

Performance portability in ecWAM

Using source-to-source translation and GPU-aware data-structures



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Motivation

- **ecWAM** is the operational wave-model coupled to the Integrated Forecasting System (**IFS**) in the Destination Earth (**DestinE**) digital twins (climate and global extremes)
- **Performance portability** across all **EuroHPC** architectures is therefore essential

Challenge

- Different **programming paradigms** and environments
- **Hardware-specific** optimization e.g. loop order, separate accelerator memory, etc
- **Large, complex and continuously evolving** scientific code needs to be **sustainably** adapted

Solution

- **Source-to-source translation** tool for Fortran source code to apply bespoke transformation recipes: **Loki**
- **GPU-aware data-structure** library to conveniently manage complex memory hierarchies: **FIELD API**

Open development on Github

ecWAM



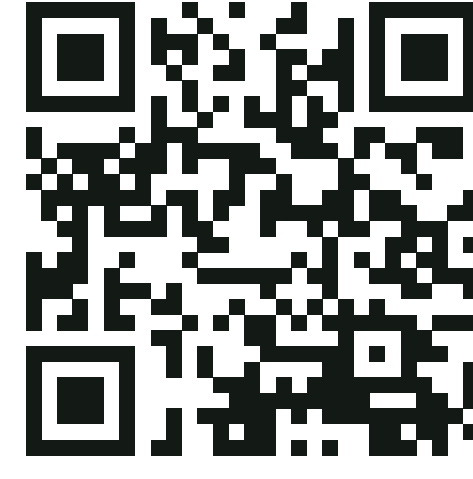
github.com/ecmwf-ifs/ecwam

Loki



github.com/ecmwf-ifs/loki

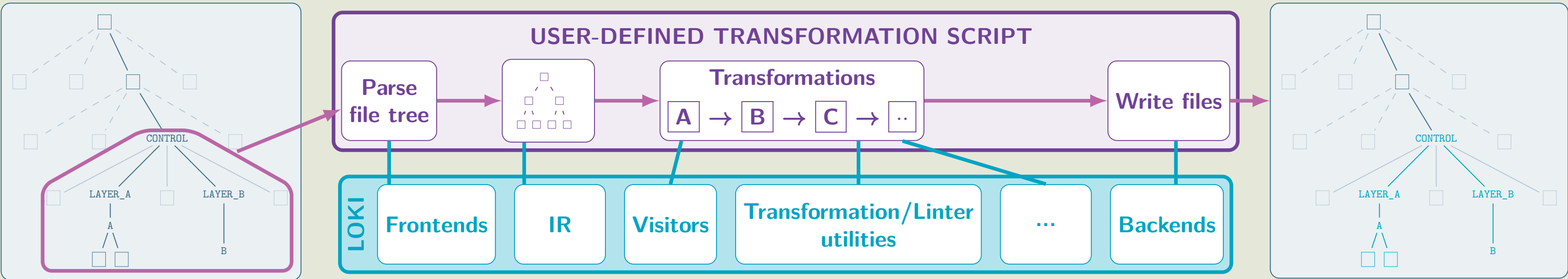
FIELD API



github.com/ecmwf-ifs/field_api

Loki

- **Loki scheduler** can be used to **batch process** large file trees
- **Multiple transformations** can be easily **combined** into pipelines

