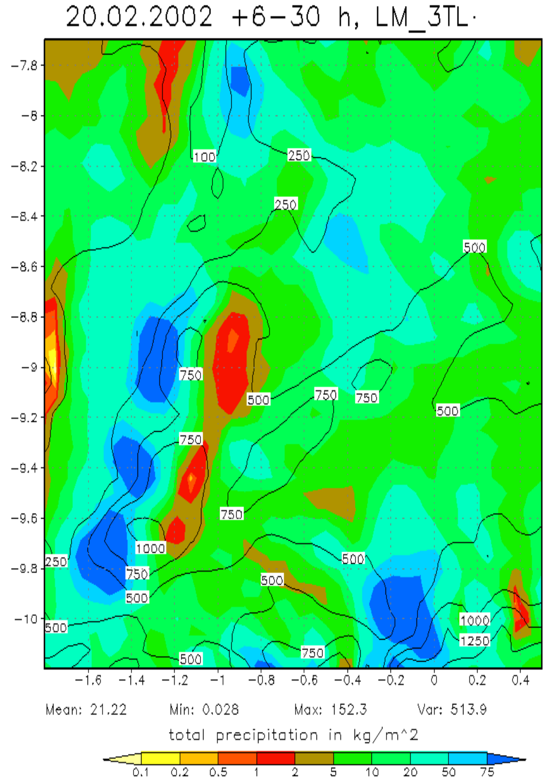




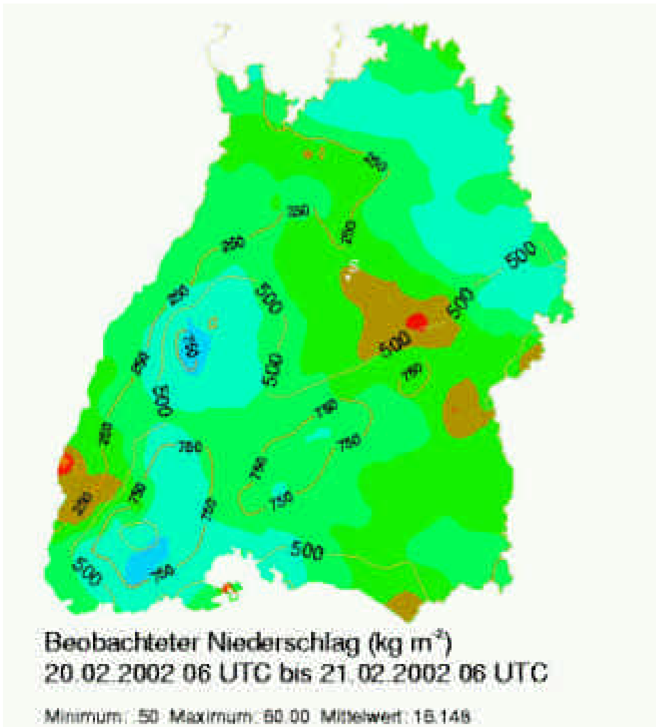
Test case: 20.02.2002 +06-30 h

total precipitation in 24 h

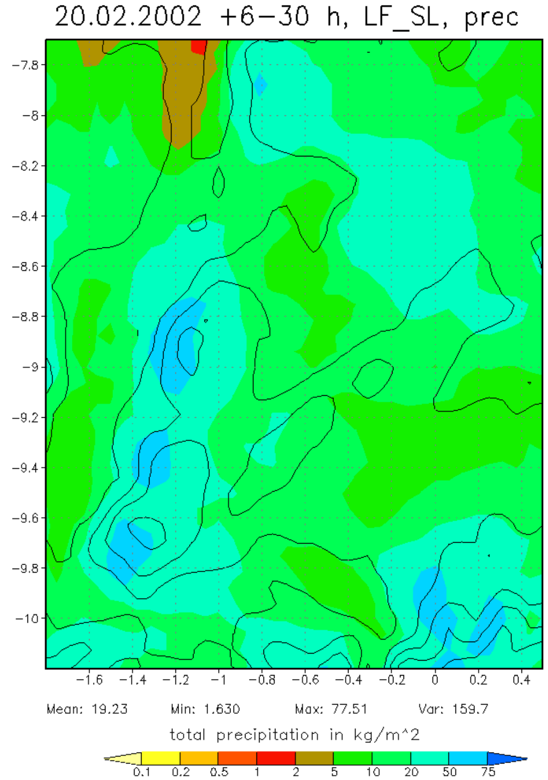
LM with diagnostic precip.



observations

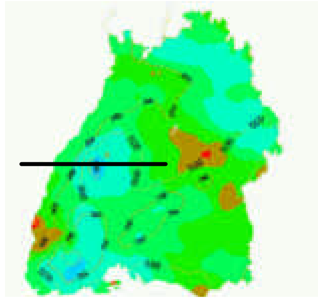


LM with progn. precip.

