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ETH zürich | C2SM Center for Climate Systems Modeling | CSCS Centro Svizzero di Calcolo Scientifico, Swiss National Supercomputing Centre

Numerical Weather Prediction at MeteoSwiss

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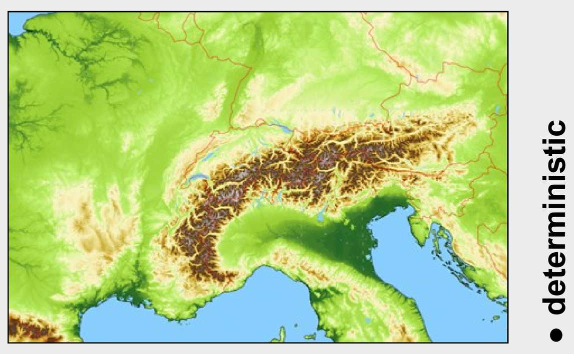
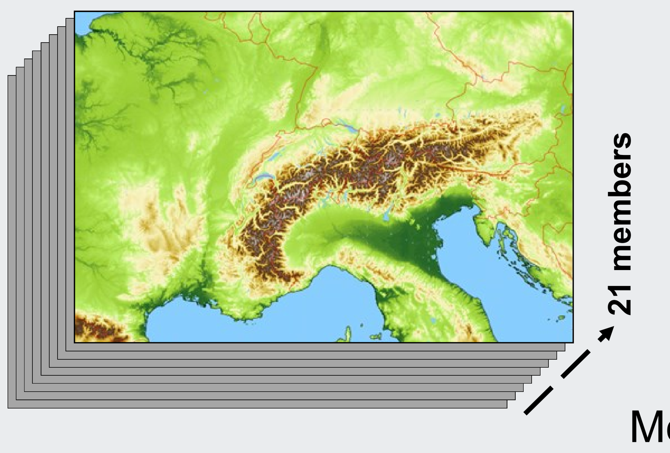
New ensemble-only forecasting system at MeteoSwiss

current operational setup: deterministic + ensemble



COSMO-1

deterministic run at 1.1 km mesh size
8x per day up to +33/45 hours
ICs: nudging analysis
LBCs: IFS HRES (ECMWF)



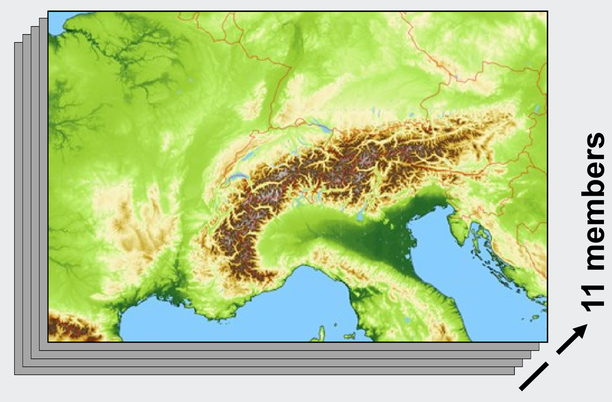
COSMO-E

21 members at 2.2 km mesh size
2x per day up to +120 hours
ICs: KENDA analysis at 2.2 km mesh-size
LBCs: IFS ENS (ECMWF)
Model perturbations: stochastically perturbed parameterisation tendencies (SPPT)

future operational setup (2020): ensemble only

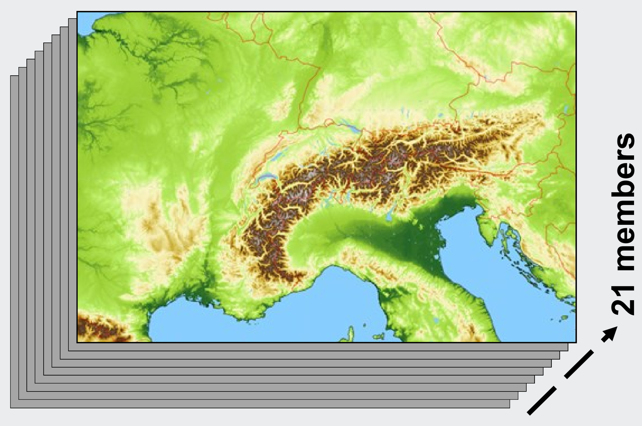
COSMO-1E

11 members at 1.1 km mesh size
8x per day up to +33/45 hours
ICs: **KENDA analysis at 1.1 km mesh size**
LBCs: **IFS ENS** (ECMWF) or **ICON-EU-EPS** (DWD)
Model perturbations: SPPT