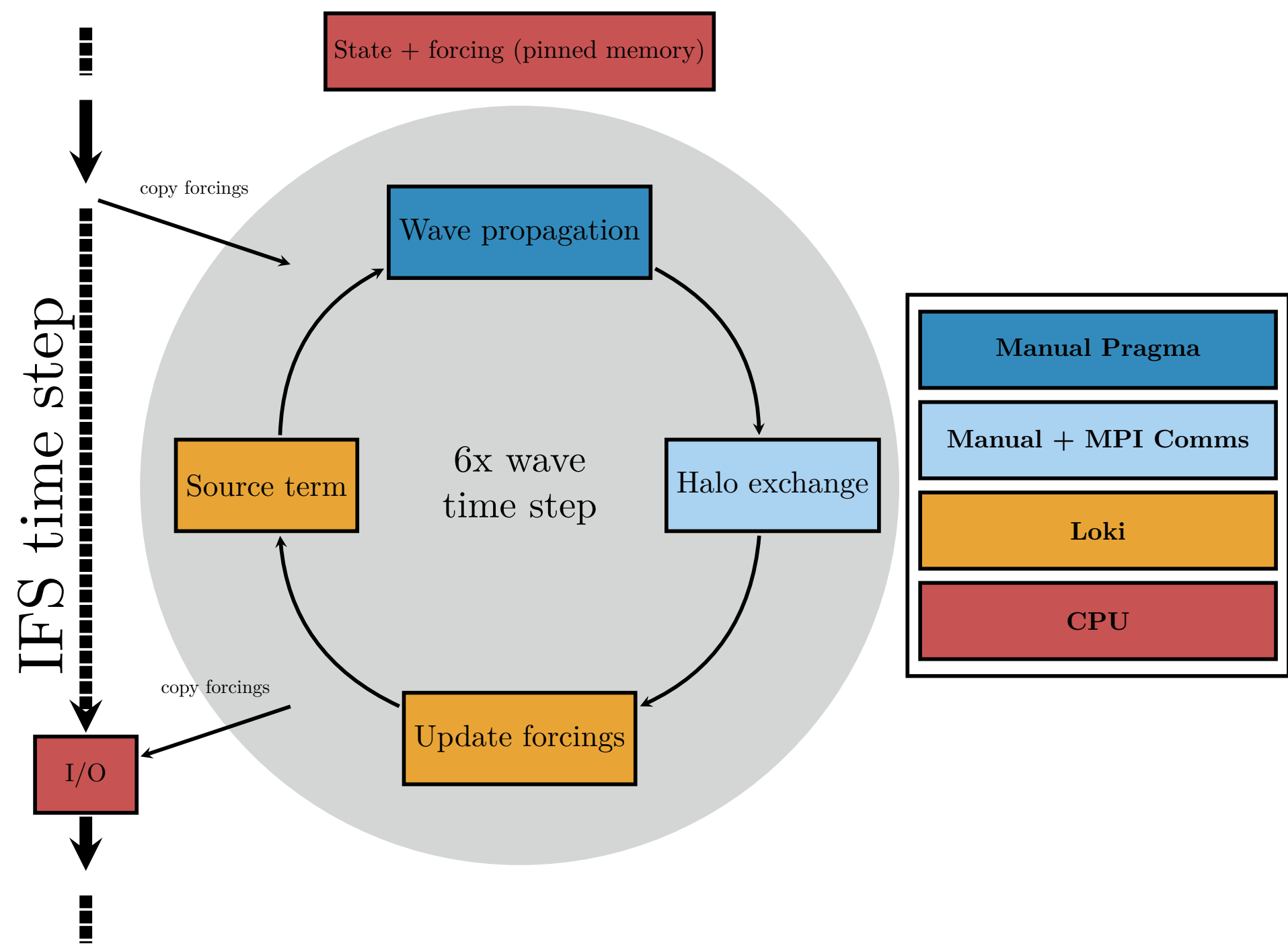


FIELD API

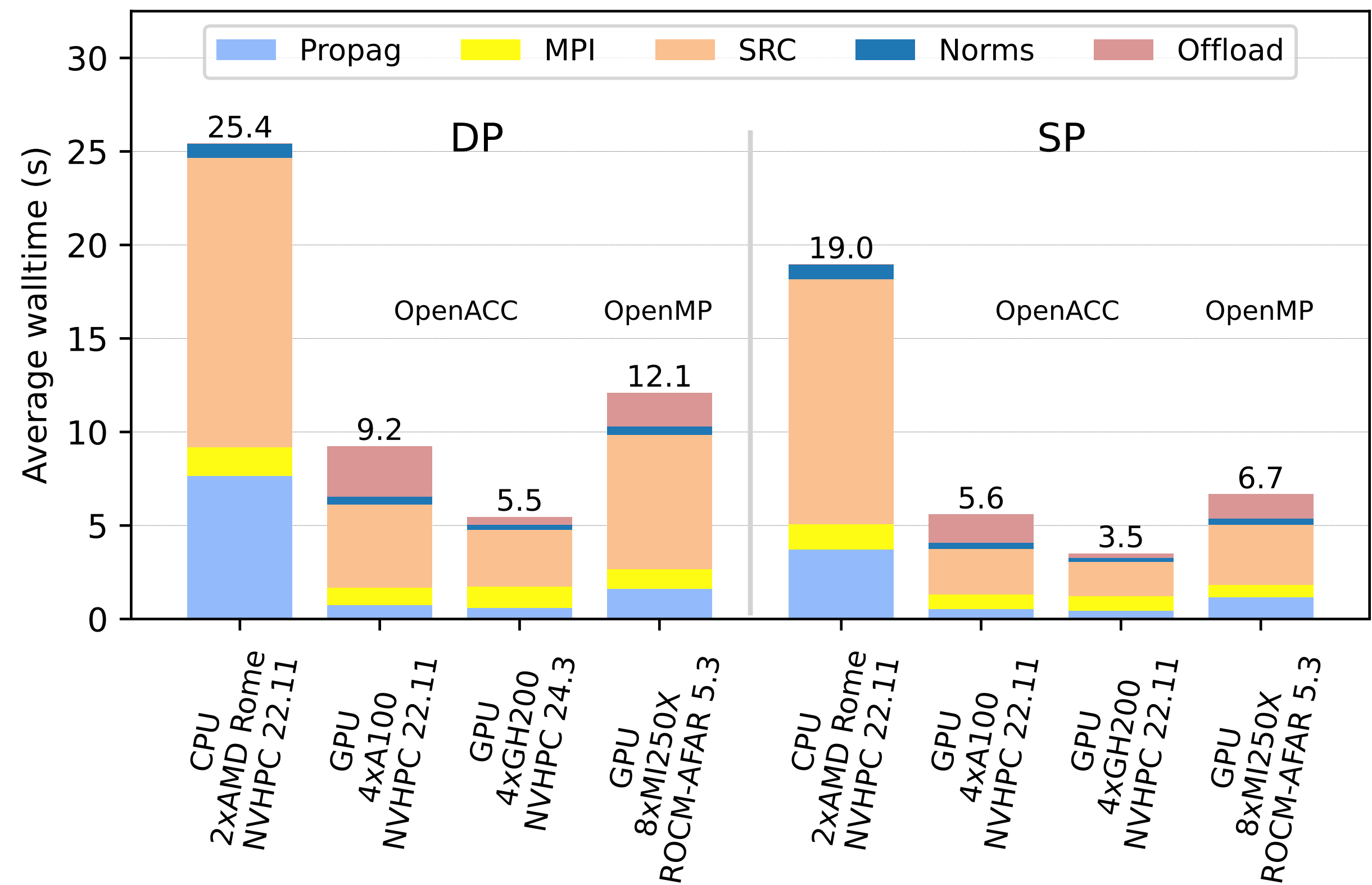
- Allows **data movement** between accelerator and host **via intuitive API** calls e.g. `FIELD%GET_DEVICE_DATA_RDWR()`
- **Complexities** of advanced functionality completely **hidden from scientific code** e.g. host memory pool, page-locked host memory allocations, asynchronous memory transfers

