



Schweizerische Eidgenossenschaft
Confédération suisse
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Eidgenössisches Departement des Innern EDI
Bundesamt für Meteorologie und Klimatologie MeteoSchweiz

ICON on GPU / Kokkos / GT4py

X. Lapillonne

COSMO-GM 2026 WG Infrastructure

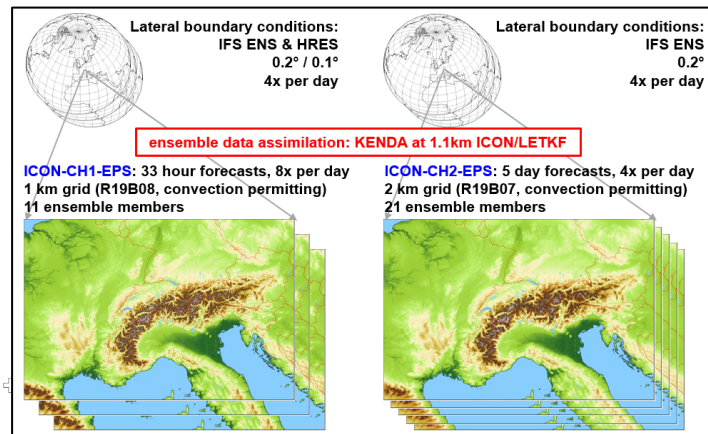
xavier.lapillonne@meteoswiss.ch

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ICON GPU port with OpenACC

- Many configurations are ported to GPU using OpenACC compiler directives, these are available in the open source ICON release
 - MeteoSwiss: in production for NWP forecast
 - ETH/C2SM: used for climate simulations on Alps at CSCS
 - MPI-M/DKRZ: used for climate simulations on Levante, Lumi, Jupiter
- OpenACC: mostly maintenance work, notable exception is the port of EMVORADO to GPU by MeteoSwiss.



MeteoSchweiz

ICON production setup on GPU system at MeteoSwiss



Modernization and GPU port efforts

Two main efforts are currently ongoing in the community:

- Kokkos/C++ re-write: using a performance portable library in C/C++ that can run a multiple hardware
 - Low level, handwritten optimization
 - DRKZ, MPI, DWD
- Gt4py : python based domain specific language (DSL) , performance portable on multiple hardware
 - Abstraction and separation of concern : optimizations in the backend at compile time
 - ETH/C2SM, MeteoSwiss



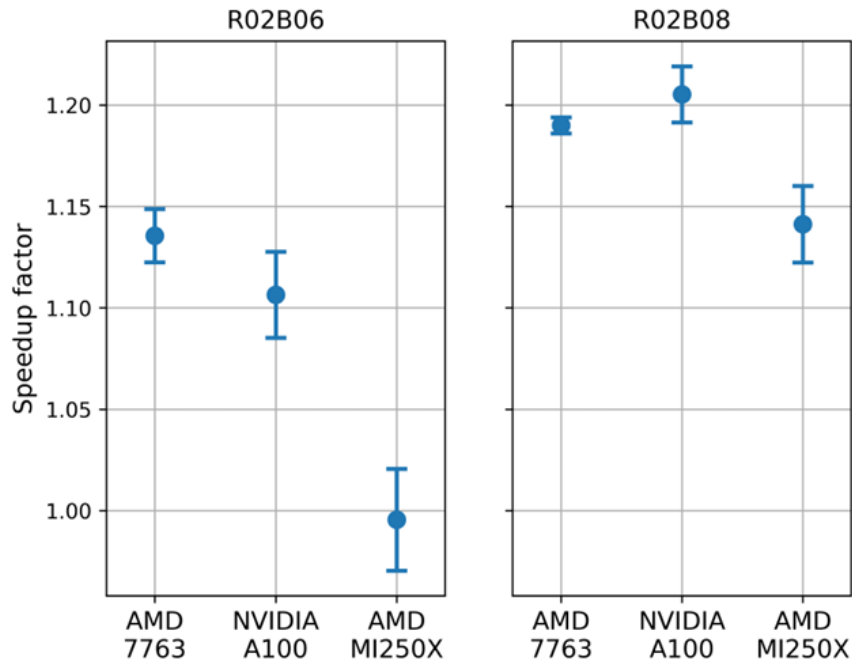
Kokkos / C++ re-write at MPI-M/DKRZ

- Developed as part of WarmWorld
- Main focus on AES physics:
 - graupel microphysics ported and merged in icon.git
 - Tmx turbulence: in progress
- Support libraries such as ICONmath
- Infrastructure code for language interoperability
- Build system



