C2SM Center for Climate Systems Modeling

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement des Innern EDI
Bundesamt für Meteorologie und Klimatologie MeteoSchweiz

EMPA Materials Science & Technology

Università della Svizzera italiana

COCoNet

The HP2C **CO**SMO **Co**mmunity **Net**work Project

PIs:

I. Bey *Center for Climate Systems Modeling (C2SM)*

C. Schaër, D. Lüthi, J. Schmidli, H. Wernli, S. Pfahl, U. Lohmann, N. Gruber *ETH*

O. Fuhrer, P. Steiner, A. Walser *MeteoSwiss*

D. Brunner *Empa*

O. Schenk *Università della Svizzera italiana*

The Consortium for Small-Scale Modeling (COSMO) code

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Main features

- Regional weather and climate prediction model
- Community model developed and applied by 2 large communities
  - 7 national weather services
  - 45 universities and research institutes
- Applied at horizontal resolutions ranging from 1 km to 50 km
- 250'000 lines of Fortran 90!

CPU demand related to COSMO at CSCS

- Climate: > 15'000'000 CPUh allocated to ETH groups (2010-2012)
- Weather: 15'000'000 CPUh per year (2 dedicated machines Cray XT4 for MeteoSwiss)

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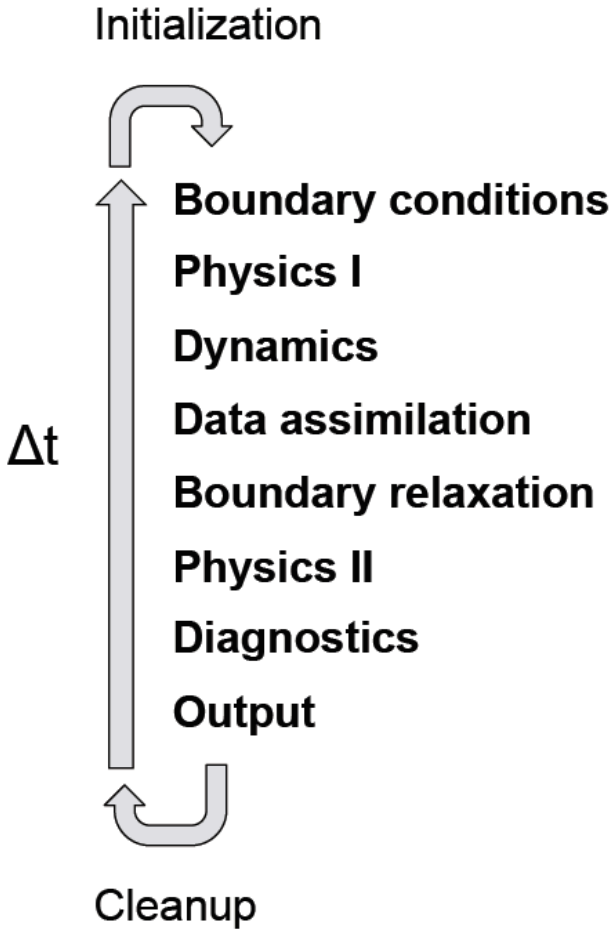
COSMO Workflow



- Finite difference solver
- Structured grid
- Sparse operators (stencils / tridiagonal matrices) acting on dense model state
- All steps access / modify model state
- Time splitting (different processes are integrated using different timesteps and integrators)
- Sequential workflow

