MeteoAG

Outline

Grid - Introduction

The Grid workflow MeteoAG

Testing the Grid

Testing the model

Grid computing with - and standard test cases for - a meteorological limited area model

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Starting point

Motivation:

- The need for finer scale analyses of heavy precipitation cases in the Alps ($\Delta x = 500$m)
- Use meteorological model of the atmosphere
- Computationally expensive and many similar model runs

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GRID

Aims:

- Create heavy precipitation database

Outline

What is Grid Computing - Idea power grid

Ask 5 experts - get 5 answers. . .

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Ask 5 experts - get 5 answers. . .

Power supply system:

- uniform access - outlet
- supplies product on demand
- always available
- origin of the product doesn't matter
- payment by usage

A Grid:

- connects dynamically different computing resources, databases and people
- provides hardware and software

Grid Computing

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keyword:

Sharing of resources

Grid Computing

3 aspects:

- “Desktop PC’s”- Grid
  - Seti@Home - student PC at Uni Innsbruck
  - cheap
  - usage of idle times

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  - managing huge amounts of distributed data
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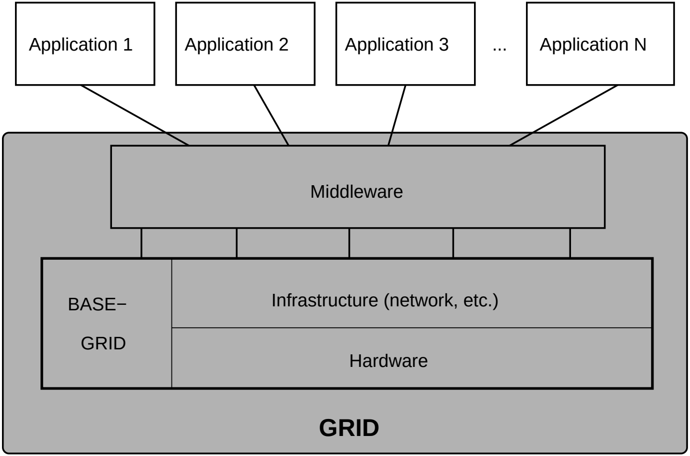
  - Seti@Home - student PC at Uni Innsbruck
  - cheap
  - usage of idle times
- Data-Grid
  - managing huge amounts of distributed data
  - cooperation of different organizations
- Distributed high-performance computers:
  - cooperation of supercomputers
  - better load-levelling and usage-rate
  - more than the sum of each

Structure of a Grid



AustrianGrid

- currently gives access to 700 - 2500 Cpus
- 25 Partners
- various groups:
  - astrophysics
  - medicine
  - business research
  - ...
- second phase just started

Outline

Motivation

Benefits for us

- many compute cluster available
- huge data transfer possibilites
- fast parameter/sensitivity studies
- many cases needed for database - can be run parallel

Software

RAMS Regional Atmospheric Modeling System

- nonhydrostatic Limited Area Model (gridpoint)
- maintained by Colorado State University (CSU)

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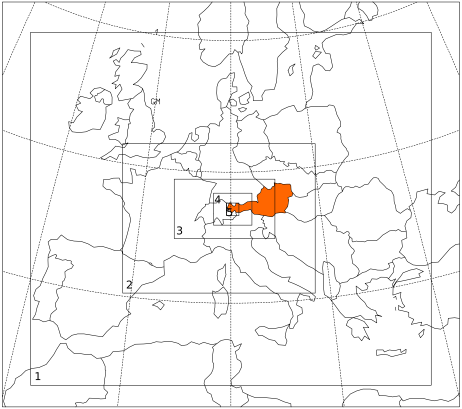
REVU

- postprocessing tool for RAMS

RAVER

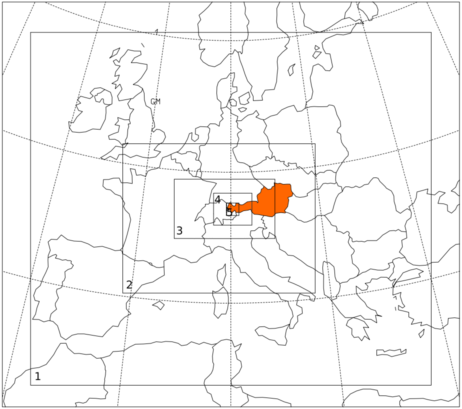
- tool for decision making

Domainlocations



Do	Pts	Δx
1	90x90	40.5km
2	150x130	13.5km
3	240x190	4.5km
4	350x270	1.5km
5	260x260	500m

