Rewrite of the graupel microphysical parameterisation of COSMO using STELLA

Exa2Green
energy-aware numerics

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COSMO User Workshop
November 27, 2013

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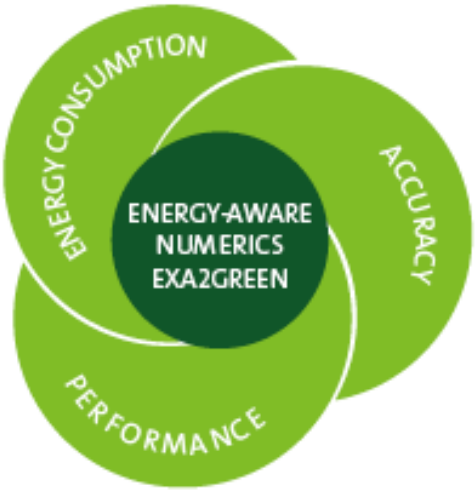
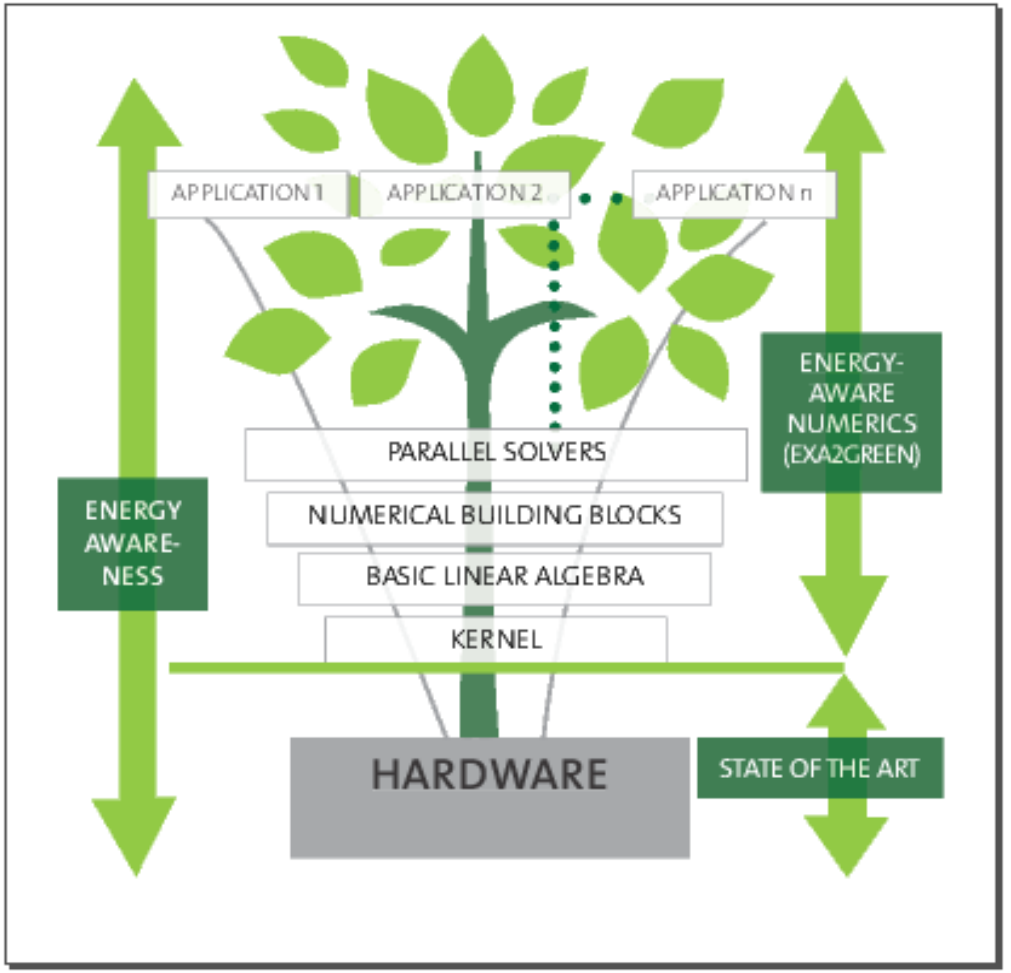
EU FP7-funded Exa2Green Project

