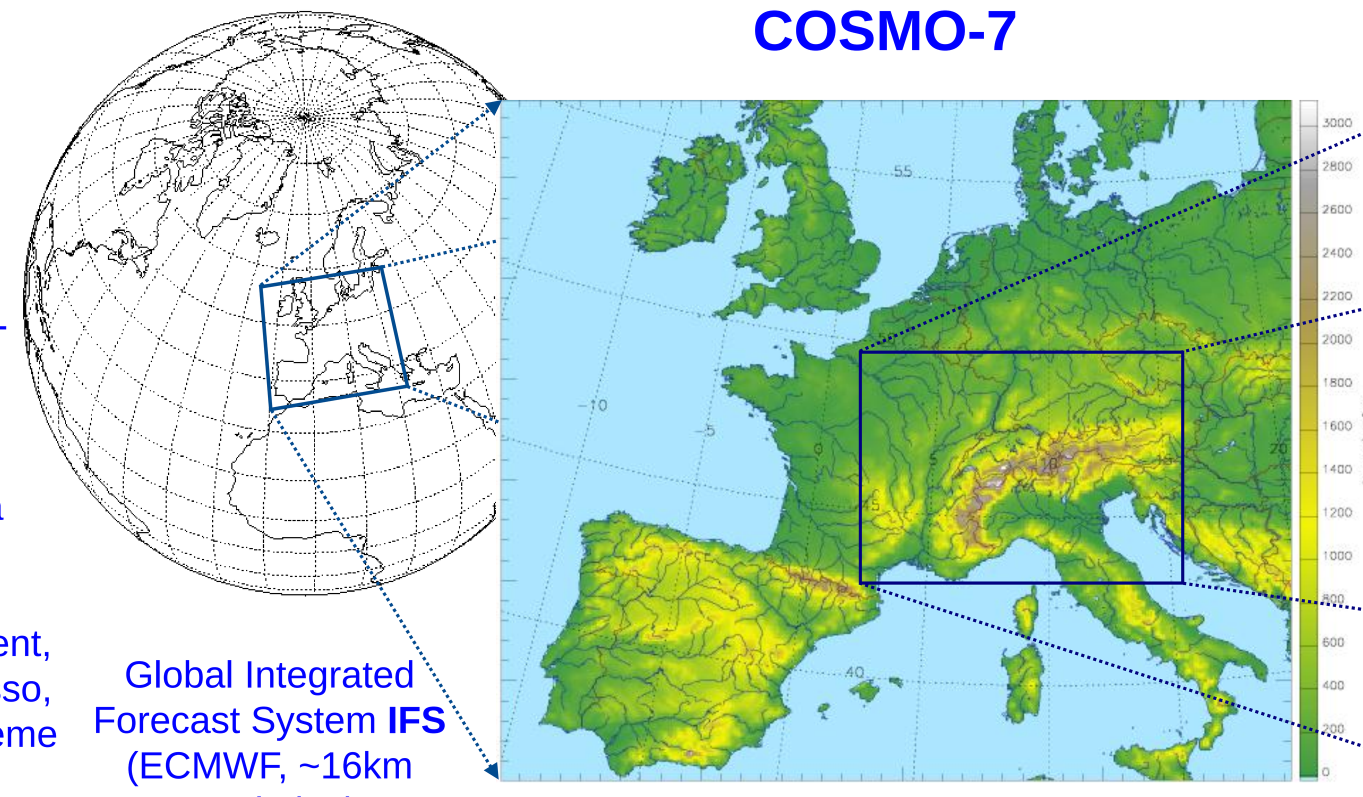
Numerical Weather Prediction at MeteoSwiss

Philippe Steiner
Federal Office of Meteorology and Climatology MeteoSwiss, Zurich, Switzerland

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, radiation, turbulence, sso, COSMO-7: Tiedtke mass flux convection scheme COSMO-2: explicit deep convection
- **Computers:** 2 Cray XE6 (production / backup & development) at Swiss National Supercomputing Centre, CSCS 144 / 336 AMD 2.1 GHz MagnyCour processors with 1728 / 4032 computational processing cores Together, the systems can reach a peak performance of 50 TFlops.
- **Time to solution:** 27 minutes for 33h COSMO-2 Effective performance 450 Gflops (5% of peak)