COSMO-2E

21 members at 2.2 km mesh size
4x per day up to +120 hours
ICs: **upscaled KENDA analysis**
LBCs: IFS ENS (ECMWF)
Model perturbations: SPPT



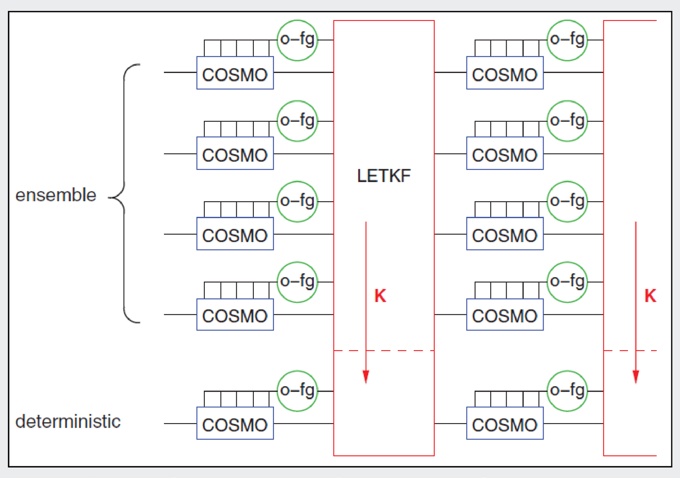
High-resolution data assimilation for the Alpine region

first guess ensemble

- 40 + 1 members at **1.1 km mesh size**
- LBCs: IFS HRES + IFS ENS perturbations (+1 day lead time)
- SPPT
- latent heat nudging

hourly LETKF analysis

- **1.1 km mesh size** for COSMO-1E
- **upscaling to 2.2 km** for COSMO-2E



KENDA: Kilometer-scale ensemble data assimilation for the COSMO model (Schraff et al. 2016). Data assimilation cycle based on the Local Ensemble Transform Kalman Filter (**LETKF**) with adaptive and multiplicative covariance inflation and relaxation to prior perturbations.

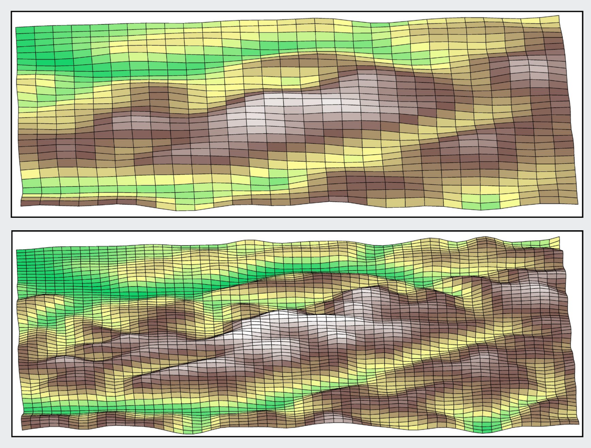
Analysis upscaling in complex terrain for soil fields

Selection of **entire soil columns** (including surface): **conditional nearest neighbour** with **height correction** for soil and lake temperatures to avoid inconsistencies and large temperature gradients in the coarse resolution fields.

