Continuation of ESCAPE-2 efforts in ESiWACE2

Florian Ziemen (DKRZ) on behalf of Joachim Biercamp
(who’s on a cycling trip somewhere near the alps)

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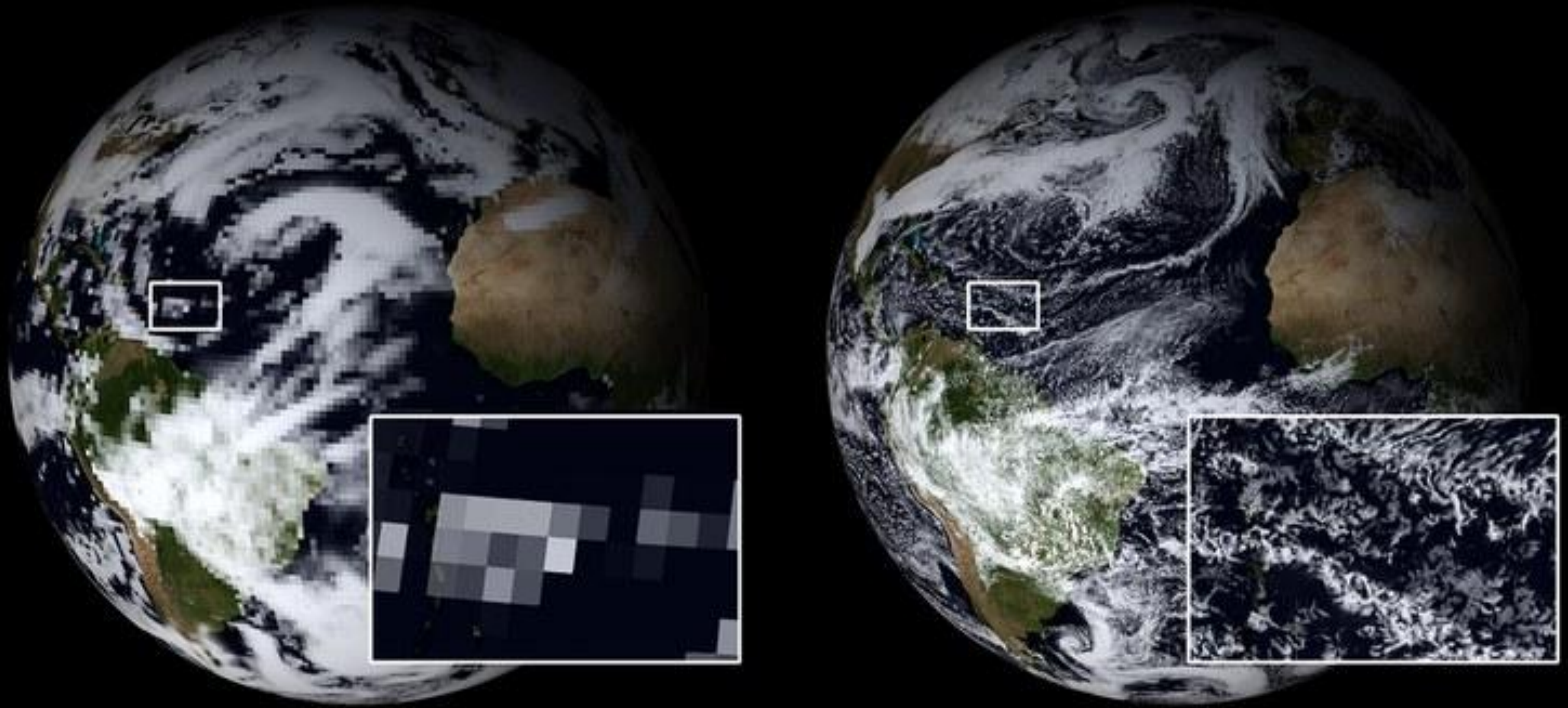
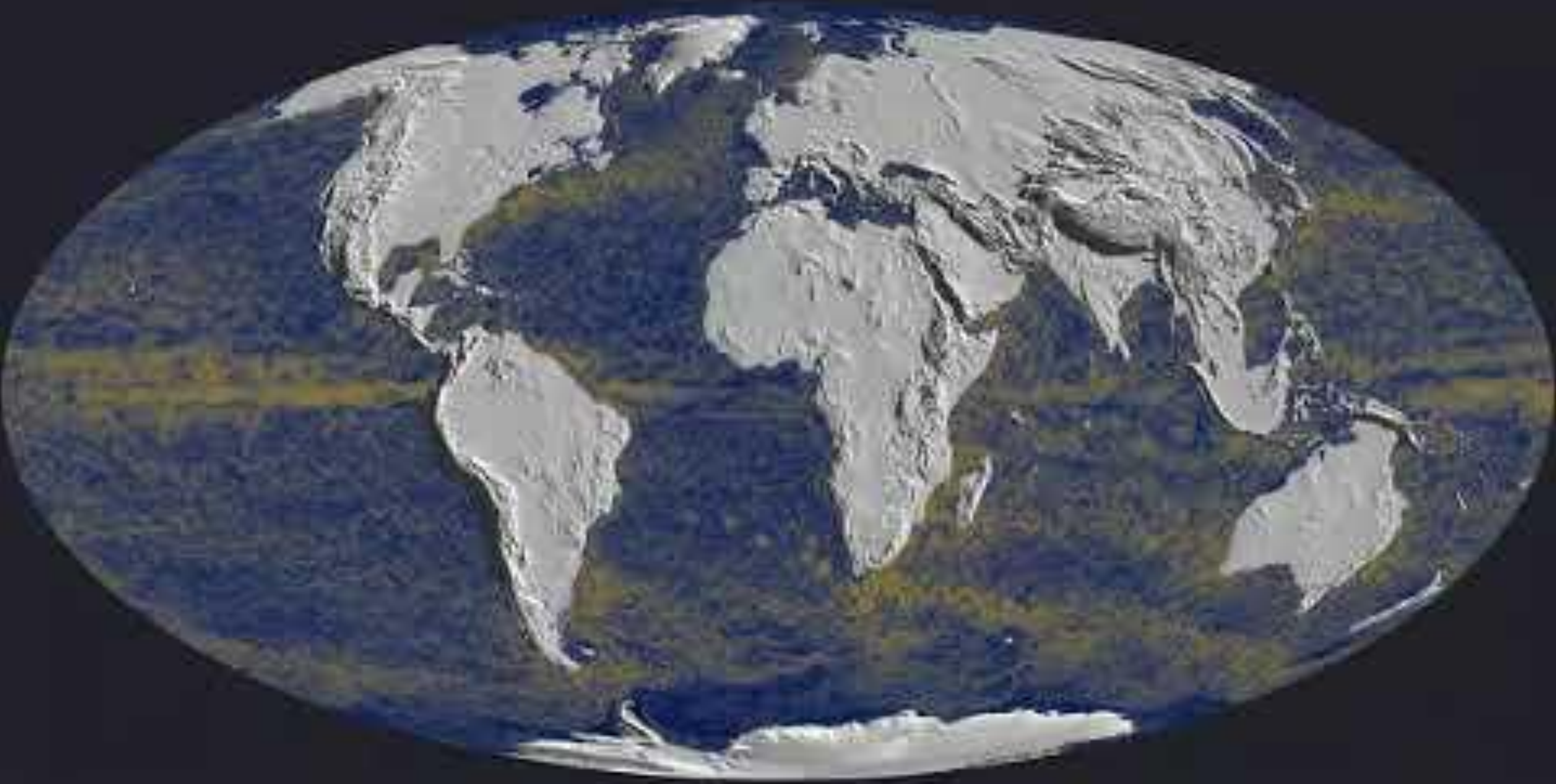
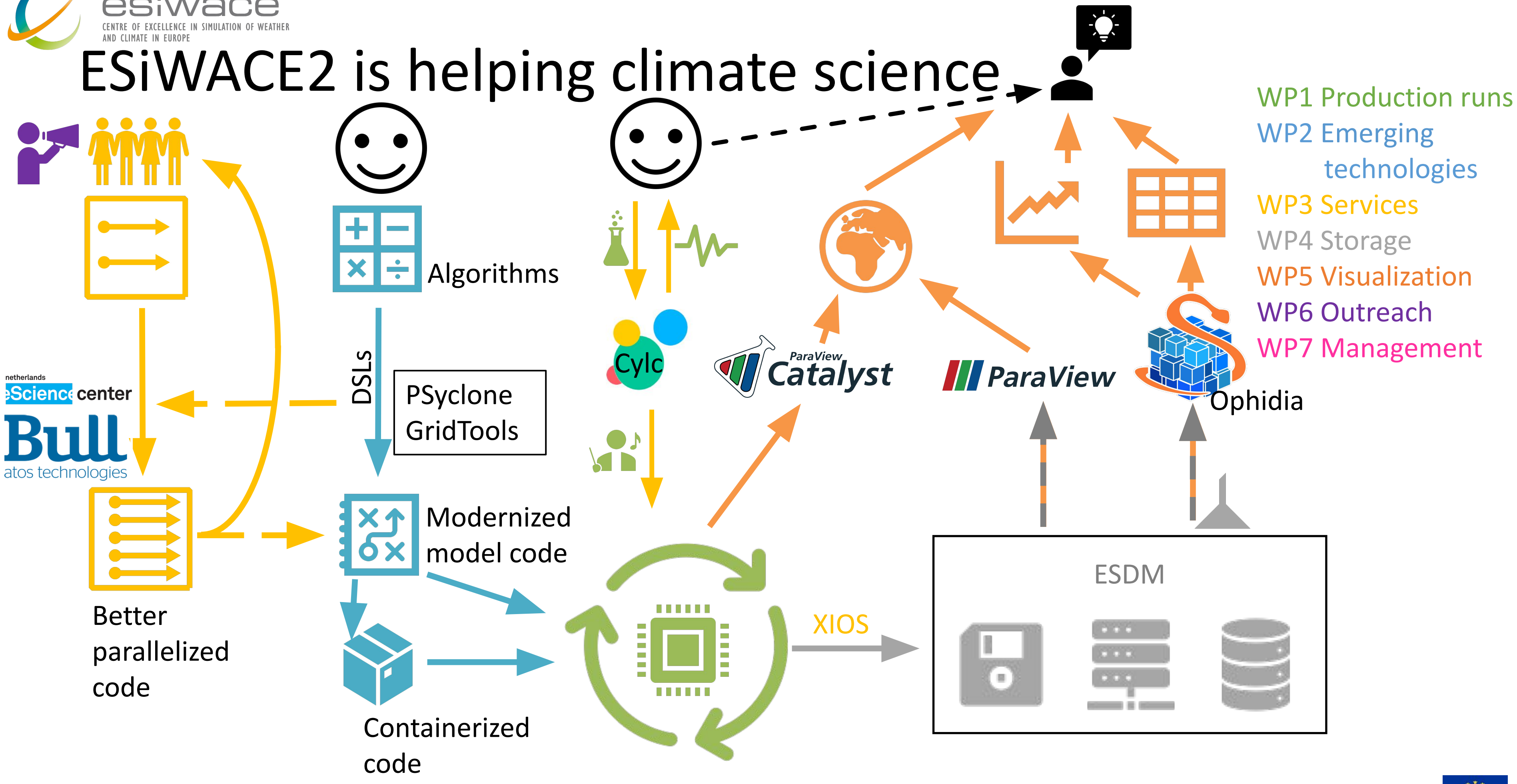