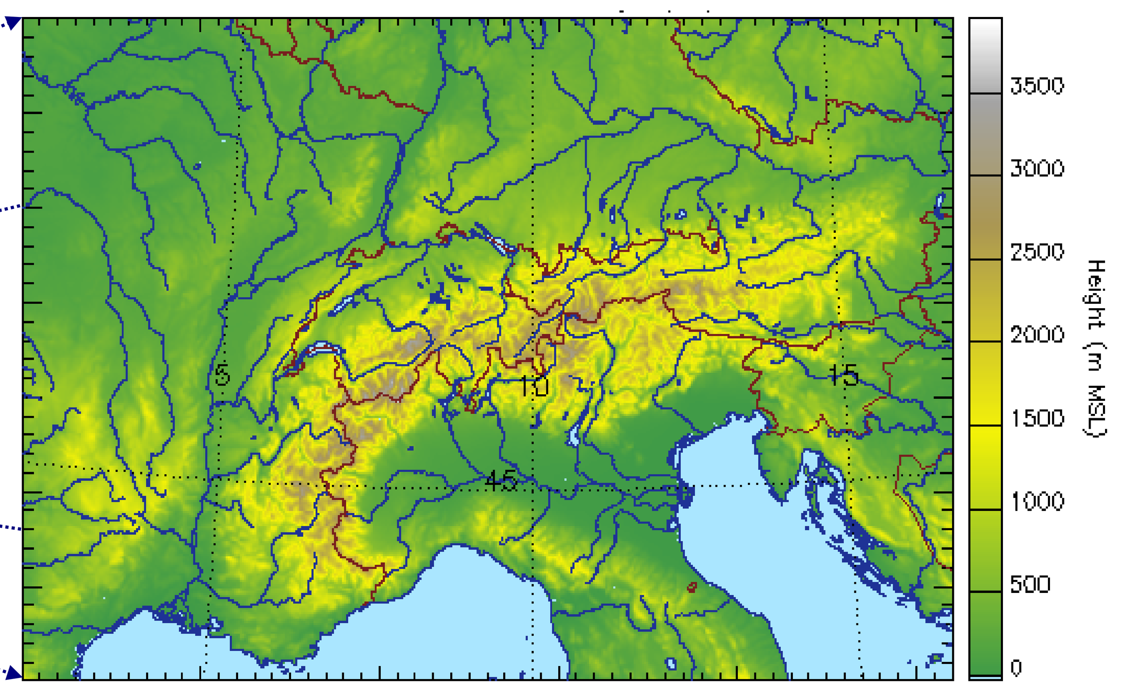
COSMO-7



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

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

COSMO-2



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	+33h at 00, 06, 09, 12, 15, 18, 21 UTC, +45h at 03 UTC
Boundary conditions	Updated every 1h 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)