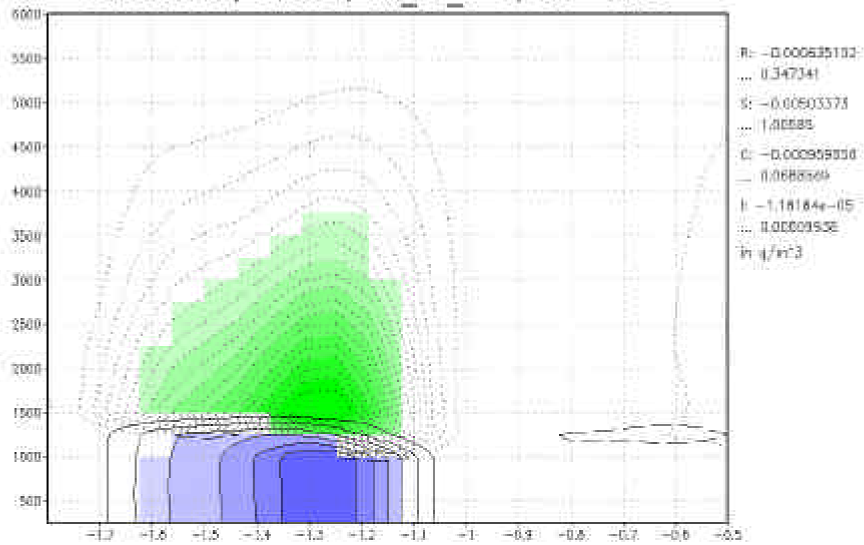


Test case: 20.02.2002

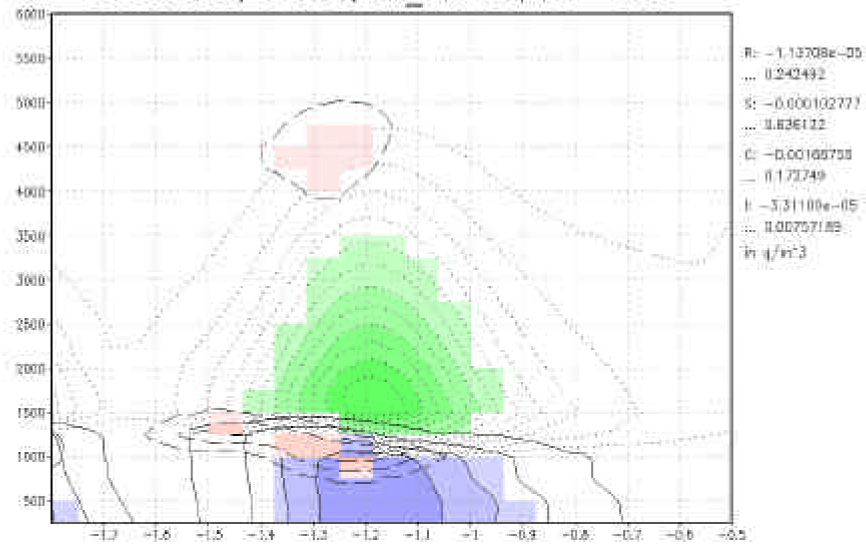
vertical cut (t=16:00)



Prognostic precip. with v=0

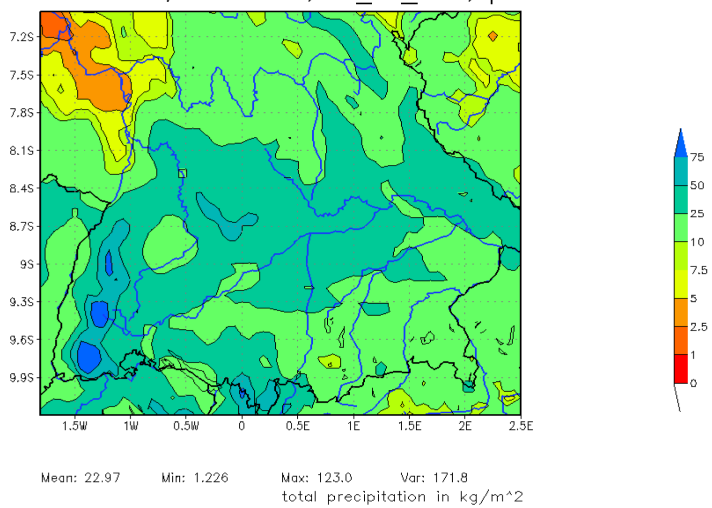


Prognostic precip.