Domainlocations



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1	90x90	40.5km
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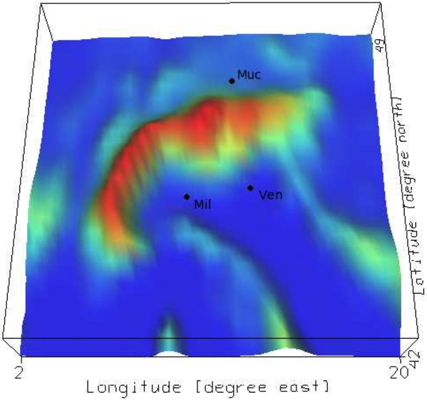
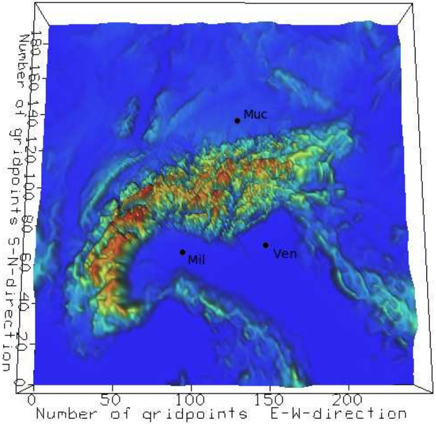
each 60 levels

initialized with ECMWF

Topography

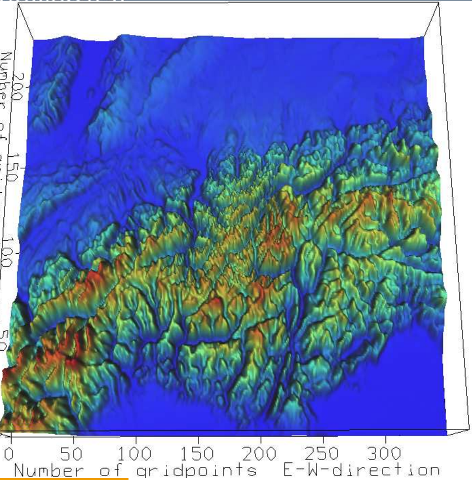


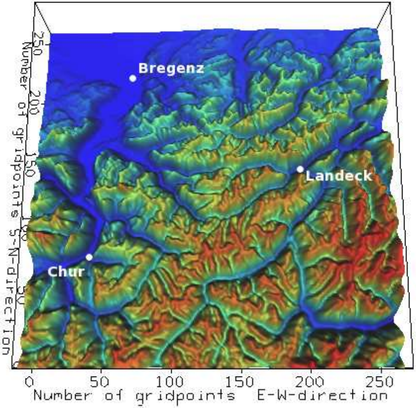


T511 topography ECMWF

RAMS domain 2 topography

Topography 2

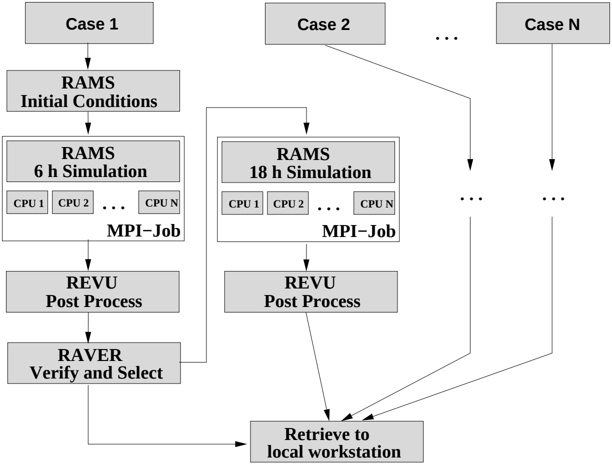




Domain 4

Domain 5 (based on SRTM 3s)

MeteoAG Workflow



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MeteoAG

AGWL

Workflow has to be ported (*as simple as possible*) to GRID...