COSMO-1

Guy de Morsier
Oliver Fuhrer

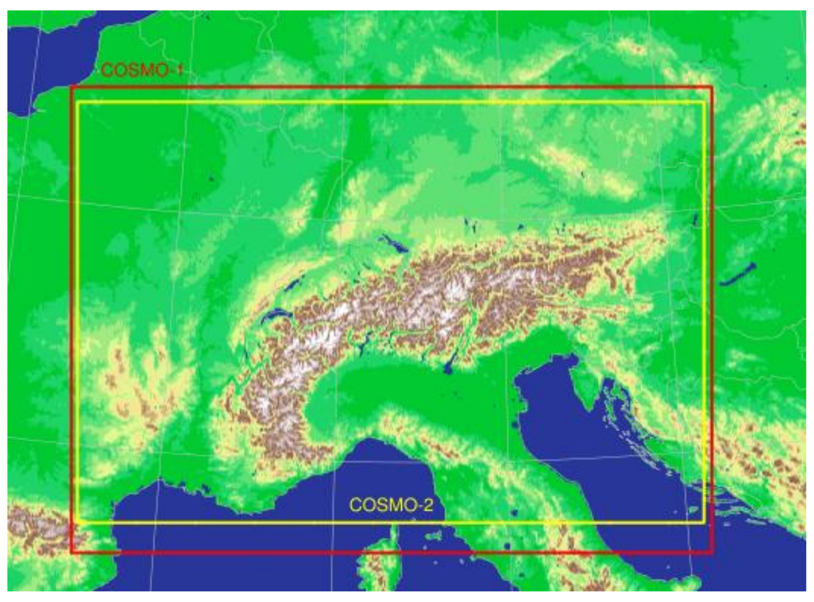
Motivation

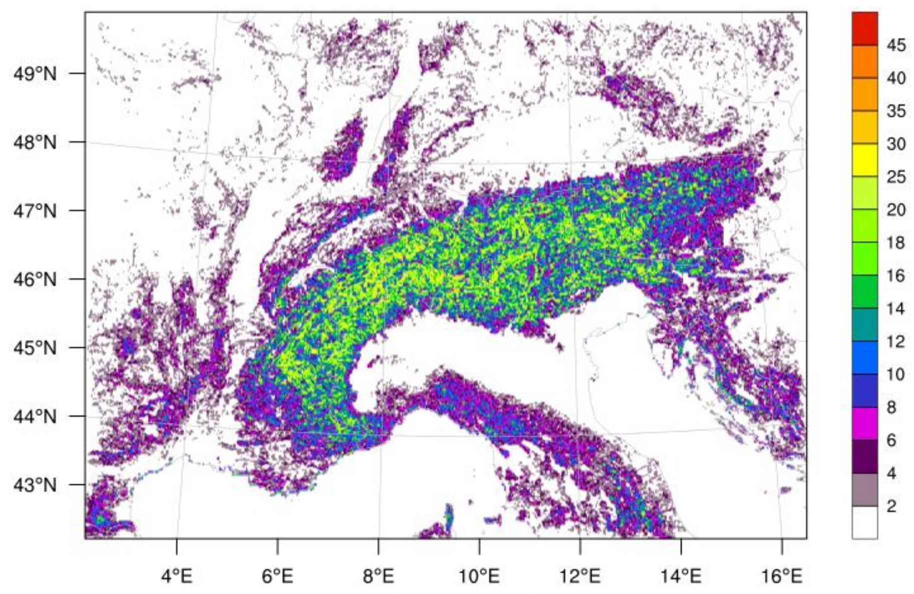
- Convection-permitting forecasts handle some aspects well (system structure, propagation) and have predictable biases (rainfall, condensation)
- Better resolution of extreme convective showers or storms can lead to a continuous improvement of forecast quality of:
  - flooding events
  - disruptive snow
- Better representation of local phenomena and Alpine meteorology for:
  - low level winds
  - fog filling valleys
  - snow cover
  - heat islands

Experimental Setup

- Continuous 1km-assimilation cycle since end of August 2012 (including latent heat nudging)
- Two forecasts per day (00/12 UTC) to +24h
- Driven by the operational COSMO-7 forecasts
- Run at CSCS in approx. 1h45' elapsed time
- Visualization, monitoring and verification for evaluation purposes but not for production!

Domain lon. x lat. x levels = 1062 × 774 x 80 ($\Delta\lambda = \Delta\phi = 0.01°$~1.1km)