Ragnarok Performance

Graupel total_avg timer speedup of C++/Kokkos over Fortran
in AES AMIP experiment, average over 10 runs



R2B6 using 8 CPU nodes on Levante and
1 GPU node on Levante/LUMI
R2B8 using 8/16 nodes on Levante/LUMI
Levante: intel/2021.0.0 and nvhpc/24.7
LUMI: cce/20.0.0, rocm/6.3.4

DWD : ICON modularization and c++ exploration

- DWD is considering a port of the dynamical core to C++/Kokkos.
- start with work on first demonstrator.
- depending on performance, readability and debuggability alternative implementation strategies may be evaluated before making a final decision which way to go.
- first impressions until mid 2027.
- Modularization of physics in ICON ongoing (cloud scheme, microphysics, further to come).
- this also allows to port individual entities (granules) into a different language. c++ version of cloud cover scheme ongoing.





MCH / C2SM / ETH : GT4py approach

- GT4py is python based DSL approach, developed as part of the EXCLAIM project
- Fully featured dynamical core for MeteoSwiss operational setup and Climate applications at ETH integrated in Fortran
- GT4py dycore merged in icon.git, will be available in the October release



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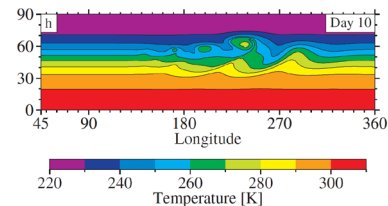
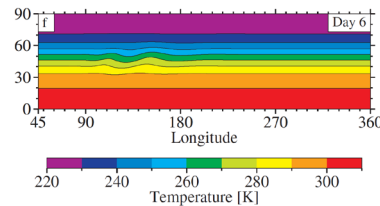
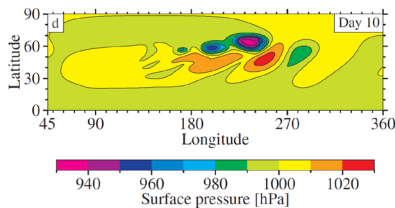
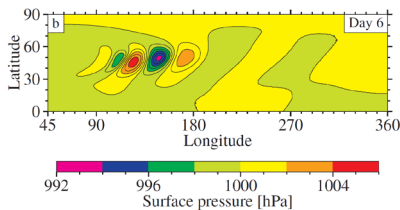
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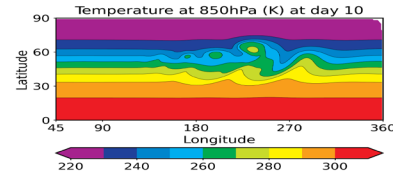
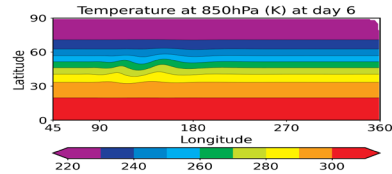
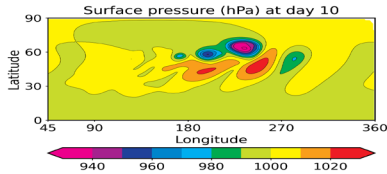
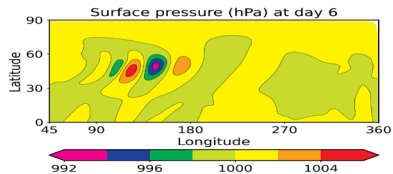
Baroclinic wave test

Scientific validation of the ICON4Py driver with the baroclinic JW test¹ by adding Gaussian hill perturbation of 1 m s^{-1} to the background zonal wind in north midlatitudes.