ESiWACE2 is helping climate science



WP1 Production runs
WP2 Emerging technologies
WP3 Services
WP4 Storage
WP5 Visualization
WP6 Outreach
WP7 Management

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Cross-disciplinarity:

Partners from Weather, Climate, HPC, Industry

Climate Modelling

Institut Pierre Simon Laplace

Max-Planck-Institut für Meteorologie

MERCATOR OCEAN INTERNATIONAL

Weather Services

Met Office

ECMWF

MeteoSwiss

SMHI

Tools and services

CERFACS

University of Reading

MANCHESTER 1824 The University of Manchester

Science & Technology Facilities Council

eScience center

cmcc Centro euro-Mediterraneo sui Cambiamenti Climatici

HPC

BSC Barcelona Supercomputing Center Centro Nacional de Supercomputación

ICHEC

CSCS

DKRZ DEUTSCHES KLIMARECHENZENTRUM

Industry (HPC, Storage, Tools)

Bull atos technologies

SEAGATE

DDN STORAGE

arm FORGE

BULL optimization of NEMO for improving performance scalability at high resolution.

Seagate development of the Clovis/Mero Object store backend for ESDM.

DDN development of the infinity memory engine backend for ESDM.

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HPCW Benchmarks

Partners involved: DKRZ (lead), BSC, BULL, ECMWF, ETH Zurich / CSCS

Extend the benchmarks

- GPUs if supported by models
- Additional experiments (needs input from the models’ teams)
- Enhance Kronos for simulating the production mode of storm resolving models on exascale systems

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HPCW Benchmarks

Tackle hardware and compilation uncertainties by running on different Platforms

- DRKZ: Mistral, Levante (once installed)
- ECMWF
- upcoming EuroHPC pre-exascale systems
  - Lumi
  - MareNostrum 5
- …

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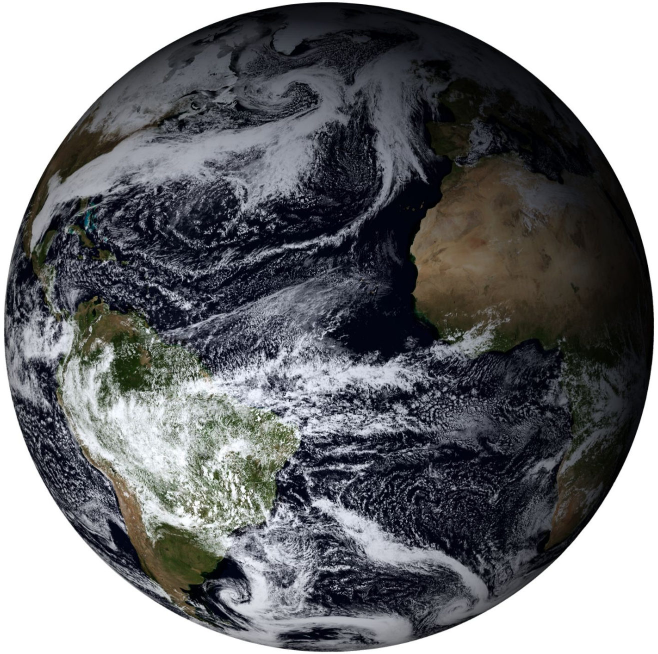
DSLs

ESCAPE

ESiWACE



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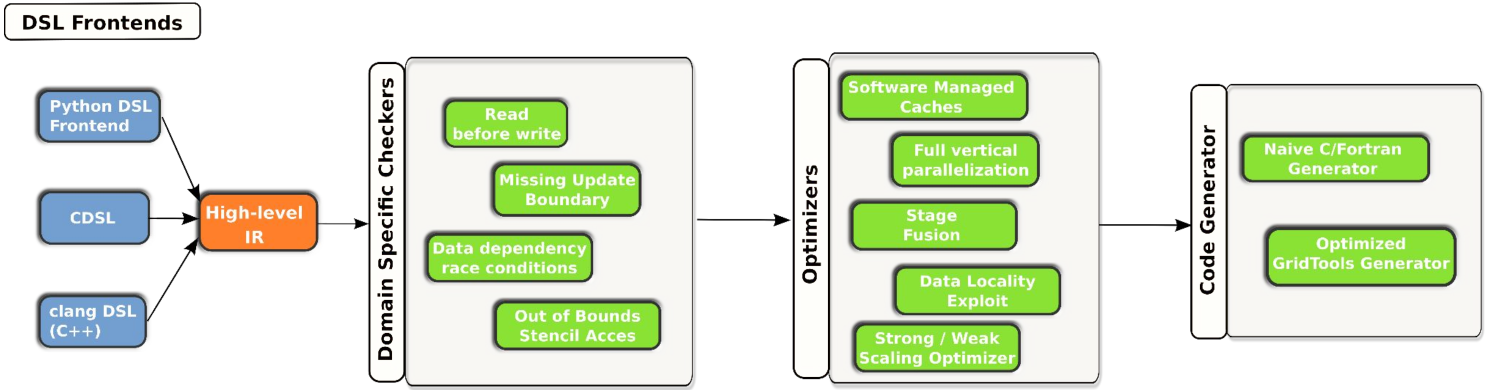
From ESCAPE-2 dwarfs to full models

- ESCAPE-2 developed a complete DSL toolchain for weather and climate models. Demonstrated in ESCAPE2 dwarfs: NEMO, ICON-O.



