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# Numerical Weather Prediction at MeteoSwiss

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## Swiss implementation of the COSMO-Model

**Prognostic variables:** pressure, 3 wind components, temperature, specific humidity, cloud water, cloud ice, rain, snow, turbulent kinetic energy (TKE), COSMO-2: also graupel

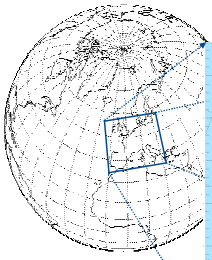
**Coordinates:** general terrain-following height-based vertical levels, Lorenz staggering; Arakawa-C, rotated Lat/Lon horizontal grid

**Dynamics**: 2-timelevel 3rd order Runge-Kutta

**Physics:** bulk microphysics for atmospheric water content, multilayer soil module, COSMO-7: Tiedtke mass flux convection scheme COSMO-2: explicit deep convection

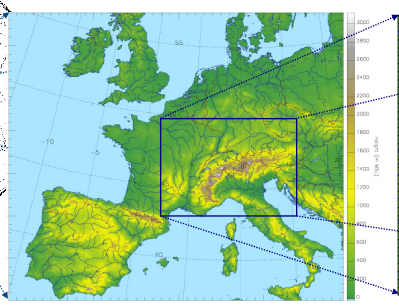
**Computers:**

| Cray XT4 buin | Cray XT4 dole |
|---|---|
|  |  |
| 260 AMD Opteron quad-core compute nodes at 2.3 GHz | 172 AMD Opteron quad-core compute nodes at 2.3 GHz |
| CSCS Swiss National Supercomputing Centre | |



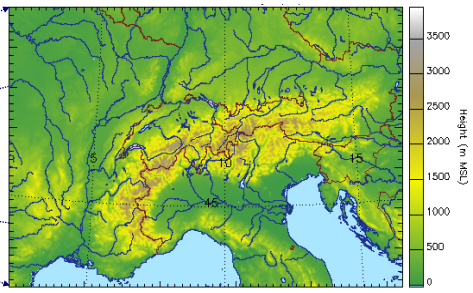
Global Integrated Forecast System **IFS** (ECMWF, ~16km resolution)

**COSMO-7**



COSMO-7 domain (maximum height at 3140m).

**COSMO-2** **(operational since 27.2.2008)**



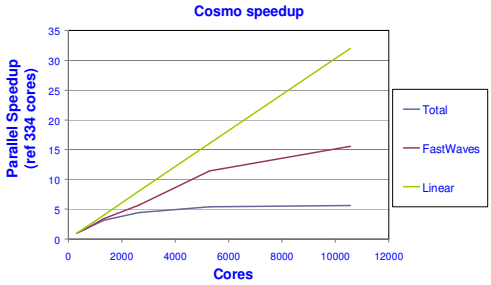

COSMO-2 domain (maximum height of 3944m).

| | COSMO-7 | COSMO-2 |
|---|---|---|
| **Mesh size** | 3/50°, ~**6.6km** | 1/50°, ~**2.2km** |
| **Domain** | 393 x 338 x 60 = 7'970'040 grid points | 520 x 350 x 60 = 10'920'000 grid points |
| **Forecasts** | +72h at 00, 06 and 12 UTC | +24h at 00, 06, 09, 12, 15, 18, 21 UTC, +48h at 03 UTC |
| **Boundary conditions** | Updated every 3h from IFS | Hourly updated from COSMO-7 |
| **Initial conditions** | Newtonian relaxation (nudging) to surface and upper air observations, intermittent cycle of 3h assimilation | Same as COSMO-7, but with use of radar data over Switzerland (latent heat nudging) |

## Preparing COSMO for next generation of High Performance Computers

**Motivations:**

- Future architectures will have more and more cores while the memory and memory access per core will tend to decrease.
- In the frame of the Swiss HP2C (High Performance High Productivity Computing) initiative, the COSMO code will be adapted to perform efficiently on next generation computers.




Scaling of the full Cosmo code and Fast Wave solver compared to an ideal linear scaling. The total code performance only significantly improves up to about 1000 cores.

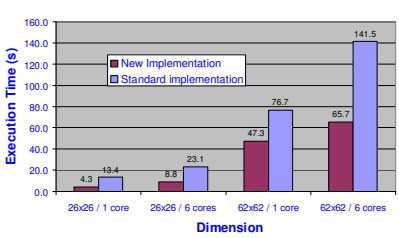
**Feasibility Study:**

- Profiling investigations have revealed that the code is essentially memory bandwidth limited
- Most of the execution time of the COSMO code is spent in the dynamical core, and in particular in the Fast Wave solver (30% of the total) which has therefore been chosen as a test case for new algorithm implementation.

A new stand alone version of the Fast Wave Solver has been written in C++ where most precalculations have been removed and a new data structure is considered to optimize cache usage.

The execution time is shown on the graph using the new and standard implementations for different grids and number of cores. For the 6 cores cases, the same problem is executed 6 times on 6 cores on one socket.

A factor two in performance can be gain with the C++ version.




**New hardware technologies:**

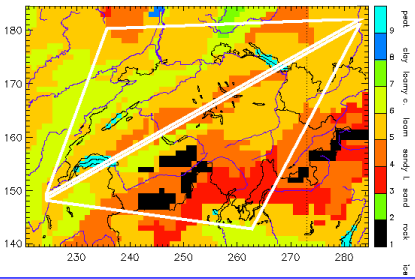
- Besides a reorganization of the data structure and precalculations, a more drastic step towards alternative architectures is taken, as part of the HP2C project, to port parts of the dynamical core and physical parameterizations to Graphical Processor Units (GPU). A first test version of the Microphysics scheme using the CUDA language is being developed.

## Standalone version of the COSMO soil model TERRA

- The package „TERRA standalone" is an externalized version of the soil-vegetation-atmosphere transfer scheme of the models GME and COSMO. It consists of the soil module TERRA combined with a simplified transfer scheme, parameterizations of the radiation interaction at the surface, and the annual cycles of vegetation parameters. Except for the transfer scheme, all components are copied from the operational model.

- The operational transfer scheme developed by M. Raschendorfer (DWD) requires information about atmospheric TKE, which is in general not available by measurements or past analysis fields. Therefore TERRA standalone uses the Louis scheme which was used by COSMO and GME in former times.

- TERRA standalone can be computed at a single point or on a geographical domain. It requires the associated external parameters, the atmospheric forcing, and some initial conditions. It uses the GRIB1 format for input/output files (or some ad hoc format for atmospheric observations).




Soil type of COSMO-7 with the 2 domains North West (ANS) and South East (ASS) of the Alps which is used to average the soil moistures on the different model levels (note that there is NO rock soil type, 2nd green, in the domain)

- TERRA standalone makes it possible to efficiently experiment with the soil module and the associated external parameters. It also supports the implementation of a measurement driven soil moisture analysis.

- The 2 figures at the right show that over a 3 year period similar mean soil moistures for the soil type loam are obtained by TERRA standalone (bottom) compared to the fully coupled operational model (top).

- The TERRA standalone run was only performed on the domain shown on the left figure and could be computed in a very short time on a single processor. Hourly atmospheric information were used to drive the run and vertical integration from the 8 original layers were performed to show the overall behavior.