Schweizerische Eidgenossenschaft
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Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

MeteoSwiss

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

Numerical Weather Prediction at MeteoSwiss

P. Steiner, P. Kaufmann, A. Pauling, M. Röthlin, A. Walser

New ensemble-only forecasting system with high-resolution data assimilation cycle for the Alpine region

COSMO-1E

- 11 members at 1.1 km mesh size
- 8x per day up to +33/45 hours
- grid points: 1170 x 786 x 80
- ICs: KENDA-1 analysis
- LBCs: IFS ENS (HRES for control)
- Model perturbations: SPPT

COSMO-2E

- 21 members at 2.2 km mesh size
- 4x per day up to +120 hours
- grid points: 582 x 390 x 60
- ICs: upscaled KENDA-1 analysis
- LBCs: IFS ENS
- Model perturbations: SPPT

KENDA-1

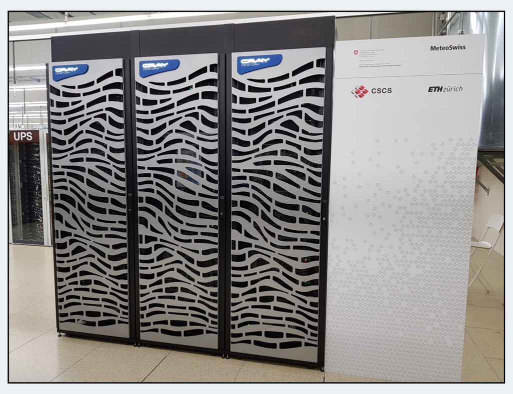
first guess (FG) ensemble every hour

- 40 + 1 members at 1.1 km mesh size
- grid points: 1170 x 786 x 80
- LBCs: IFS HRES + IFS ENS perturbations (+1 day lead time)
- SPPT, latent heat nudging

hourly LETKF analysis

Cray CS-Storm cluster

- 3 cabinets divided into two logical partitions: production + R&D
- 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
- node assignment to partitions exchangeable within 10min
- Time-to-solution for COSMO 5.07, single precision:
  - COSMO-1E: 55 min (for +33h)
  - COSMO-2E: 45 min
  - KENDA-1 FG: 9 min
  - LETKF: 8 min



Benefit of high-resolution ensemble forecasts: COSMO-1E vs COSMO-2E/COSMO-E

Surface verification (stations)

Summer	(2019s3)	18.08. – 02.09.		
Parameter	**Spread / Error**	**RPSS**	**Reliab. Diag. (low thr.)**	**Reliab. Diag. (high thr.)**
Precipitation (6h)	Similar	Slightly better	Similar	Similar
Cloud amount	Slightly better	Slightly worse	Similar	Similar
Temperature	Similar	Slightly worse	Similar	Similar
Dewpoint	Better	Slightly better	Similar	Similar
Wind speed	Better	Better	Similar	Similar
Gusts	Slightly better	Better	Slightly worse	n.a.
Pressure	Slightly worse	n.a.	n.a.	n.a.

Winter	(2020s1)	22.12. – 07.01.		
Parameter	**Spread / Error**	**RPSS**	**Reliab. Diag. (low thr.)**	**Reliab. Diag. (high thr.)**
Precipitation (6h)	Slightly better	Slightly better	Similar	Similar
Cloud amount	Slightly better	Slightly better	Similar	Similar
Temperature	Slightly better	Better	Similar	n.a.
Dewpoint	Better	Much better	Slightly worse	n.a.
Wind speed	Much better	Much better	Slightly better	Similar
Gusts	Slightly better	Much better	Similar	Similar
Pressure	Much better	n.a.	n.a.	n.a.

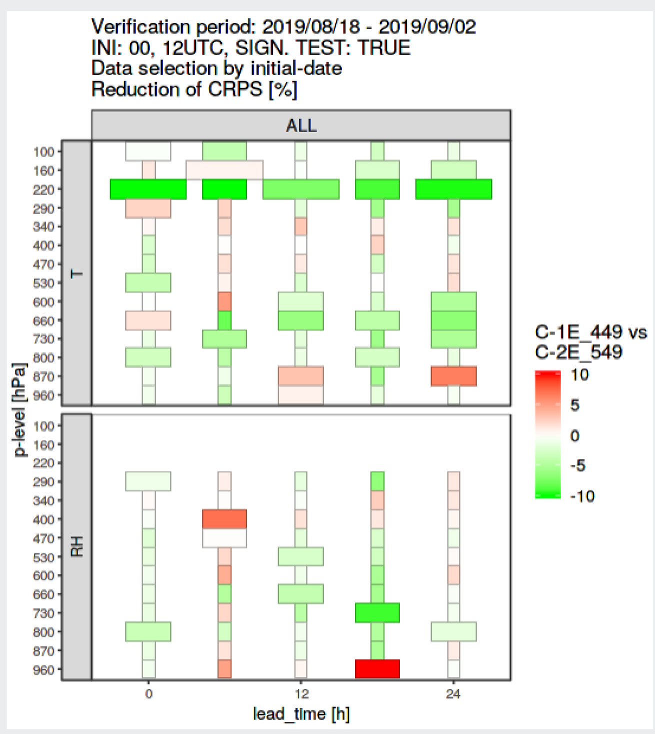
Performance of COSMO-1E (1.1km and 11 members) compared to COSMO-2E (2.2km and 21 members) and COSMO-E (old ensemble system, 2.2km and 21 members)