"Energy-aware Sustainable Computing on Future Technology"





http://exa2green-project.eu

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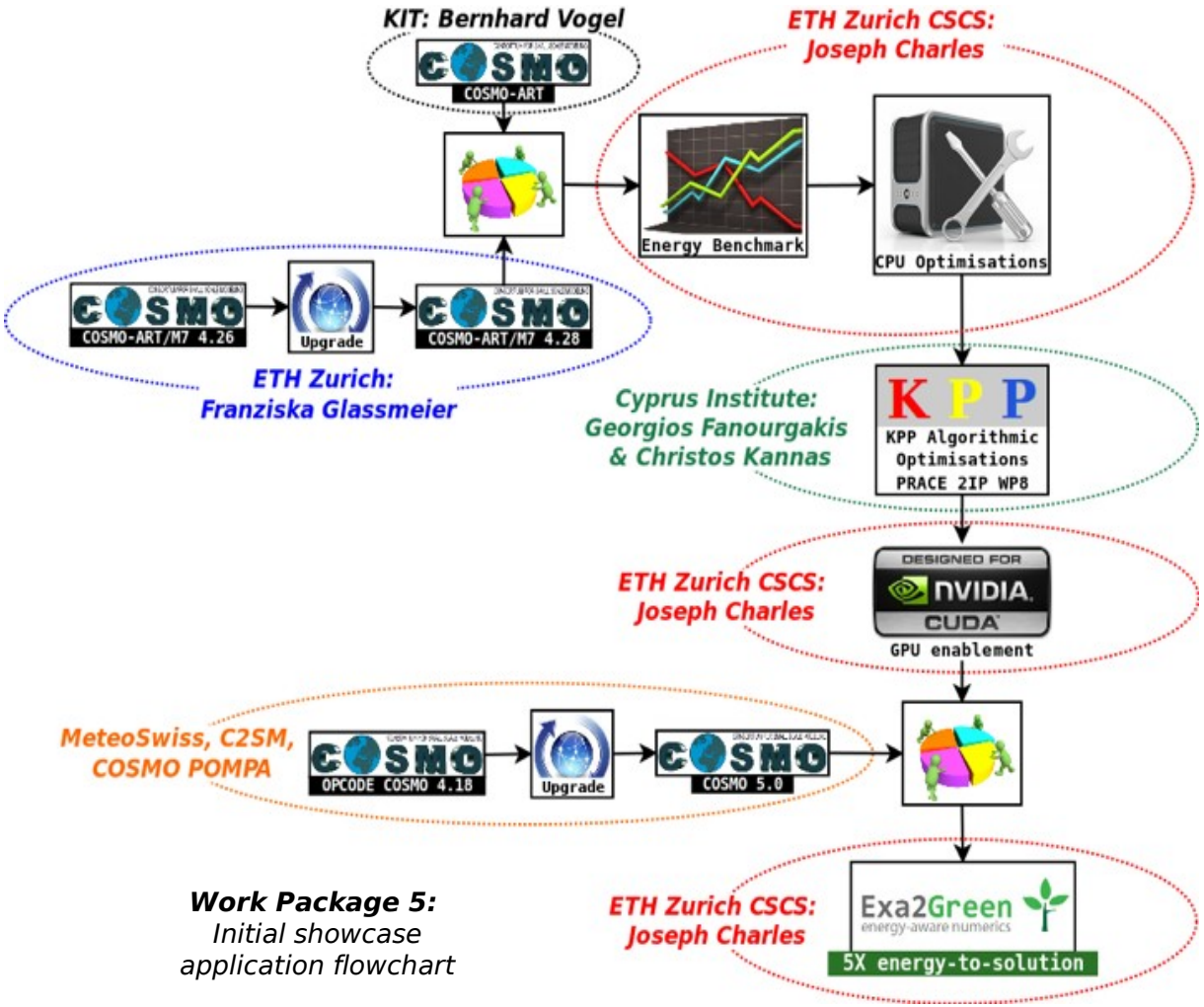
SEVENTH FRAMEWORK PROGRAMME