FV3



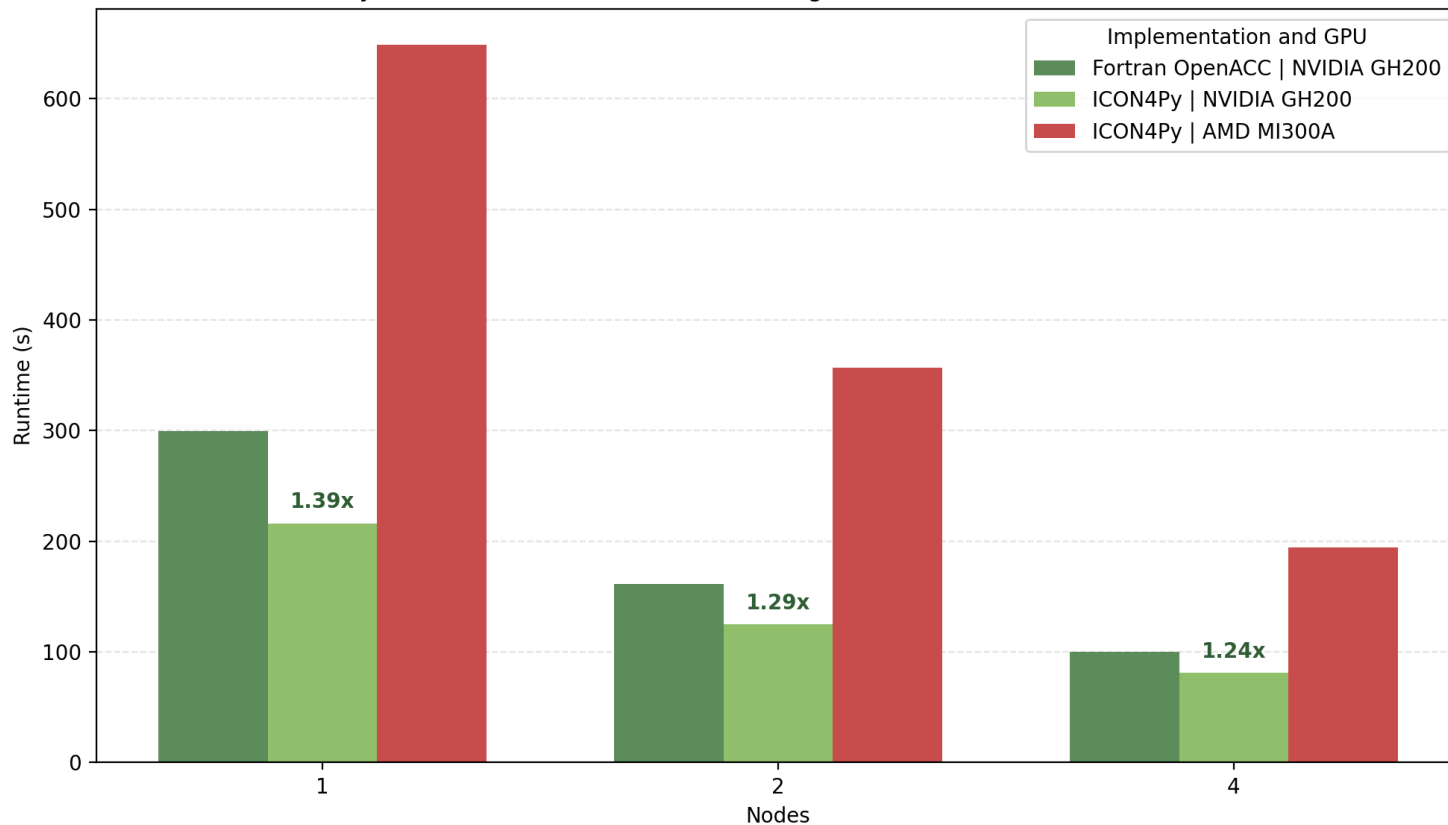
Icon4py





ICON4Py VS FORTRAN

ICON Dynamical Core run time for R02B07 grid (1310720 cells, 35 vertical levels)