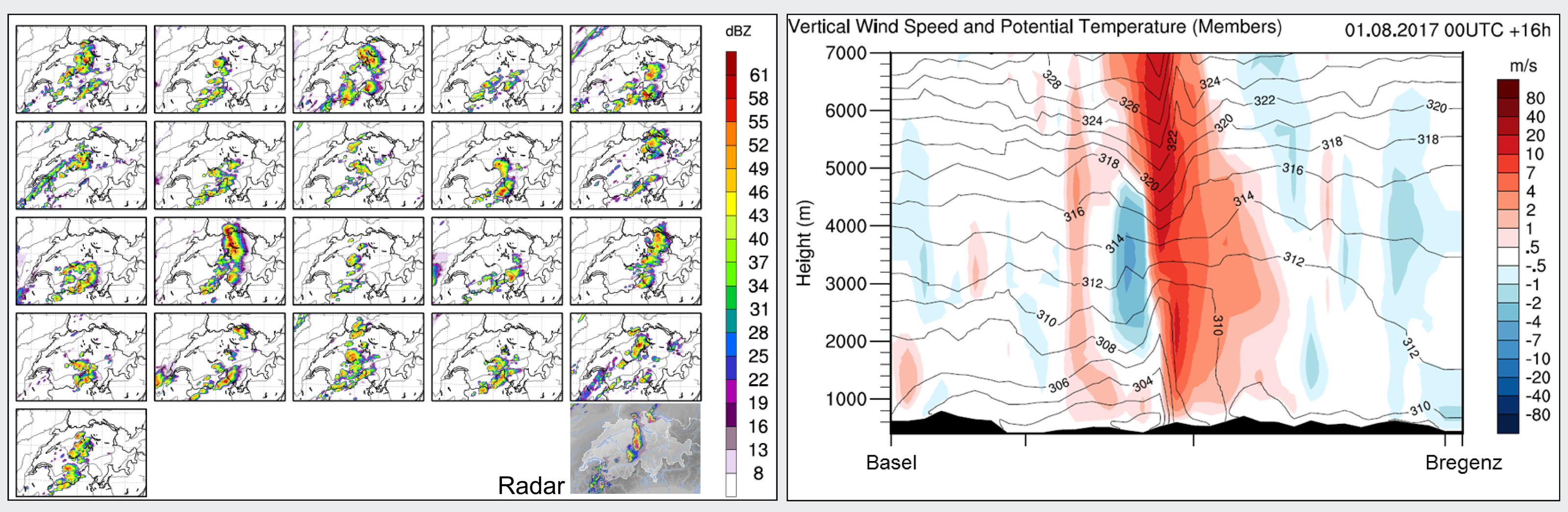
fine resolution → radius $2.1 \cdot \Delta x$ → same soil type → smallest height difference → coarse resolution

Advantages of the new high-resolution ensemble

- **better representation of small-scale processes, e.g. convection**
- prediction of **different possible realisations** of the future 8x per day; estimation of the **predictability**
- making best use of observations in complex terrain by operation of a **high-resolution data assimilation** system

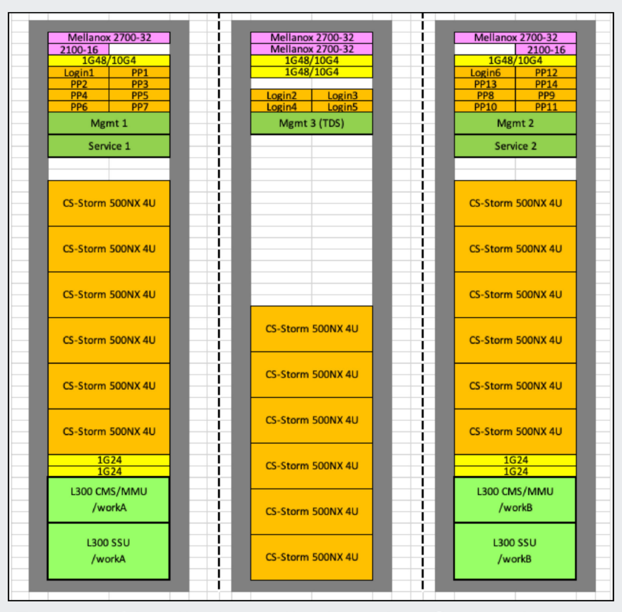


Orography of Rhone valley and Berner Oberland for 2.2 km (top) and 1.1 km (bottom) grid spacing.