ecWAM - Open-source standalone wave model control flow and performance comparison

Time step control flow:



O320 12-hour forecast
(1/4 of operational spatial resolution)



	Hardware	Propag	MPI	SRC	Norms	Offload
DP	CPU	7.66	1.53	15.46	0.77	0.00
	GPU A100	0.73	0.95	4.44	0.43	2.69
	GPU 4xH100	0.59	1.15	3.02	0.28	0.41
	GPU MI250X	1.63	1.03	7.17	0.48	1.79
SP	CPU	3.73	1.34	13.12	0.78	0.00
	GPU A100	0.53	0.78	2.45	0.32	1.51
	GPU H100	0.44	0.80	1.83	0.22	0.22
	GPU MI250X	1.17	0.67	3.21	0.32	1.30

*Average walltime (s)

- All performance results averaged over 3 runs
- *CPU config*: 16 MPI ranks; 8 OMP threads; NPROMA 24
- *GPU config*: MPI rank per GPU; #OMP threads to utilise all cores; NPROMA 64

Loki transformation example

Committed CPU code

```
!$OMP PARALLEL DO ! CPU parallelisation
DO ICHNK=1,NCHNK
  CALL IMPLSCH( WVPRT%WAVNUM(:, :, ICHNK), ...)
...
SUBROUTINE IMPLSCH(WAVNUM, ...)
...
DO IJ=KIJS,KIJL ! innermost vector loop
  WAVNUM(IJ, :) = ...
...
END SUBROUTINE IMPLSCH
```

Generated GPU code

```
CALL WVPRT%GET_DEVICE_DATA_RDWR() ! get pointers to device buffers using FIELD API
!$ACC PARALLEL LOOP GANG PRESENT(WVPRT, ...) ! offload via OpenACC OR
!$OMP TARGET TERAMS DISTRIBUTE MAP(TO: WVPRT, ...) ! offload via OpenMP
DO ICHNK=1,NCHNK
  !$ACC LOOP VECTOR
  !$OMP PARALLEL DO
  DO IJ=KIJS,KIJL ! hoisted vector loop
    CALL IMPLSCH( WVPRT%WAVNUM(:, :, ICHNK), IJ=IJ, ...)
  ...
SUBROUTINE IMPLSCH(WAVNUM, IJ, ...) ! offloaded routine
  !$ACC ROUTINE SEQ
  !$OMP DECLARE TARGET
  ...
  WAVNUM(IJ, :) = ...
END SUBROUTINE IMPLSCH
```

User base

- DestinE Climate and Extremes Digital Twins
- ECMWF operational weather forecast

Outlook and Plans

- Continue to optimize performance for all supported architectures
- Widen support for EuroHPC systems

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