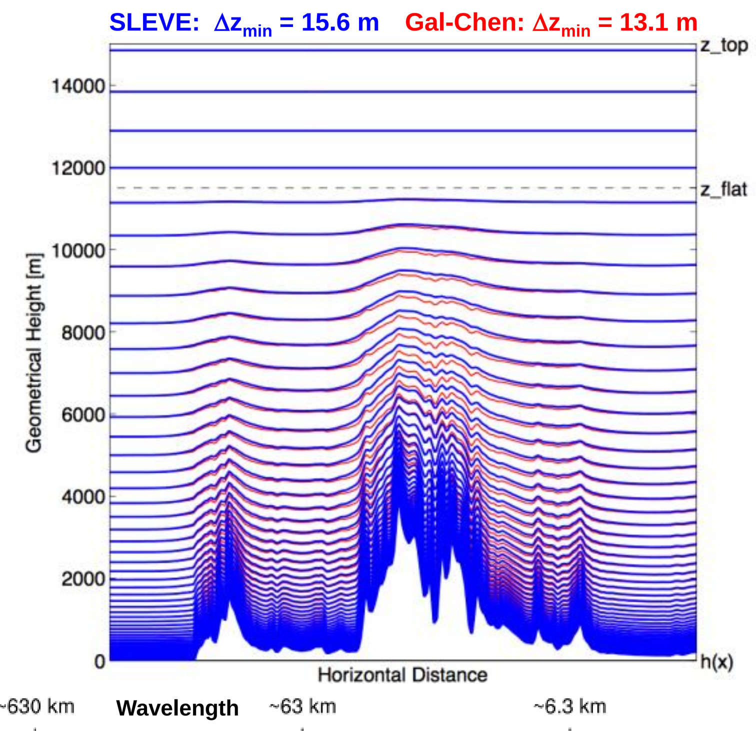


Maximum of the 4 finite difference gradients in x- and y-direction in degrees (max. 36°).

Dynamical and physical settings

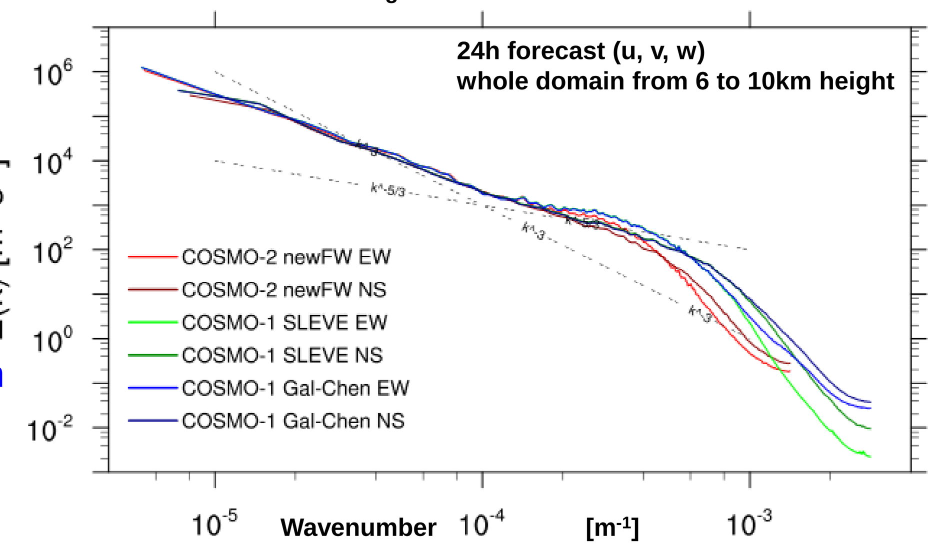
- No hyper-diffusion
- Horizontal non-linear Smagorinsky diffusion (Baldauf et al. 2012)
- Same soil, microphysics and turbulence parametrization as COSMO-2
- Tiedtke shallow convection
- Radiation every 6 minutes (COSMO-2 every 15 minutes)
- No subgrid-scale orographic drag

Generalized SLEVE vertical coordinate (Leuenberger et al. 2010)



Impact of the SLEVE coordinate

For a stormy case (Carmen, 12.11.2010) with winds up to 150km/h a comparison of the kinetic energy spectra (figure right) using the standard height-based terrain-following coordinate (Gal-Chen) or the SLEVE coordinate (above) shows for the latter a much smoother (green) decay of energy for wavelengths below 6km. The two energy spectra lines represent mean East-West and North-South components and with the same numerical kernel (new fast wave solver) the COSMO-2 results (on a smaller domain) can be seen.