Squall line case study for the 01.08.2017, 16UTC (+16h). COSMO-1E (here with 21 members) reflectivity and radar measurement (left) and vertical wind speed and potential temperature for member 12 (right).

New GPU-based high-performance computing system



Pigne d'Arolla installed at the Swiss National Supercomputing Centre (CSCS)

Cray CS-Storm cluster

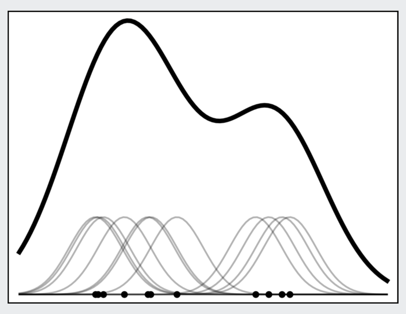
- 3 cabinets divided into **two logical partitions** (production and R&D)
- **node assignment** to partitions **exchangeable** within 10min
- **12+6 compute nodes** with
  - 2 Intel Skylake (12 cores) CPUs
  - 8 NVIDIA Tesla V100 GPUs
- **7+7 post-processing** and **3+3 login nodes** with 2 Intel Skylake (20 cores) CPUs

model code

- **GPU-capable version** of COSMO model
- rewrite of COSMO dynamical core with C++ using a DSL (GridTools framework)
- remaining Fortran code (e.g. model physics) ported with OpenACC

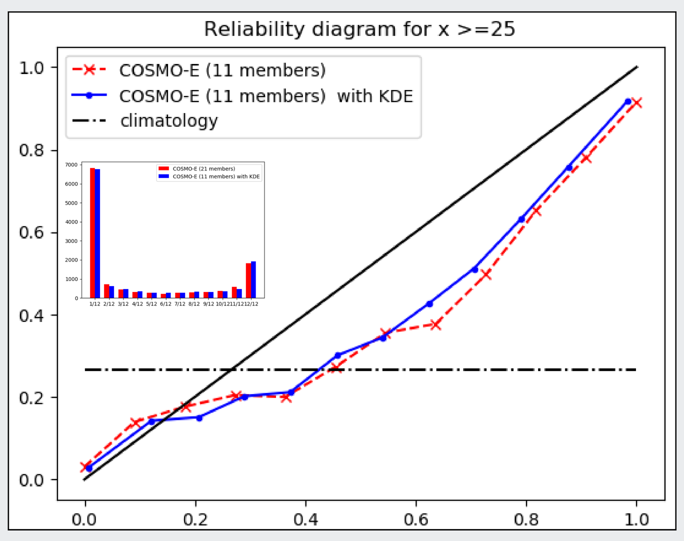
Probabilistic forecasts with a kernel density estimation

- Probability forecasts for the COSMO-1E ensemble with only 11 members can potentially be improved by statistical methods such as kernel density estimation (KDE).



Schematic representation of a Gaussian KDE for 11 ensemble members.

- For daily temperature, taking only the first 11 members of COSMO-E and **applying Gaussian KDE** yield slightly lower Brier-Scores (ca. -2%) than the empirically calculated probability forecasts. Most of the reduction comes from a lower reliability score with KDE (i.e. resolution term shows less improvement). A slight improvement by KDE is also visible in reliability diagrams.



Reliability diagram with 12 probability bins for daily temperatures exceeding 25°C in summer 2019 (Observations: SwissMetNet). The red line shows COSMO-E probability forecasts (reduced to 11 members), the blue line depicts the result after applying Gaussian KDE (bandwidth selection following Silverman's rule of thumb).

- For non-Gaussian distributed and zero-bounded parameters such as wind gusts or precipitation, **asymmetric Kernels** (e.g. Gamma-Kernels) can be used for probabilistic KDE forecasts.