EU FP7-funded Exa2Green Project

"Energy-aware Sustainable Computing on Future Technology"

- **Seven European partners:**
  - University of Hamburg,
  - University of Jaume,
  - University of Heidelberg,
  - ETH Zurich CSCS,
  - IBM Rueschlikon,
  - Karlsruhe Inst. of Tech.,
  - Steinbeis Innovation gGmbH
- **Human resources:**
  36 PMs for CSCS, 261.6 PMs overall
- **Framework:**
  Covers all essential fields of expertise in energy-efficient computing
- **Showcase application:**
  COSMO-ART and/or COSMO-ART/M7
- **Ultimate goal:**
  5x improvement in energy-to-solution over baseline
- **Boundary conditions:**
  leverage off of HP2C COSMO work, maximize benefit for Swiss climate community



Work Package 5:
Initial showcase application flowchart

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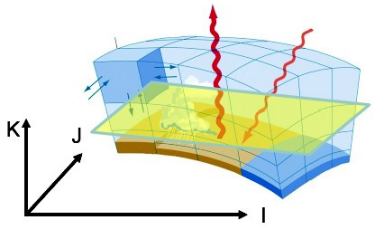
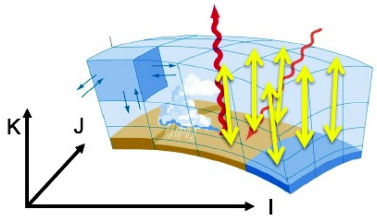
COSMO specific requirements

HP2C COSMO-CLM project: design of STELLA (STEncil Loop LAnguage)



Explicit solves in the horizontal IJ-planes
using finite difference stencils
No loop carried dependencies



Implicit solves in the vertical K-direction
using one tri-diagonal solve per column
Loop carried dependencies in K

Dynamical core

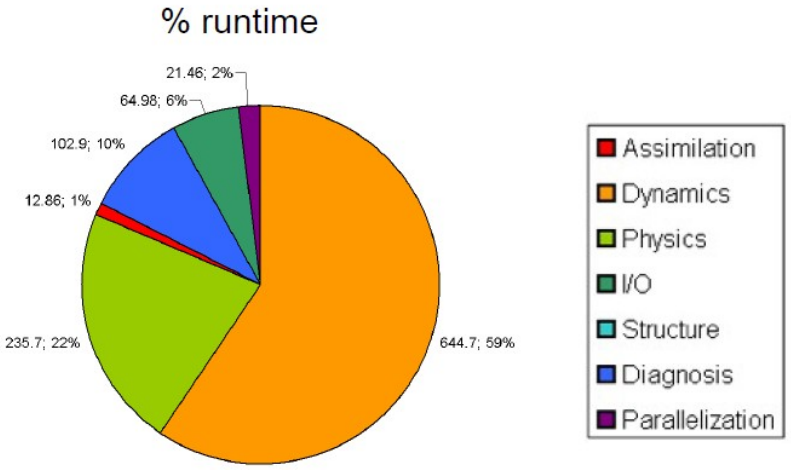
- Small group of developers
- Memory bandwidth bound
- Complex stencils (3D)
- 60% of runtime

→ **Complete rewrite in C++/CUDA**
→ Development of a stencil library
→ Development of new communication library (GCL)
→ Target architecture CPU (x86) and GPU.
→ Extendable to other architectures
→ Long term adaptation of the model

Physics and Data Assimilation

- Large group of developers
- Code may be shared with other models
- Less memory bandwidth bound
- Large part of code (50% of the lines)
- 20% of runtime

→ **GPU port with compiler directives (OpenACC)**
→ Little code optimization
→ Some parts stay on CPU
→ Most ported routines currently have CPU and GPU version



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STELLA Library

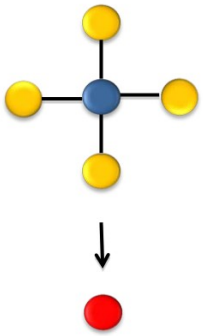
Design considerations for efficient parallelisation