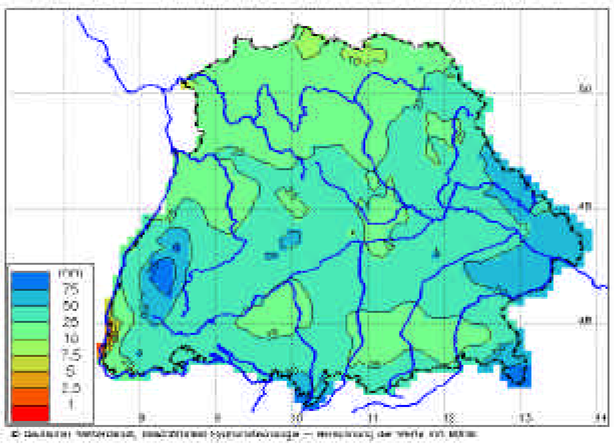


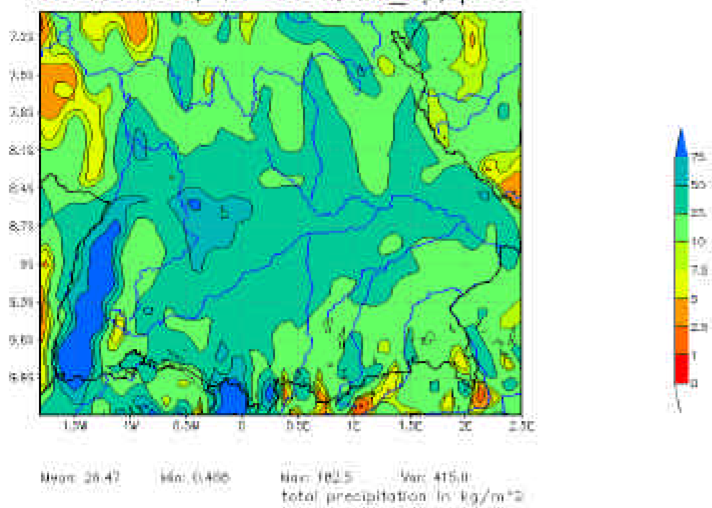
ρ_c ρ_r ρ_s

Numeric experiment:
day 13.01.2004 +06-30 h



BONIE-Analysis

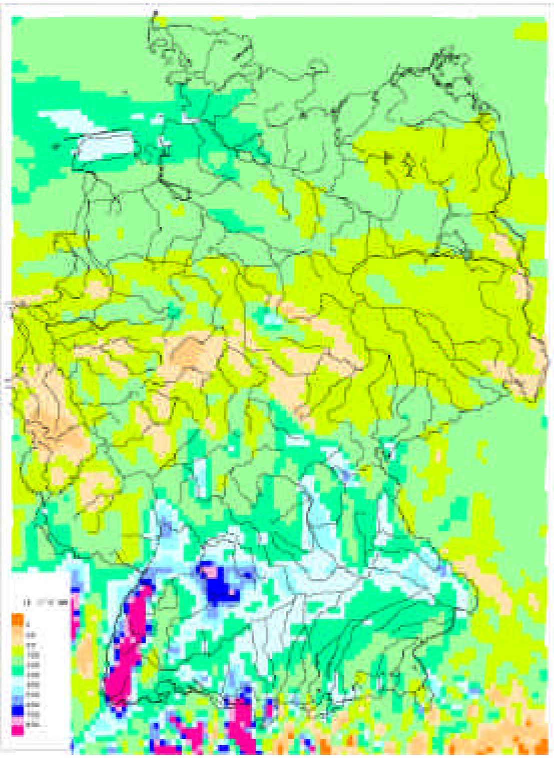




Deutscher Wetterdienst

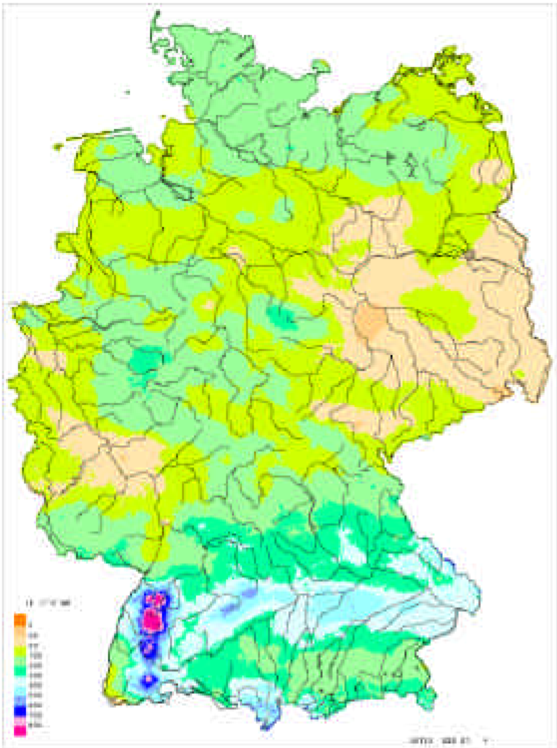
Numeric experiment:
day 13.01.2004 +06-30 h

LM with diagnostic precipitation



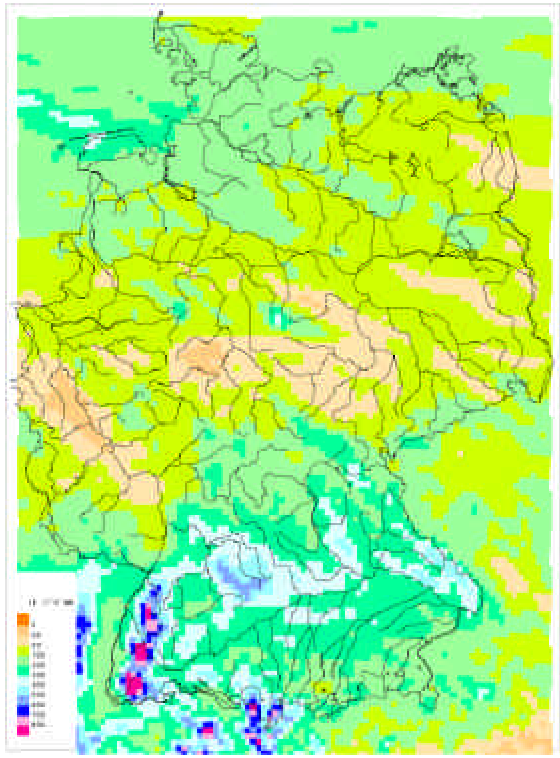
LM 13.01.2004 00UTC 06 UTC bis 06 UTC FT