Challenges: Going towards cloud-resolving simulations

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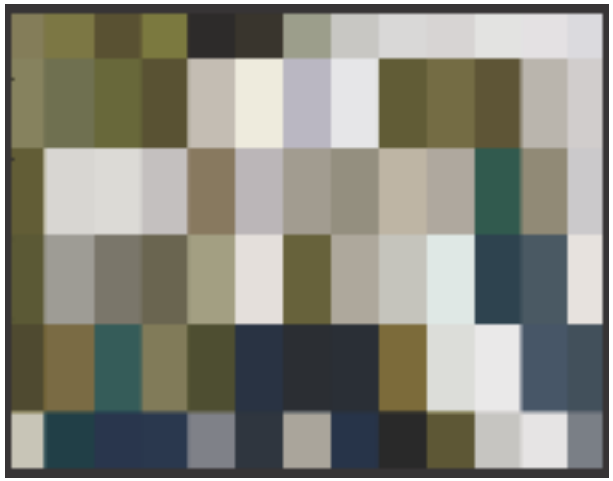
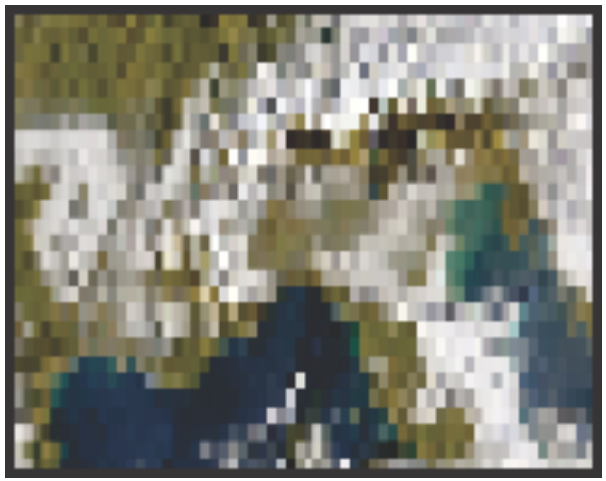
The Alpine region at three different horizontal resolutions

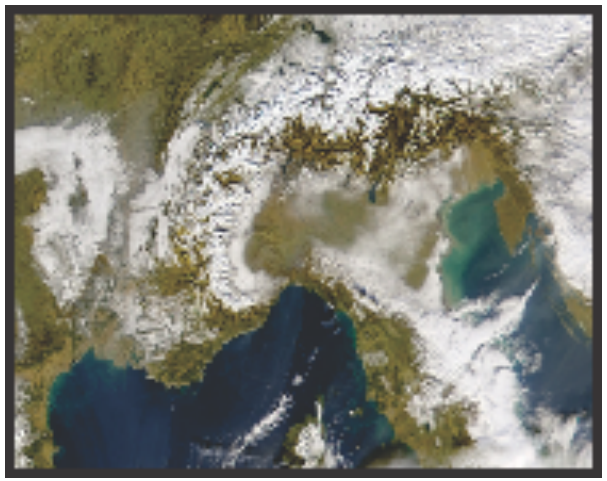
100 km High Res. Global Model



25 km Regional Climate Model



2 km High Res. Regional Model



Figures: E. Zubler, IAC ETH

Added value:

- **Mesoscale circulations resolved**
- **Land surface, topography, land-sea-contrast**
- **Local extreme events**
- **Improved process description**

Challenges: Going towards cloud-resolving simulations

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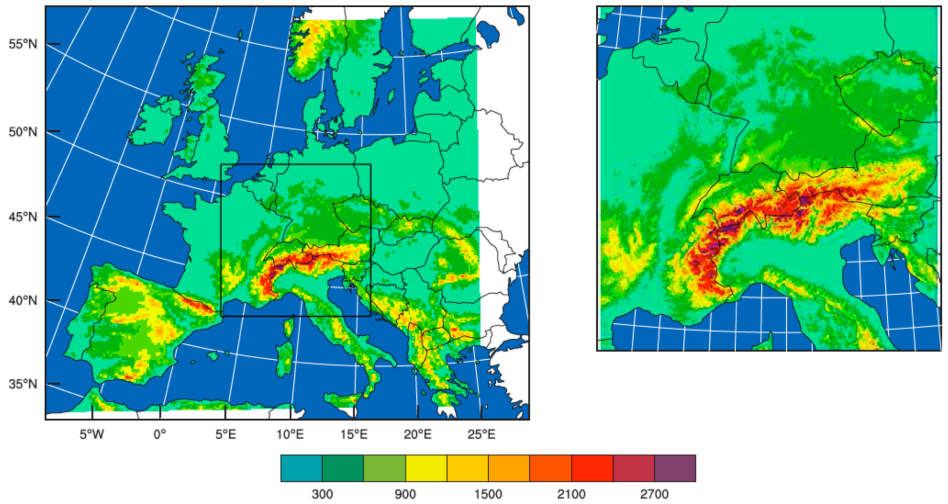
Computational Resources Requirement for Current Climate Simulations

- Simulate 2 months within 24 h wallclock time (60 d for 10-yr run), on Cray XE6 (Monte Rosa, CSCS) using about 2000 cores
- 19000 CPUh/month; ca 2.3 MCPUh for 10 years
- Storage: about 1.1 TB/year (4 TB/year with 3D output)