Description with Abstract Grid Workflow Language (AGWL)

```
<agwl name=‘‘MeteoAG’’> <agwlInput>
<dataIn name=‘‘geodata’’ type=‘‘file’’ source=‘‘...’’/>
<dataIn name=‘‘casedata’’ type=‘‘collection’’ source=‘‘...’’/>
</agwlInput>
<agwlBody>
<activity name=‘‘initialize’’ type=‘‘meteoag:initialize’’>
<dataIns>
<dataIn name=‘‘geo’’ type=‘‘file’’ sour collection=‘‘MeteoAG/casedata’’,
<loopBo
............
```

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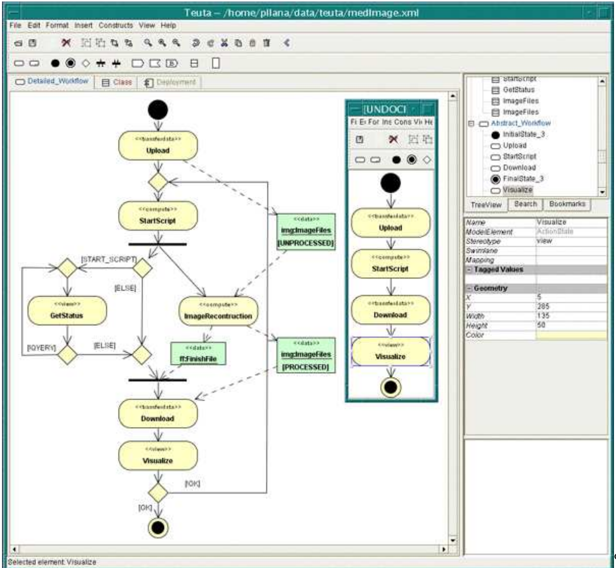
<loopBo
.............
```

Representation WITHOUT any reference to hardware!!!

Teuta


Teuta – /home/pllana/data/teuta/medImage.xml
File Edit Format Insert Constructs View Help
Detailed_Workflow
Class
Deployment
Upload
StartScript
[START_SCRIPT]
[ELSE]
GetStatus
ImageRecontruction
[QYERY]
[ELSE]
<<data>>
imgImageFiles
[UNPROCESSED]
ff:FinishFile
imgImageFiles
[PROCESSED]
Download
Visualize
[OK]
[UNDOC]
Upload
StartScript
Download
Visualize
GetStatus
ImageFiles
Abstract_Workflow
InitialState_3
FinalState_3
TreeView
Search
Bookmarks
Name
ModelElement
Stereotype
Swimlane
Mapping
Tagged Values
Geometry
X
Y
Width
Height
Color
ActionState
view
5
285
135
50
Selected element: Visualize

Outline

Idea / Motivation

Quality: correct setup of computing environment

Question / Problem

Does the GRID influence my model results?

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Quality: correct setup of computing environment

Question / Problem

Does the GRID influence my model results?