REGNIE-Analysis



24. STD. ND.HOEHE GEMESSEN AM 14.01.2004 06UTC

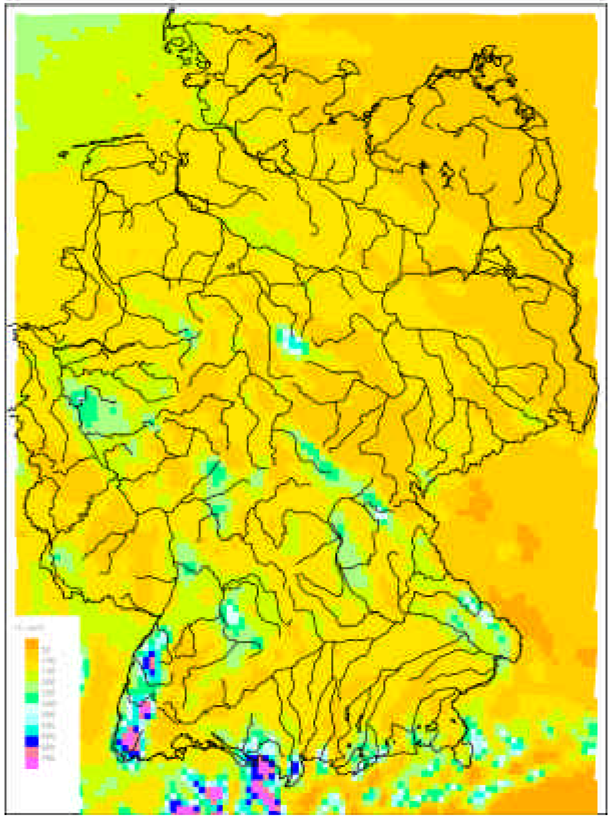
with prognostic precipitation



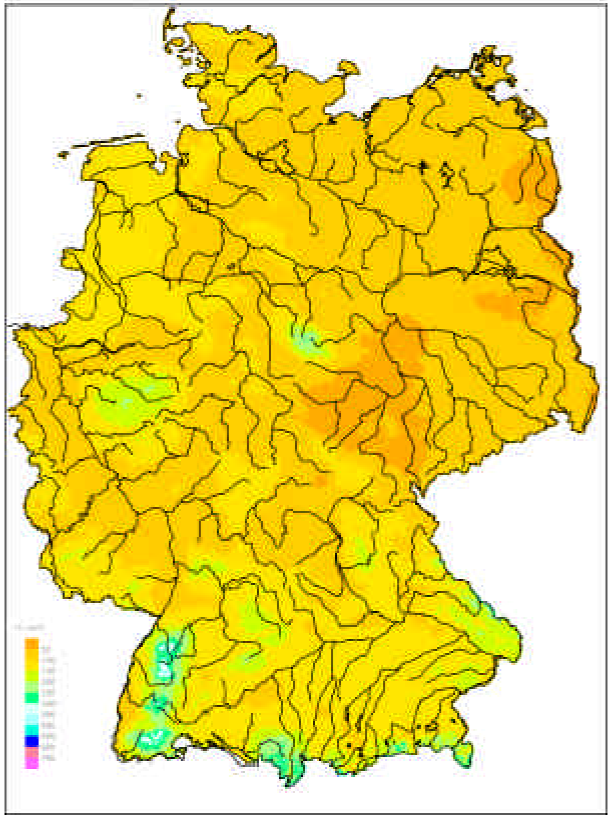
LF_SL 13.01.2004 06 UTC bis 06 UTC FT

24 h - mean values of precipitation for 06.-31.Jan 2004

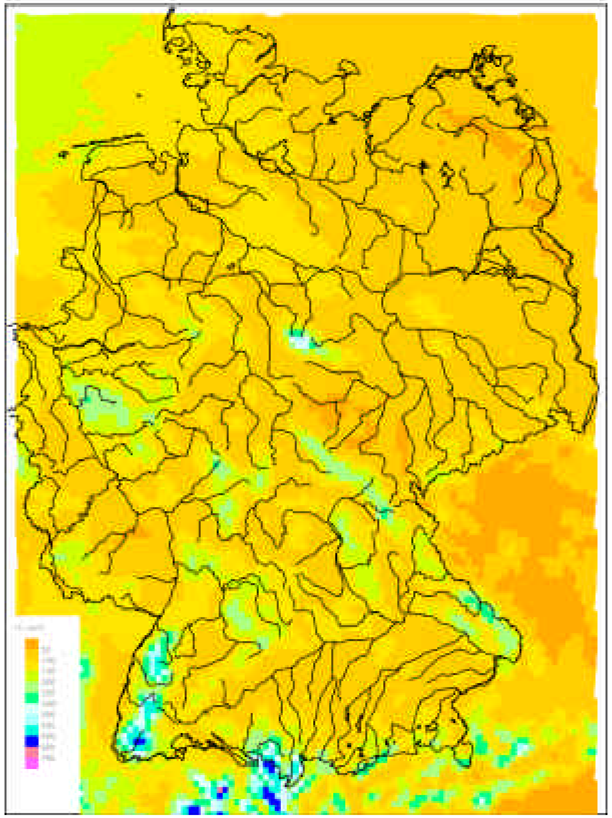
LM 3.5 with diagn. precip.



Beobachtungen (REGNIE)

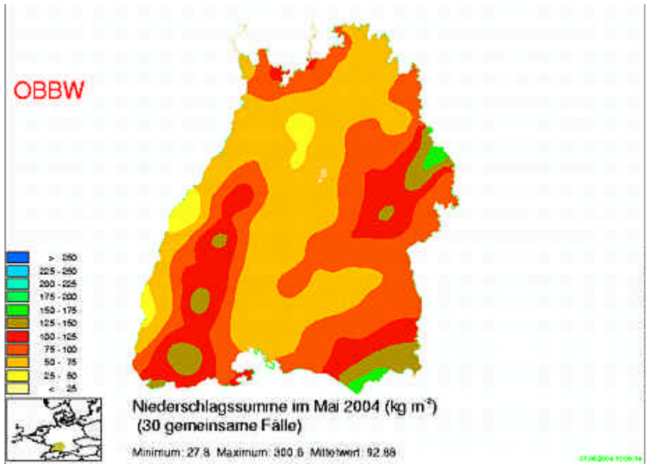


LM 3.9 with progn. precip.

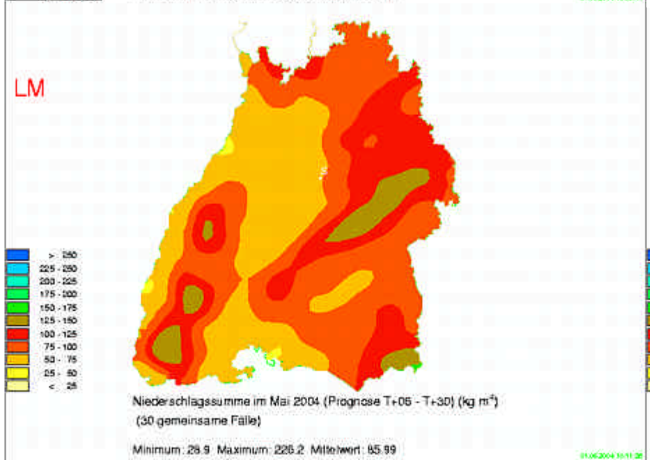


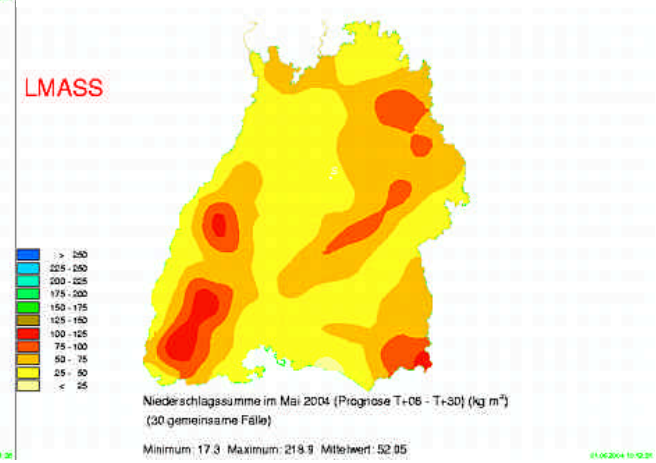
Dr. B. Dietzer (VB HM1)