CCLM 12 km (260x228x60) CCLM 2.2km (500x500x60)

From Nikolina Ban, ETH Zürich
SNF Project Schär & Schmidli
(2010-2013)

Schär, ET

Next steps

- 1x1 km resolution
- Larger domain and multi decadal simulations for climate research
- Ensemble simulations for weather forecast

COCoNet builds one 2 HP2C Projects

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- **2 running Projects**

- HP2C-COSMO 930 kCHF 06.2010 – 06.2013
- HP2C-OPCODE 540 kCHF 07.2011 – 06.2013

- **One common objective:**

- Prepare the COSMO code for the next generation of computers

- **Core HP2C Team**

  Oliver Fuhrer (MeteoSwiss), Tobias Gysi (SCS), Xavier Lapillonne (C2SM), Carlos Osuna (C2SM), Mauro Bianco (CSCS), Peter Messmer (NVIDIA), Ticiano Diamanti (MeteoSwiss), Ben Cunningham (CSCS)

- **Main Achievements**

- Complete version of COSMO running full timestep on GPU-hardware with significant reduction in power-to-solution
- Very successful collaboration of domain scientists, computer scientists and computer vendors

HP2C High Performance and High Productivity Computing

HP2C Projects: Specific achievements

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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

→ **Speedup: by up to 4**

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

→ Most ported routines currently have CPU and GPU version

→ **Speedup: factor up to 4**

COSMO **Co**mmunity **Net**work Project: **COCoNet**

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- **Main Goals**

(A) To **initiate the adoption of the new COSMO code** by the CLM and COSMO Communities

(B) To explore possibilities for **sharing computational approaches and methods with related communities (e.g., seismology community)**

(C) To **prepare joint proposals** with the existing COSMO and related community for **long-term support and co-design activities**.

COCoNet: Disseminating new computational tools

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A: Disseminating new COSMO code within the weather and climate communities

- Deliver a fully operational version of the new code for climate and weather applications
- Run a real test case (small demonstration project in C. Schär's group)
- Engage key COSMO developers

➔ December 2012: Stencil Library Workshop hold for COSMO developers (25 attendees)

B: Sharing computational approaches and methods (Stencil and GCL libraries) with related communities

- Joint workshops between the Swiss Seismology and Climate/Weather communities (Q1 2013 and Q4 2013?)
- International Symposium on High-performance Stencil Computations (2013?, jointly with the Community Network Development Project in Solid Earth Dynamics)

COCoNet: Joint proposals

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1. **COSMO HPC Community Network (PASC 1st Pillar)**
   - To secure resources for code maintenance and longer-term support to the users of the new codes developed in the HP2C projects

2. **Co-Design proposals (PASC 2nd Pillar)**
   - To develop new approaches for stencil computations associated with finite-difference solution of PDEs on structured and unstructured grids
   - To exploit new hardwares/softwares for I/O

3. **Sinergia Proposal (2014)**
   - Towards the first European-scale cloud-resolving simulations

Additional slides

Performance of Dynamical Core

Test domain 128x128x60. CPU: 16 cores Interlagos CPU; GPU : X2090

CPU Version

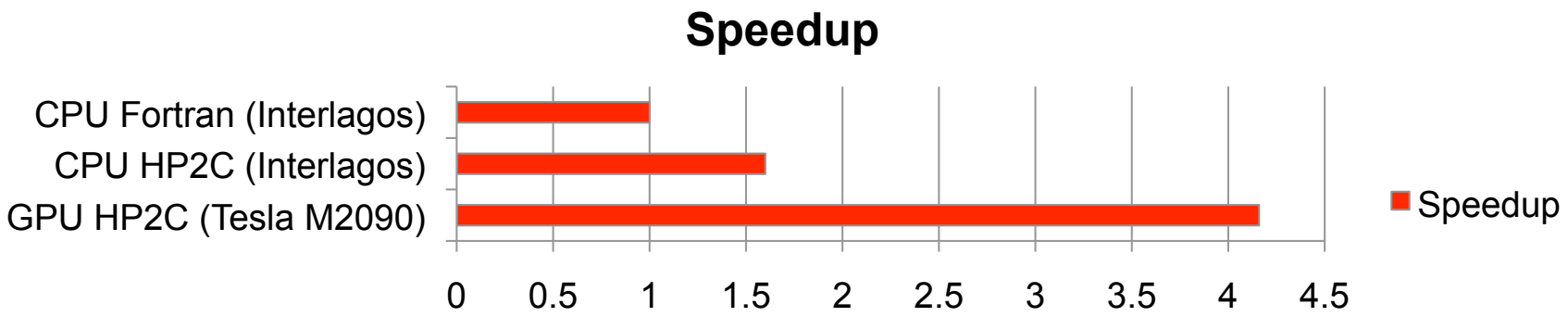
Factor 1.6x - 1.7x faster than the COSMO dycore