Full blown meteorologcial simulations are too complex to verify

- Error sources abundant and not separable:
  - meteorological origin
  - computational origin

Strategy

Simplified **meteorological** test:

- idealized flow over hill
- linear, dry, 2 dimensional

$\Rightarrow$ **Analytical Solution**

Strategy

Simplified **meteorological** test:

- idealized flow over hill
- linear, dry, 2 dimensional

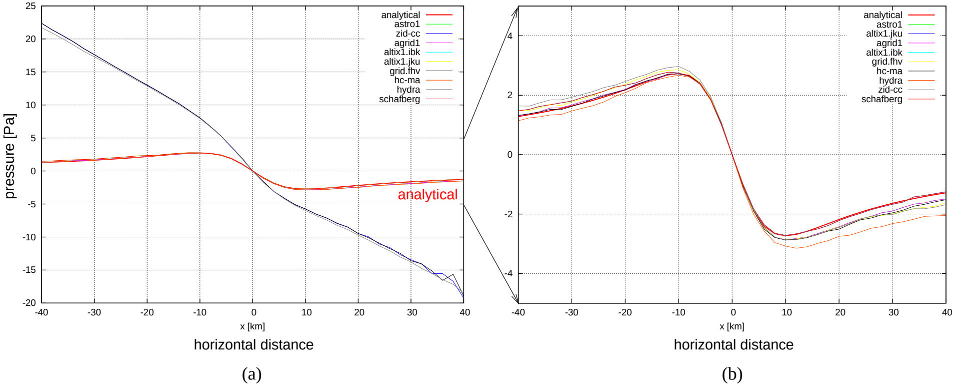
⇒ **Analytical Solution**

Computational setup:

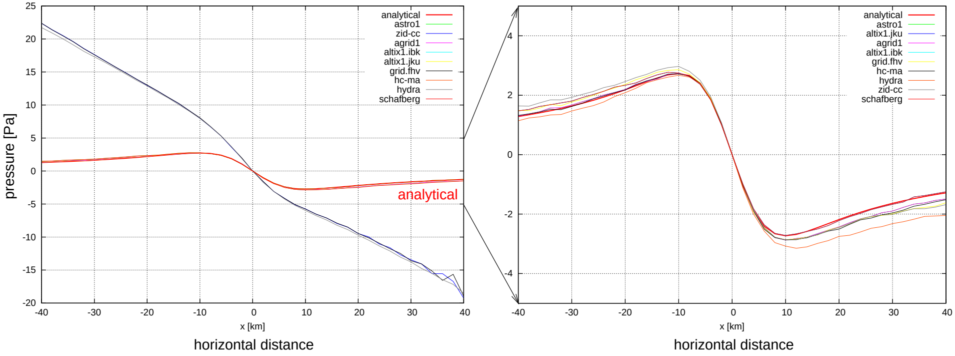
3 **static** executables on single CPU

- ia64 - Intel type 64bit CPU
- x86-64 - i686 (Opteron) type 64bit CPU
- x86-32 - i386 32bit CPU

Surface pressure pertubation - Comparison



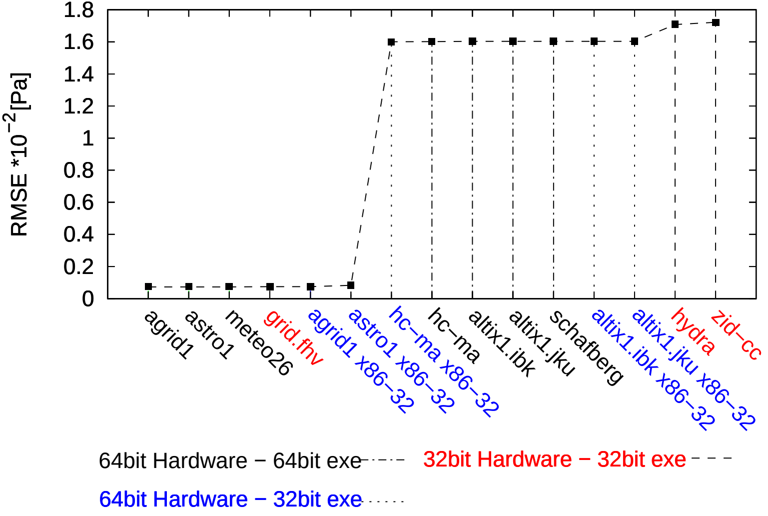
Surface pressure pertubation - Comparison



(a) (b)

The analytical solutions are identical.

Root Mean Squared Error



Further tests

MeteoAG

- performance behavior: does it always execute the same way? $\longrightarrow$ Yes $\longrightarrow$ necessary for load leveling
- scaleing: is there any benefit in distributing it? $\longrightarrow$ Yes
- parallel behavior: does parallel environment influcence results? $\longrightarrow$ No

Further tests

MeteoAG

- performance behavior: does it always execute the same way? → Yes → necessary for load leveling
- scaleing: is there any benefit in distributing it? → Yes
- parallel behavior: does parallel environment influcence results? → No

- the low error levels are meteorologically acceptable