Monthly precipitation sum over Baden-Württemberg (SW Germany) in Mai 2004



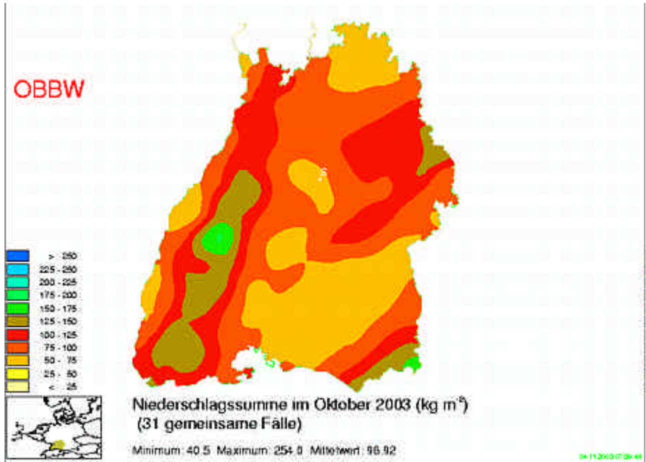
LM 3.9 with
prognostic precipitation



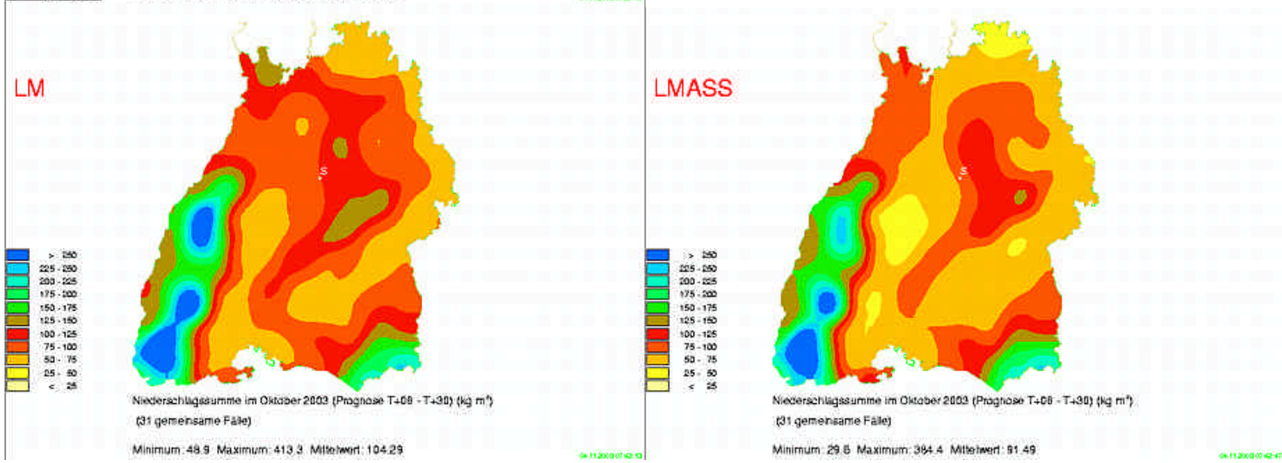


Dr. U. Damrath, FE 14

Monthly precipitation sum over Baden-Württemberg (SW Germany) in October 2003



LM 3.5 with
diagnostic precipitation



Dr. U. Damrath, FE 14

Results

from the actual numeric experiment
(analysis over South-Germany in 06.01.-08.02.2004)

compared to the LM 3.5:

- Windward-Lee-distribution improved in most cases
- spatial averaged precipitation is reduced by about 15-25%
- precipitation maxima are reduced by about 20-40%
- computation time increased by about 20%

Verification

BONIE (Bodenniederschlag)

- learning strategy derived from theory of artificial intelligence
- derivation of statistical properties of the spatial distribution patterns
- interpolation in analogy to Kriging-method

data base:

- measurements at the stations of DWD and AWGeophysBDBw
- additional about 100 ombrometer measurements in Baden-Württemberg

DWD, Geschäftsbereich VB/HM, Dr. T. Reich
Homepage: http://inet1.dwd.de/vb/hm/BONIE/index.htm

REGNIE (Regionalisierung räumlicher Niederschlagsverteilungen)

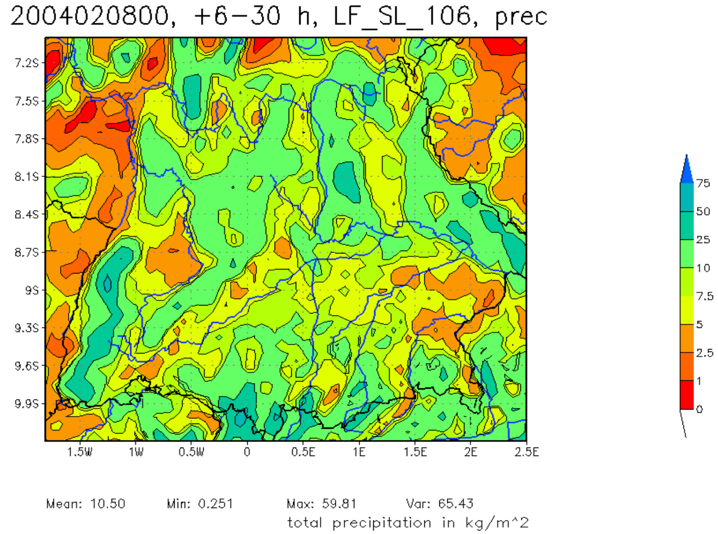
- use of regionalised, monthly averaged precipitation values (1961-1990)
- distance dependent interpolation (background field-method)

data base:

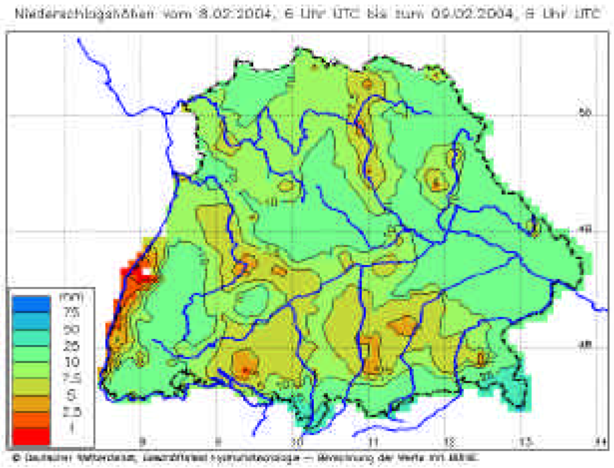
- about 600 stations in Germany

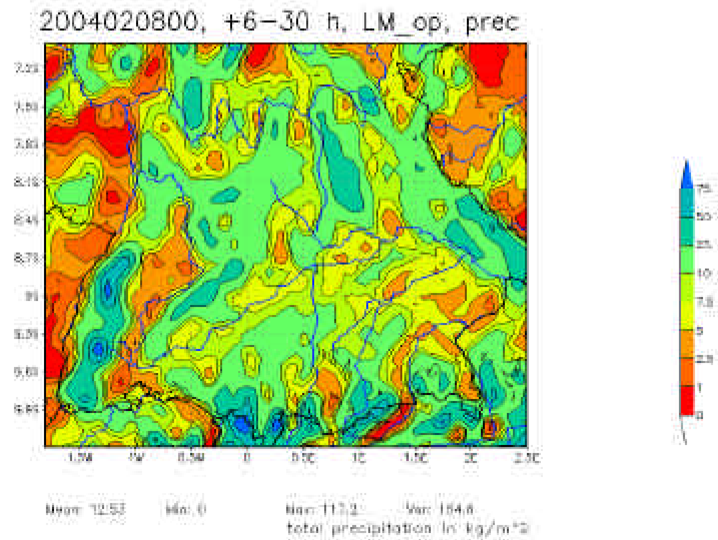
DWD, Geschäftsbereich VB/HM 1, Dr. B. Dietzer

Numeric experiment:
day 08.02.2004 +06-30 h



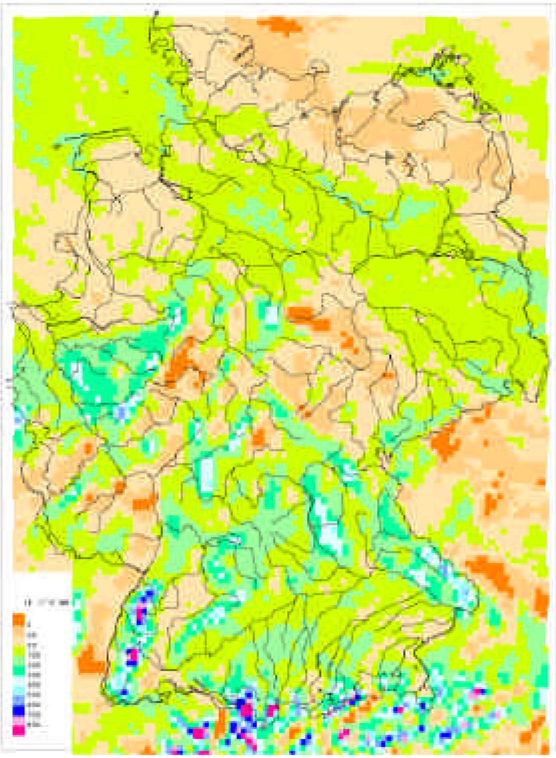
BONIE-Analysis





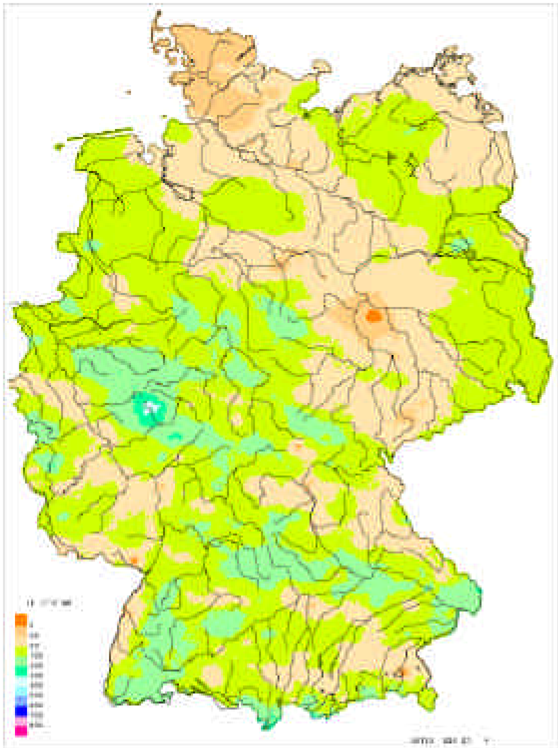
Numeric experiment:
day 08.02.2004 +06-30 h

LM 3.5 with diagnostic precipitation



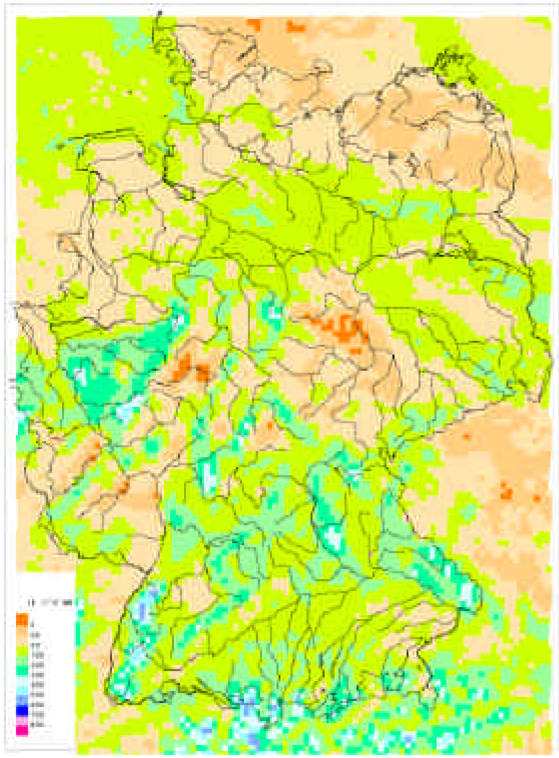
LM 08.02.2004 00UTC 06 UTC bis 06 UTC FT