No explicit use of vector instructions (potential for 10-30% improvement)

GPU Version

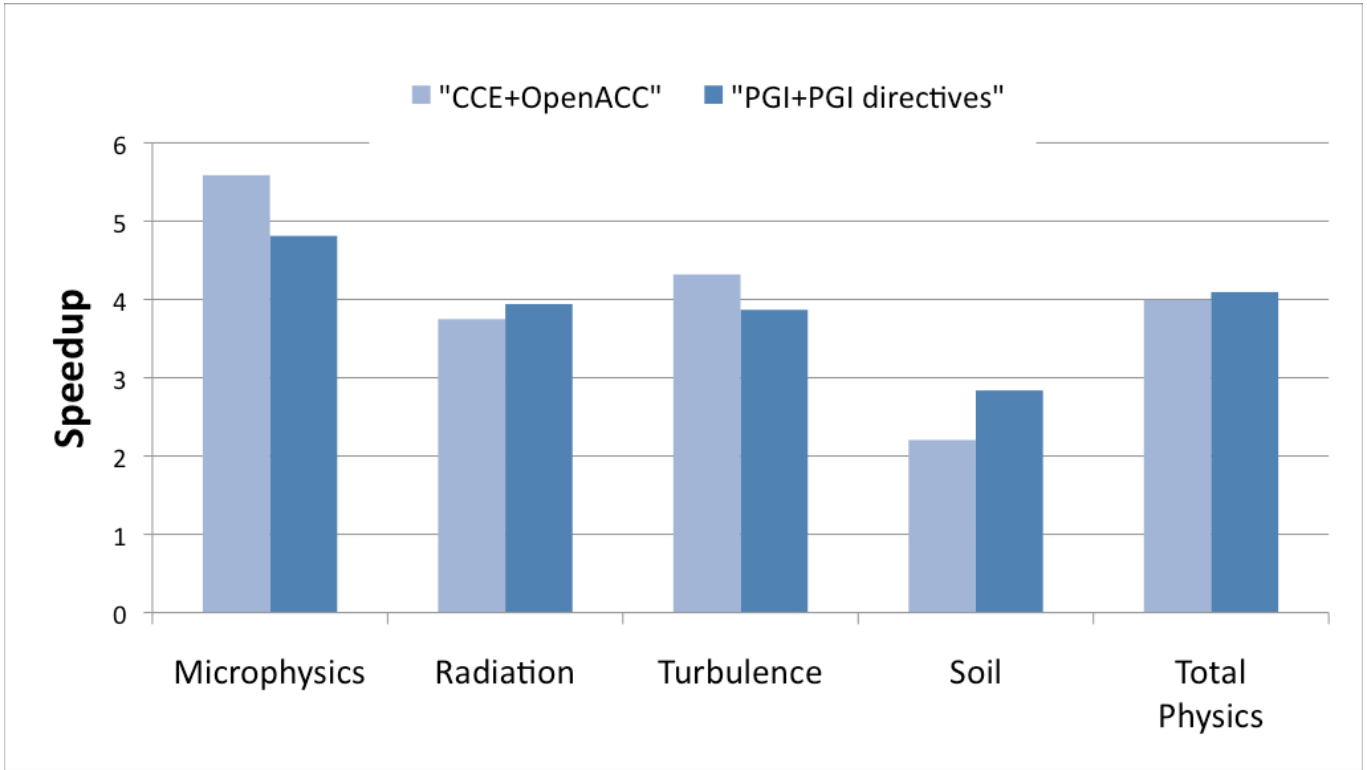
Same generation GPU is roughly a factor 2.6x faster than CPU

Ongoing performance optimizations



Performance of Physics

- Test domain 128x128x60 – 16 cores CPU vs GPU



- Overall speed up ~4x
- Similar performance with OpenACC and PGI directives
- Running the GPU-Optimized code on CPU is about 25% slower
  ➔ separate source for time critical routines