- BUT: significant differences between GRID sites!

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Idee / Motivation

- Often change of:
  - modelversion
  - hardware
  - software (Compiler. . .)
  - parametrizations

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- Often change of:
  - modelversion
  - hardware
  - software (Compiler. . .)
  - parametrizations

Question / Problem

Does my model still produce the “right” results ?
OR: is another model better than mine (Evaluation)?

Testdesign

Standard tests, which

- are easy to setup

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- easy to verify (best: analytical solution). **reference solution**

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- have minimal requirements (Inputdata...)

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Approach W. Skamarock und Jim Doyle

Testdesign

Standard tests, which

- are easy to setup
- easy to verify (best: analytical solution). **reference solution**
- test a specific aspect
- have minimal requirements (Inputdata. . .)

Approach W. Skamarock und Jim Doyle

in my case applied to RAMS

Reference solution

Either

Analytical solution

- linearization and variable reduction
- easy to reproduce
- deterministic
- very idealized and not available for complex problems

"Grid converged solution"

Or

Grid converged solution

Lax-Richtmeyer theorem for linear systems

stable + consistent → convergenz

"Grid converged solution"

Or

Grid converged solution

Lax-Richtmeyer theorem for linear systems

$$\textbf{stable} + \textbf{consistent} \rightarrow \textbf{convergenz}$$

so a stable and consistent system with

- $\Delta x \rightarrow 0$
- $\Delta t \rightarrow 0$

produces a converging solution.

Interpretation of results

- *Mathematical approach*
  - easy and automatically computable
  - but sometimes show no improvement even if there is some

Interpretation of results

- *Mathematical approach*
  - easy and automatically computable
  - but sometimes show no improvement even if there is some
- *Empirical intuitive approach*
  - good overall picture
  - but subjective and hard to reproduce

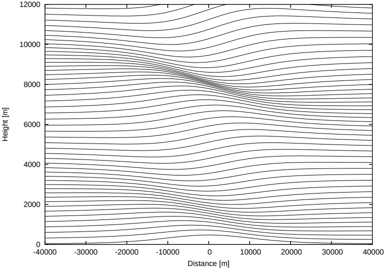
MeteoAG

Linear mountain flow

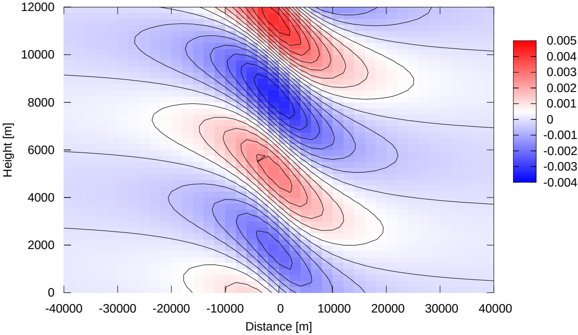
- 2D, dry isothermal atmosphere
- constant wind profile
- no radiation, no rotation, free-slip lower boundary
- bell shaped mountain (Witch of Agnesi) with h=1m
- analytical solution

Test for checking different hardware

Reference solution

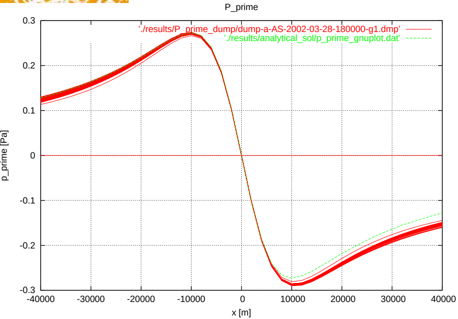


displacement of streamlines (600 time exagerated)

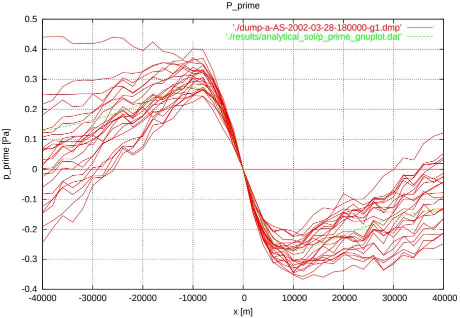


vertical velocity w[m/s]; u0=20m/s; hm=1m; a=10km

Results pressure pertubation

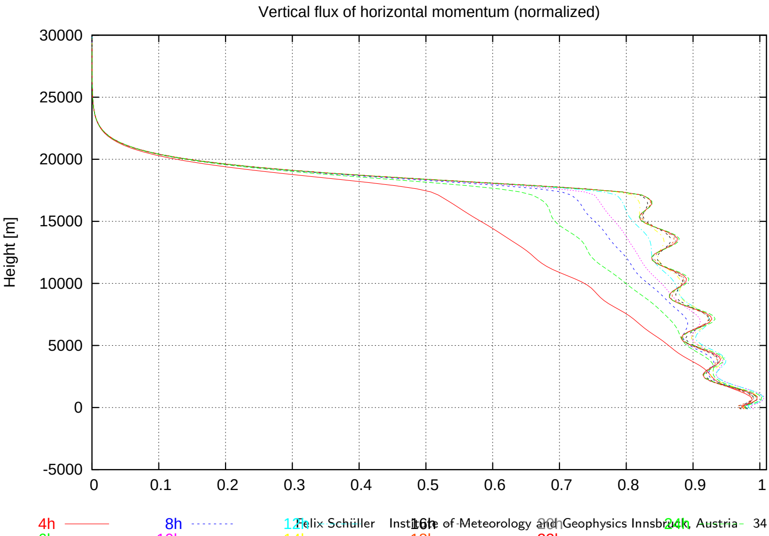


double precision



single precision

Results vertical flux



Zängl

- 3D
- dry, stable stratified atmosphere
- NO wind
- no radation, no rotation, free slip lower boundary
- bell shaped mountain