GT4py status and next steps

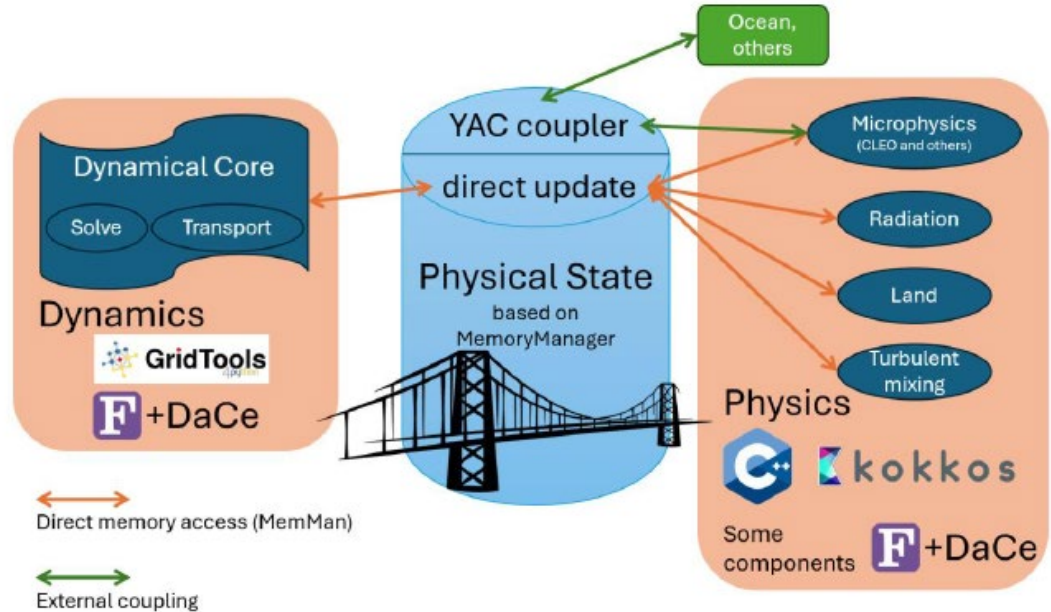
- ICON fortran combined with GT4py dycore is being used at ETH for km scale simulations on Alps at CSCS
- GT4py dycore is considered for production at MeteoSwiss, testing and performance validation is ongoing
- Work on infrastructure, libraries and physics is ongoing for a full python implementation demonstrator



Phoenix project

Combine GT4py dycore, Kokkos aes physics and other approaches to get a a full ICON version that can run without OpenACC on multiple GPU types in particular AMD GPUs

Note : Some missing features of the gt4py dycore will be ported such as nesting.





Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

MeteoSchweiz

Operation Center 1

CH-8058 Zürich-Flughafen

T +41 58 460 91 11

www.meteoschweiz.ch

MeteoSvizzera

Via ai Monti 146

CH-6605 Locarno-Monti

T +41 58 460 92 22

www.meteosvizzera.ch

MétéoSuisse

7bis, av. de la Paix

CH-1211 Genève 2

T +41 58 460 98 88

www.meteosuisse.ch

MétéoSuisse

Chemin de l'Aérologie

CH-1530 Payerne

T +41 58 460 94 44

www.meteosuisse.ch

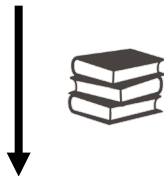
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GT4Py Domain Specific Language (DSL)

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



Modern, maintainable
Python code

```
@field_operator
def _psi(E2C, KDim),
float, lhat: Field[[EdgeDim], float],
) -> Field[[EdgeDim], KDim], float]:
    return (psi(E2C(1)) - psi(E2C(0)))/lhat
```



GT4Py



Optimized and
hardware specific
code

```
double _var_25[5] DACE_ALIGN(64);
double _var_35[5] DACE_ALIGN(64);
double _var_38[5] DACE_ALIGN(64);
double _var_41[1] DACE_ALIGN(64);
for (auto i_Edge_36 = 0; i_Edge_36 < _num_Edges;
    __stencil_arg0_i_Edge =
    const double* _inp = &__stencil_arg0[0];
    double* _out = _var_35;
    ...
```



Separation of concerns