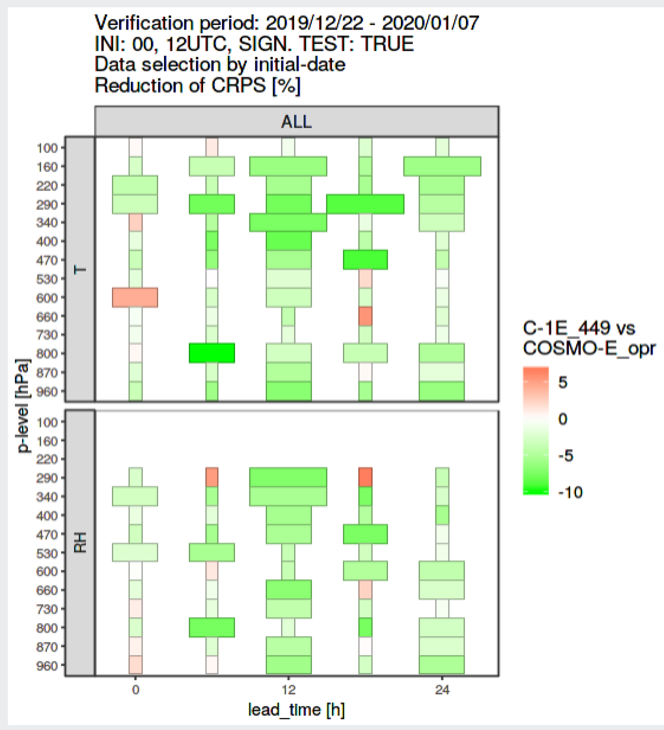
Based on lead time ranges 1h-12h, 13h-24h

Conclusions

- Overall more positive than negative performance differences
- Clear benefit of higher resolution, despite the smaller ensemble size

Profile verification (Radiosondes)





Green: COSMO-1E better; Red: COSMO-2E/COSMO-E better

Width of bars indicates significance of differences

Conclusions

- COSMO-1E outperforms COSMO-2E/COSMO-E
- Similar results for spring and autumn periods
- Wind: COSMO-1E slightly better than COSMO-2E/COSMO-E

Development of a new high-level domain specific language for ICON

DSL consisting of dusk frontend (user code) and dawn compiler under development at MeteoSwiss

dusk

- **Python** embedded DSL designed around the **unstructured** concepts in ICON
- Focus on **usability** / **learning curve**
- v 1.0 version should be soon available : feature complete with respect to the **ICON dycore**

dawn

- **Special purpose compiler** accepting **dusk** and other Frontends (gtclang, gt4py)
- **Structured** and **unstructured** code generation
- C++, CUDA backends

Mathematics / "Science"

$$\nabla_n \psi(e) = \frac{\psi(c_1(e)) - \psi(c_0(e))}{\hat{l}}$$

dusk Code

```
grad_norm_psi_e =
sum_over(Edge > Cell, psi_c,
         weights=[1/lhat,-1/lhat])
```

Backend: CUDA

dawn Compiler

High Performance CUDA Code

```
template <int E_C_SIZE>
__global__ void gradient_stencil(...
 unsigned int pidx = blockIdx.x * ...
 unsigned int kidx = blockIdx.y * ...
 int klo = kidx * LEVELS_PER_THREAD + 0;
 int khi = (kidx + 1) * LEVELS_PER_THREAD + 0;
 for (int kIter = klo; kIter < khi; kIter++) {
   ::dawn::float_type lhs_23 = 0;
   ::dawn::float_type weights_23[2] =
     {1/lhat[pidx],-1/lhat[pidx])};
   for (int nbhI = 0; nbhI < E_C_SIZE; nbhI++) {
     int cIdx = ecTable[pidx * E_C_SIZE + nbhI];
     lhs_23 += weights_23[nbhI] * psi_c[cIdx];
   }
   grad_norm_psi_e[pidx] = lhs_23;
 }
}
```

Conclusions

- **Ease of** development / **maintenance** due to **usability** focused DSL
- **Portable** code, compiler can emit code for a number of **different HPC architectures**
- **Efficient** code shown to outperform expert tuned manually implemented code

MeteoSwiss

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