REGNIE-Analyse



24. STD. ND.HOEHE GEMESSEN AM 09.02.2004 06UTC

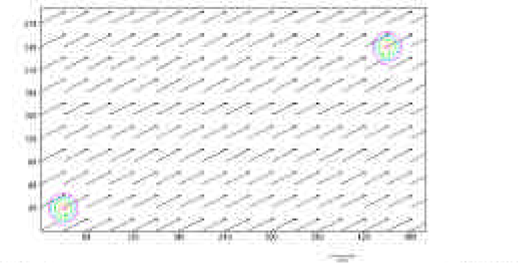
LM 3.9 with prognostic precipitation



LF_SL 08.02.2004 06 UTC bis 06 UTC FT

Advection tests

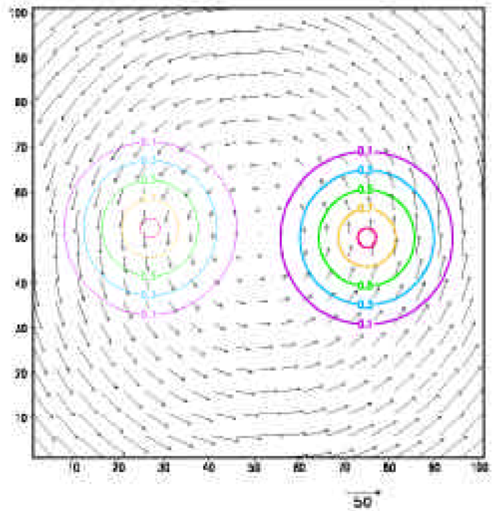
‚constant v‘



Courant numbers

$C_x = 0.4,\ C_y = 0.2$

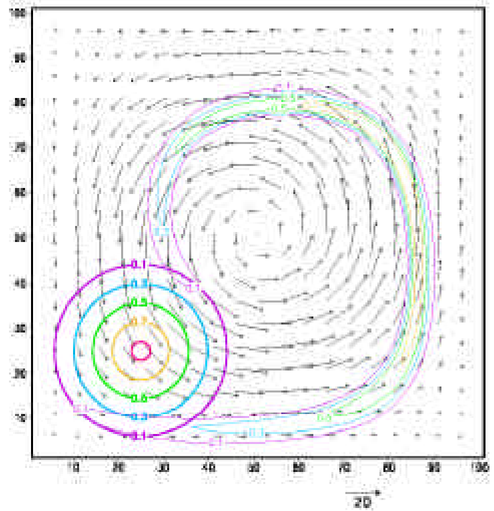
‚solid body rotation‘



Courant numbers

$C_{cone} = 0.4,\ C_{max} = 0.8$

‚LeVeque (1996)‘

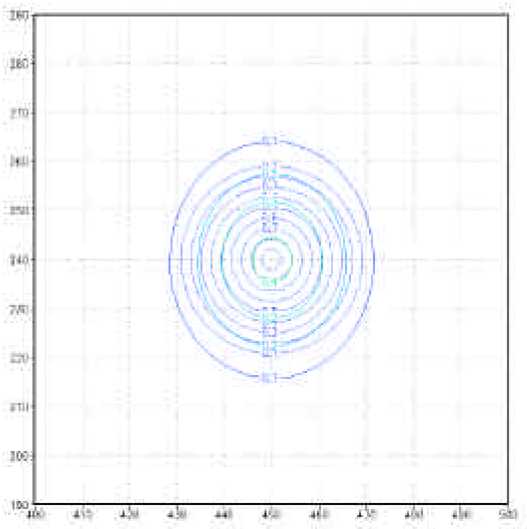


Courant numbers

$C = 0 \ldots 0.4$

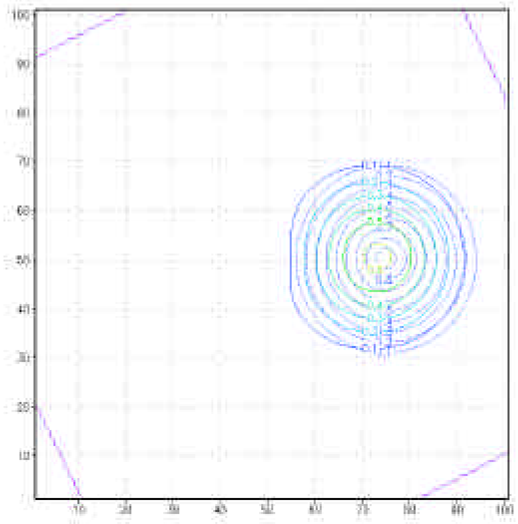
Semi-Lagrange-advection, backtrajectory $O(\Delta t)$, bilinear interpolation

‚constant v‘



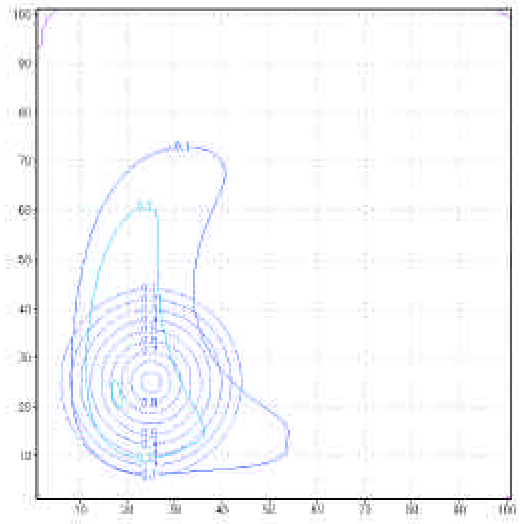
Min. = 0.0
Max. = 0.4204
rel. cons.= -0.000079