References

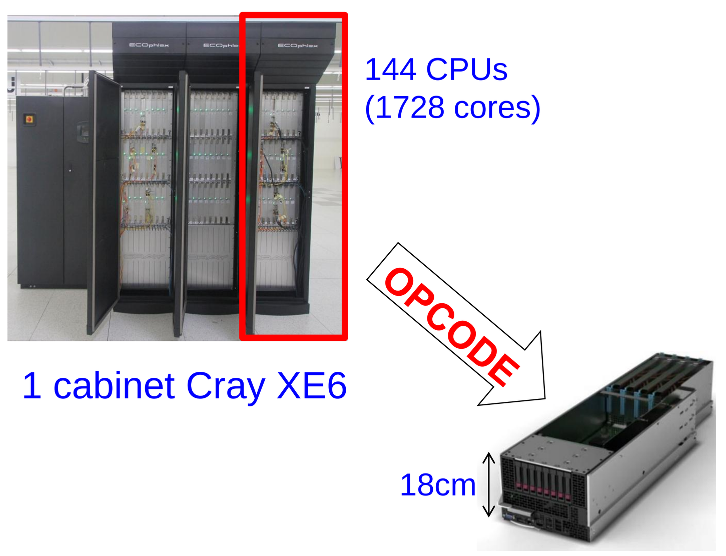
Baldauf, M., G. Zängl, 2012: Horizontal nonlinear Smagorinsky diffusion. COSMO newsletter, 12, 3-7, [online at: http://www.cosmo-model.org].
Leuenberger, D., M. Koller, O. Fuhrer, and C. Schär, 2010: A generalization of the SLEVE vertical co-ordinate. Mon. Wea. Rev., 138, 3683–3689.

HP2C-OPCODE Project: Operational COSMO Demonstrator

André Walser

Goals:

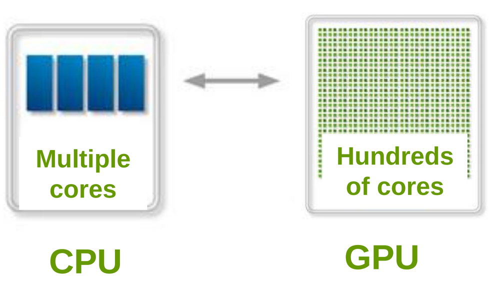
- Leverage the research results of the ongoing HP2C-COSMO project that makes COSMO ready for next-generation HPC systems
- Prototype implementation of current COSMO production suite of MeteoSwiss making aggressive use of GPU technology
- Same time-to-solution on substantially cheaper hardware:



GPU based hardware

Why GPUs?

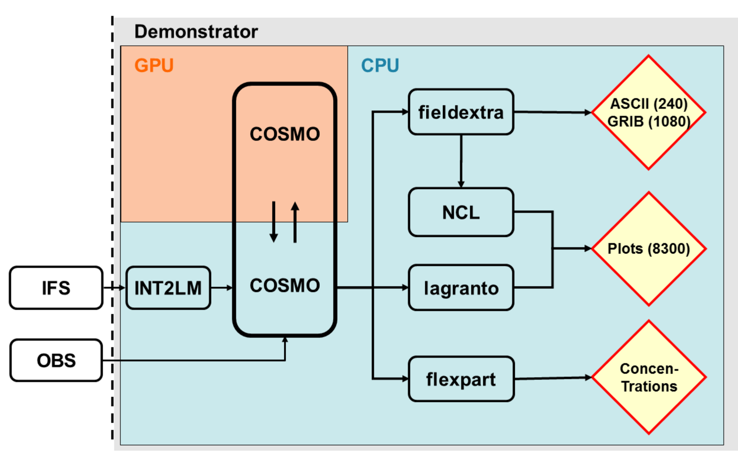
Interesting option for scientific computing as they can provide significantly larger peak performance and memory bandwidth for comparable energy consumption.



	Cores	Freq. (GHz)	Peak Perf. S.P. (GFLOPs)	Memory Bandwith (GB/sec)	Peak Perf. D.P. (GFLOPs)	Power Cons. (W)
CPU: AMD Magny-cours	12	2.1	202	42.7	101	115
GPU: Fermi M2050	448	1.15	1030	144	515	225
				x 3	x 5	

Forecast suite

- Running COSMO mainly on GPU, I/O remains on CPU
- Other applications are order of magnitude less compute intense and stay on CPU
- OpenMP parallelization of post-processing tools fieldextra (non-graphical forecast products) and FLEXPART (dispersion modelling)
- Evaluation of ecFlow (successor of SMS) as scheduler and platform for steering scripts of suite



GPU Implementation of COSMO

- Rewrite of dynamical core with C++/CUDA
- Compiler directive approach (OpenACC) for physics parametrizations and data assimilation
- New library for GPU-GPU communication (halo-updates)
- Compiling environment for mix of C++, CUDA, Fortran and OpenACC directives
- Software layer controlling copying of fields from CPU to GPU and vice versa for I/O