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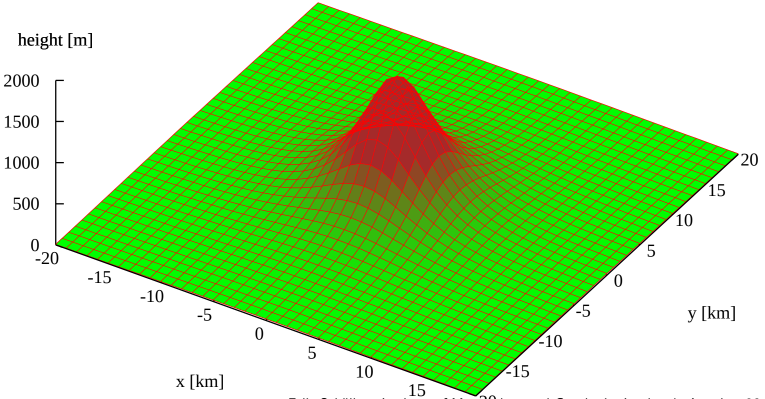
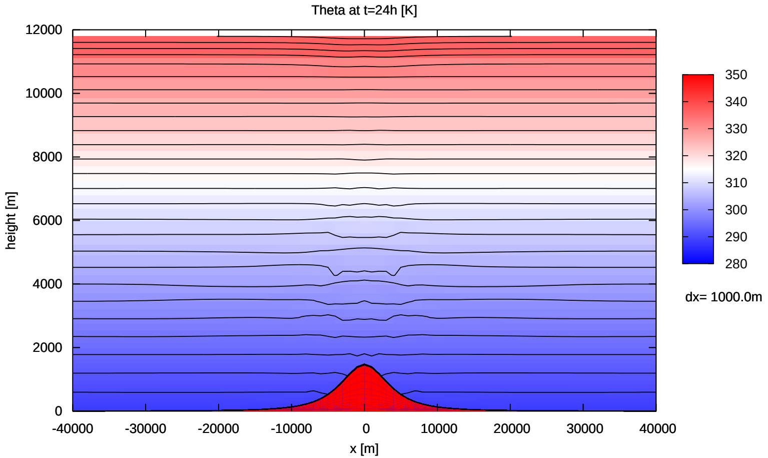
Good test for parallel computing environment

Topography

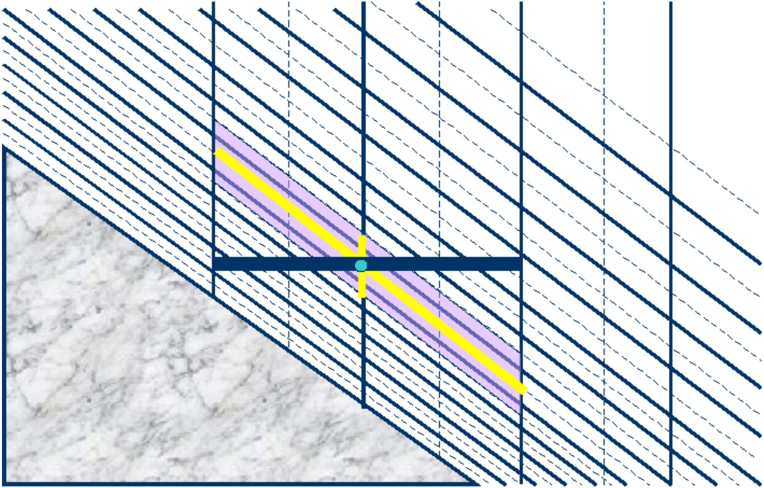


IHOR1

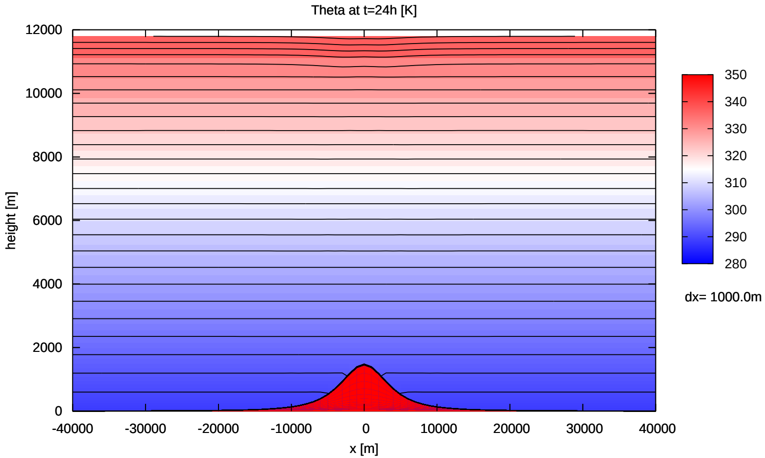


Gradient along model levels

Horizontal gradient



IHOR2

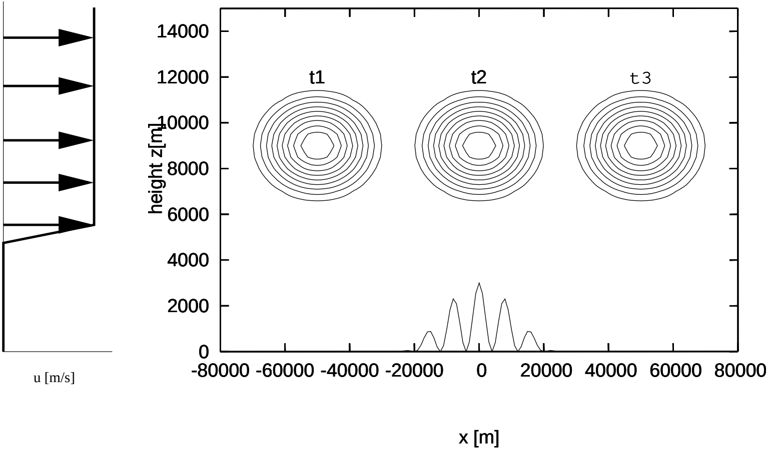


true horizontal gradient

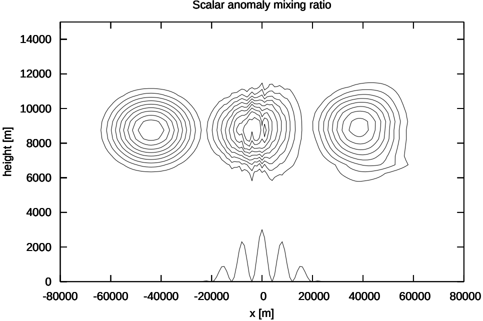
Schär 2

- 2D
- dry, stable stratified atmosphere
- no wind at bottom, constant wind aloft
- scalar anomaly (no explicit diffusion applied)
- bell shaped mountain with short wave pertubation
- no radation, no rotation, free slip lower boundary

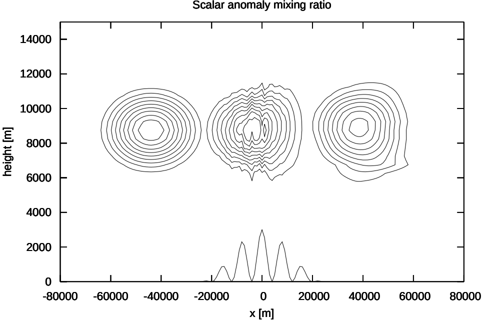
Reference solution



Scalar mixing ratio; u0=10m/s; hm=3000m; a=25km



Ihor 1, dz=500m



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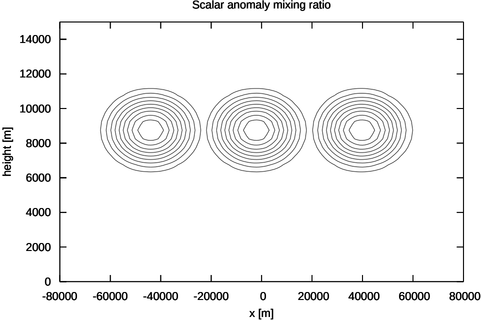
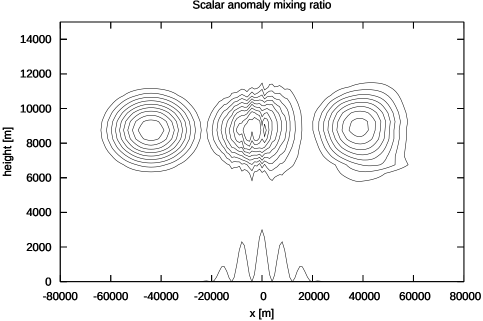


lhor 1, dz=500m, no topo



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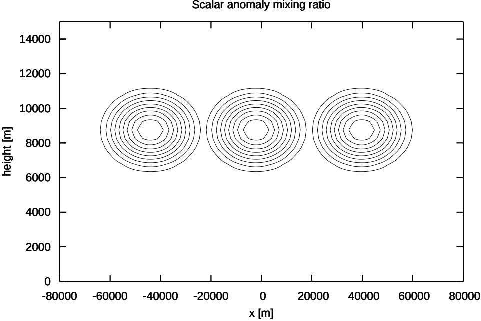

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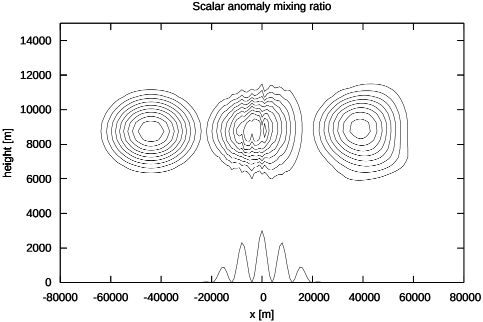
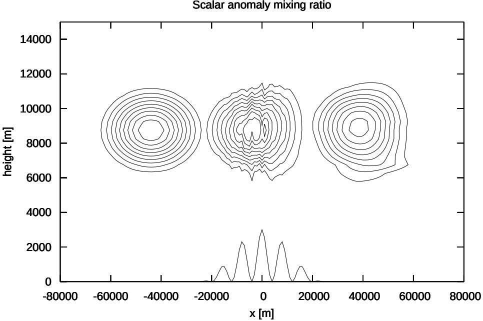


lhor 2, dz=500m



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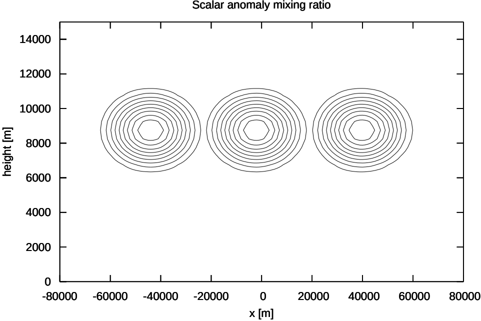

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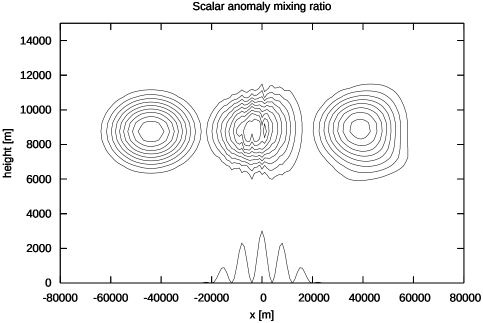
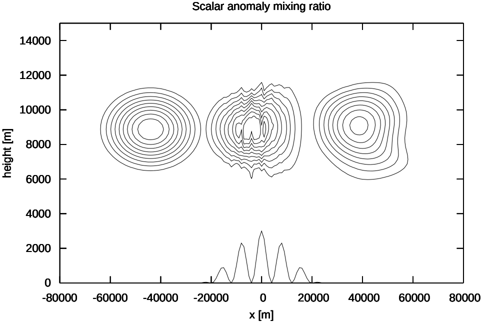


Ihor 2, dz=500m



Ihor 2, dz=250m

Further tests

Stratocumulus