- 2 fundamental concepts treated separately:
  - loop-logic: platform specific, implemented by the library
  - update-function: platform independent, implemented by the user

```
do k = kstart, kend
  do j = jstart, jend
    do i = istart, iend
      lap(i, j, k) = -4.0_ir * data(i, j, k) + &
        data(i+1, j  , k) + data(i-1, j  , k) + &
        data(i  , j+1, k) + data(i  , j-1, k)
    end do
  end do
end do
```

Loop-logic

Update-function



- Domain Specific Embedded Language using C++ template meta-programming to define:
  - loop-logic (sweeps: K-loops, stages: parallel IJ-loops)
  - temporary fields (stencil buffers, stage variables)

- 2 optimised backends:
  - X86 CPU: OpenMP, KIJ-storage
  - NVIDIA GPU: CUDA, IJK-storage

- Many features:

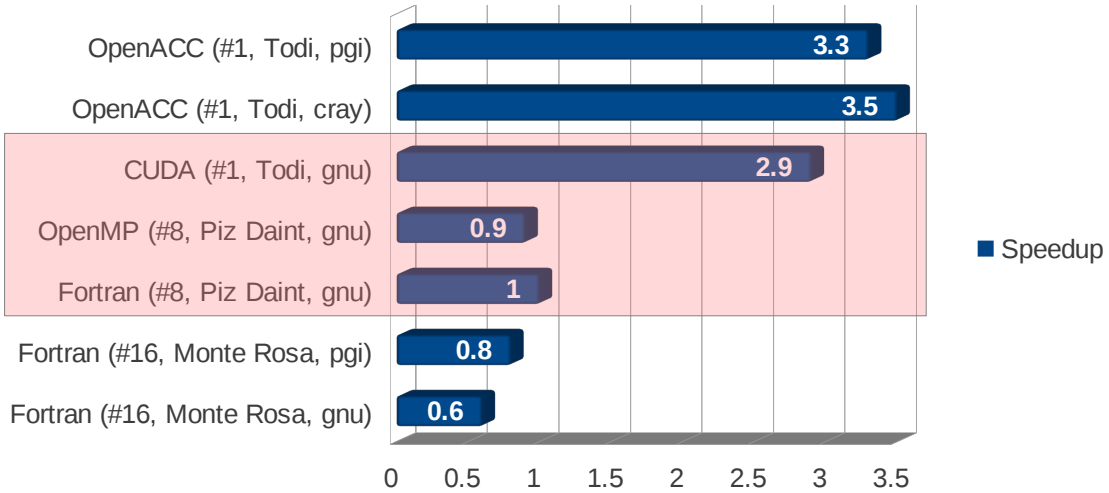
  loop definitions, loop merging, boundary conditions, functions, vertical K-Domains, buffers, software managed caching / data locality, parallelization, ...

STELLA Library

Evaluation of the graupel microphysical parameterisation of COSMO

Single-node evaluation on a 263x92x60 test domain with 1000 iterations

Computing resources	Socket infrastructure description	Compilers
Monte Rosa – Cray XE6	16-core AMD Opteron Interlagos CPU	GNU and PGI compilers
Piz Daint – Cray XC30	8-core Intel Sandy Bridge CPU	GNU compiler
Todi – Cray XK7	K20x GPU	GNU, CRAY and PGI compilers



OpenACC additional optimization

Loops restructured to iterate over blocks:
f(ie,je,ke) → f_b(nproma, ke)

with nproma = ie x je

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SEVENTH FRAMEWORK PROGRAMME

Conclusion

- ***Pros of STELLA:***
  - *Easy of use:* based on standard programming language and compiler, only C++ tool chain needed, better separation of implementation strategy and algorithm, single source code runs on CPU and GPU
  - *User-friendliness:* frees model developer from implementation details: CPU and GPU specific implementation strategies are abstracted
  - *Performance:* achieves good speedups on CPU and GPU for stencils-based codes
  - *Support:* unit testing and serialization framework were crucial for efficient porting and bug hunting

- ***Cons of STELLA:***
  - *Specificity:* provides fixed set of features, some of them are very COSMO specific
  - *Procedure:* generates long compilation times
  - *Coding investments:* requires big change with respect to an original Fortran code, forces sometimes to adopt heavy coding conventions syntax
  - *Effectiveness:* retains not necessarily efficiency with single source code

Thank you for your attention!

Questions?