‚solid body rotation‘



Min. = 0.0
Max.= 0.62
rel. cons. = -0.18

‚LeVeque‘

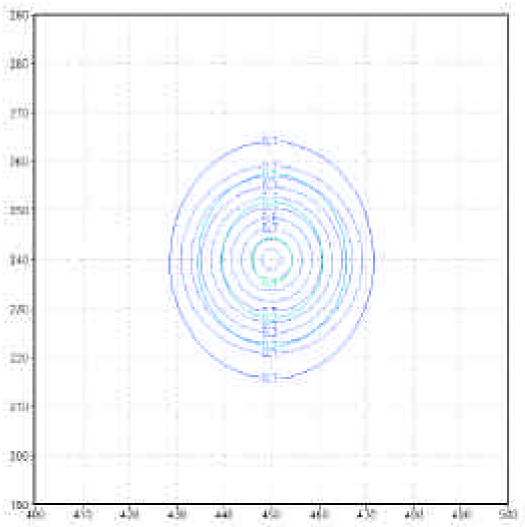


Min. = 0.0
Max. = 0.3018
rel. cons. = -0.0027

computer time relative to upwind 1. order = 2.5

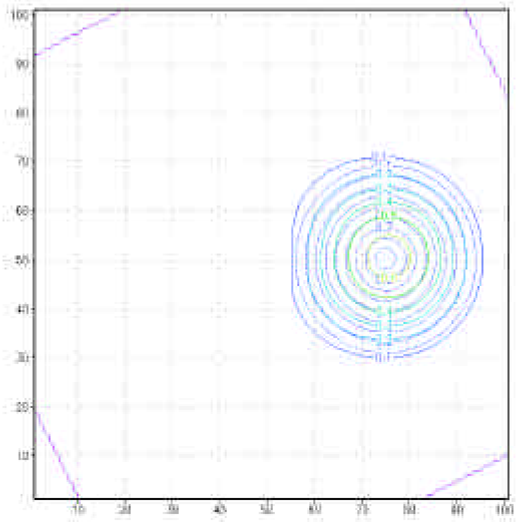
Semi-Lagrange-advection, backtrajectory $O(\Delta t^2)$, bilinear interpolation

‚constant v'



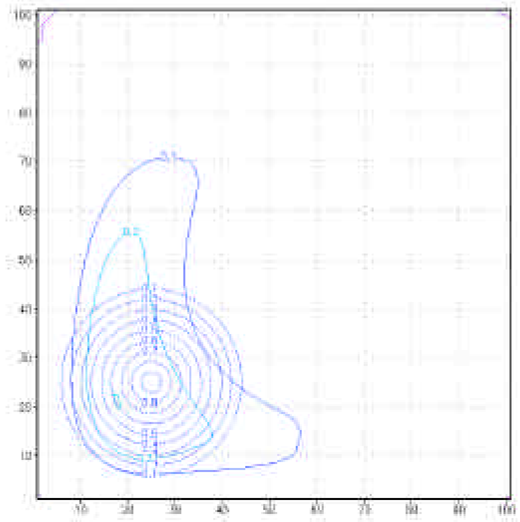
Min. = 0.0
Max. = 0.4204
rel. cons.= -0.000079

‚solid body rotation'



Min. = 0.0
Max.= 0.6437
rel. cons. = -0.0049

‚LeVeque'

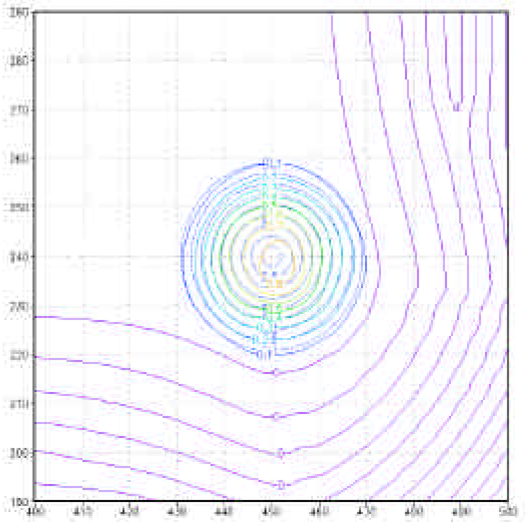


Min. = 0.0
Max. = 0.301
rel. cons. = -0.059

computer time relative to upwind 1. order = 3.75

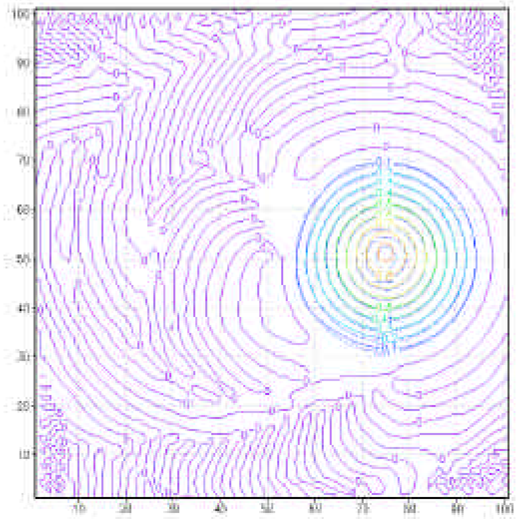
Semi-Lagrange-advection, backtrajectory $O(\Delta t^2)$, biquadratic interpolation

‚constant v'



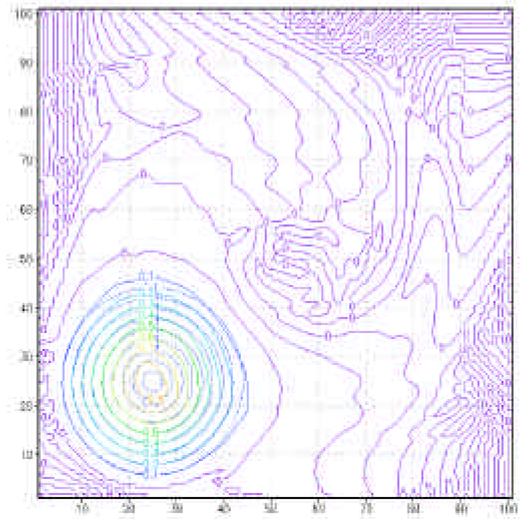
Min. = -0.053
Max. = 0.875
rel. cons.= -0.000061

‚solid body rotation'



Min. = -0.026
Max.= 0.9263
rel. cons. = -0.00020

‚LeVeque'



Min. = -0.0263
Max. = 0.8652
rel. cons. = 0.000019

computer time relative to upwind 1. order = 5.3