- 3D
- nighttime boundary layer topped with stratocumulus

Further tests

Stratocumulus

- 3D
- nighttime boundary layer topped with stratocumulus

Convection

- 3D warm air bubble

Further tests

Stratocumulus

- 3D
- nighttime boundary layer topped with stratocumulus

Convection

- 3D warm air bubble

Density current

- 2D cold air bubble

Further tests

Stratocumulus

- 3D
- nighttime boundary layer topped with stratocumulus

Convection

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Density current

- 2D cold air bubble

Mountain flow

- 2D mountain flow with complex topography

Conclusions

- Grids
  - useful tool for research
  - not mature enough for operational environments

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- Grids
  - useful tool for research
  - not mature enough for operational environments
- Standard tests
  - useful for finding model weaknesses/problems
  - make model intercomparison possible
  - good for checking hardware

Thanks

Final Words:

Thank you for your attention!
Questions welcome!

More reading:

- Schüller, F., and J. Qin, 2006: Towards a workflow model for meteorologcial simulations on the Austrian Grid. Austrian Computer Society, 210, 179-190.
- Schüller, F. et al, 2007: Perfomance, Scalability and Quality of the Meteorological Grid Workflow MeteoAG. Austrian Computer Society, 221, 210-221.
- Schüller, F. 2007: Grid computing with - and standard test cases for - a meteorological limited area model, Diploma Thesis, pp 128.