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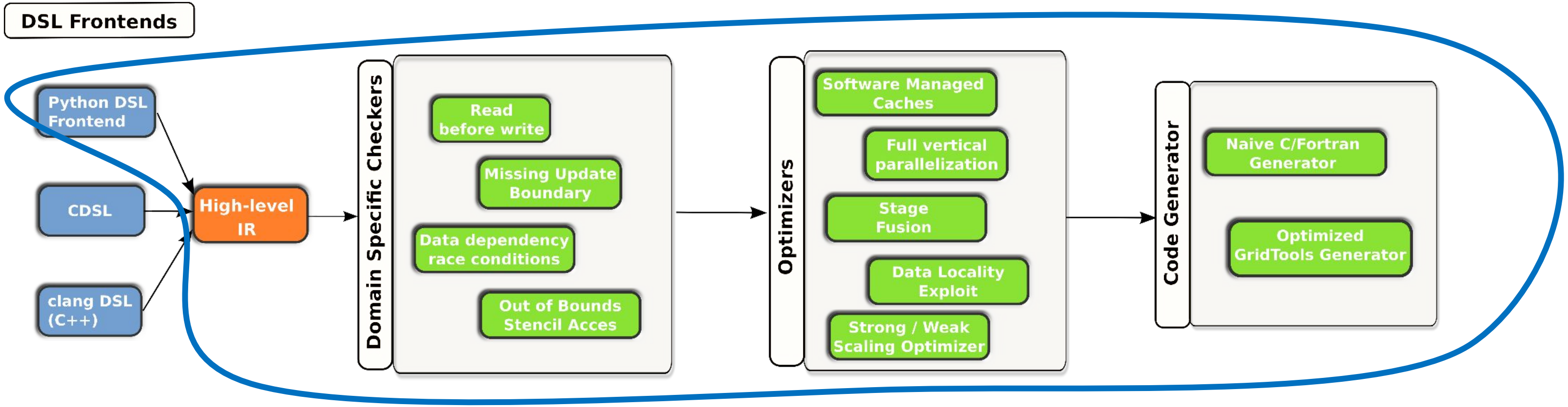
From ESCAPE-2 dwarfs to full models

- ESCAPE-2 developed a complete DSL toolchain for weather and climate models. Demonstrated in ESCAPE2 dwarfs: NEMO, ICON-O.
- ESiWACE-2 adopted the toolchain with the dusk python frontend, specifically designed for ICON (unstructured nature on icosahedral grids)
- An entire dry-dynamical core of ICON was implemented on the python DSL, integrated in operational model, NWP verifying on GPU



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Example of ICON Fortran -> Python DSL translation

```
rl_start = start_bdydiff_e
rl_end   = grf_bdywidth_e

i_startblk = p_patch%edges%start_block(rl_start)
i_endblk   = p_patch%edges%end_block(rl_end)

...


         ! Lateral boundary diffusion for vn
     i_startblk = p_patch%edges%start_block(start_bdydiff_e)
     i_endblk   = p_patch%edges%end_block(grf_bdywidth_e)

!$OMP DO PRIVATE(je,jk,jb,i_startidx,i_endidx) ICON_OMP_DEFAULT_SCHEDULE
     DO jb = i_startblk,i_endblk

       CALL get_indices_e(p_patch, jb, i_startblk, i_endblk, &
                          i_startidx, i_endidx, start_bdydiff_e, grf_bdywidth_e)

!$ACC PARALLEL LOOP DEFAULT(NONE) GANG VECTOR COLLAPSE(2) ASYNC(1) IF( i_am_accel_node .AND. acc_on
)
       DO jk = 1, nlev
!DIR$ IVDEP
         DO je = i_startidx, i_endidx
           p_nh_prog%vn(je,jk,jb) =    &
             p_nh_prog%vn(je,jk,jb) + &
             z_nabla2_e(je,jk,jb) * &
             p_patch%edges%area_edge(je,jb)*fac_bdydiff_v
         ENDDO
       ENDDO
     ENDDO
!$OMP END DO
```

```
fac_bdydiff_v = Global("fac_bdydiff_v")

@stencil
def mo_nh_diffusion_stencil_09(
   z_nabla2_e: Field[Edge, K],
   area_edge: Field[Edge],
   p_nh_prog_vn: Field[Edge, K]
):
   with domain.upward.across[lb+4:nudging-1]:
       p_nh_prog_vn += z_nabla2_e * area_edge *
fac_bdydiff_v
```

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Integration of the DSL into ICON Fortran

- # computation kernels

  velocity_adv: 22
  diffusion: 18
  solve_nonhydro: 60

  were translated to DSL and integrated in Fortran

- Still in Fortran
  - MPI Communication
  - Control flow

```
CALL sync_patch_array (SYNC_E, p_patch, p_nh_prog%vn,opt_varname="diffusion: vn sync"

...

IF (diffu_type == 3) THEN ! Only Smagorinsky diffusion
 IF ( jg == 1 .AND. l_limited_area .OR. jg > 1 .AND. .NOT. lfeedback(jg)) THEN
  ...
 ENDIF
ENDIF
```

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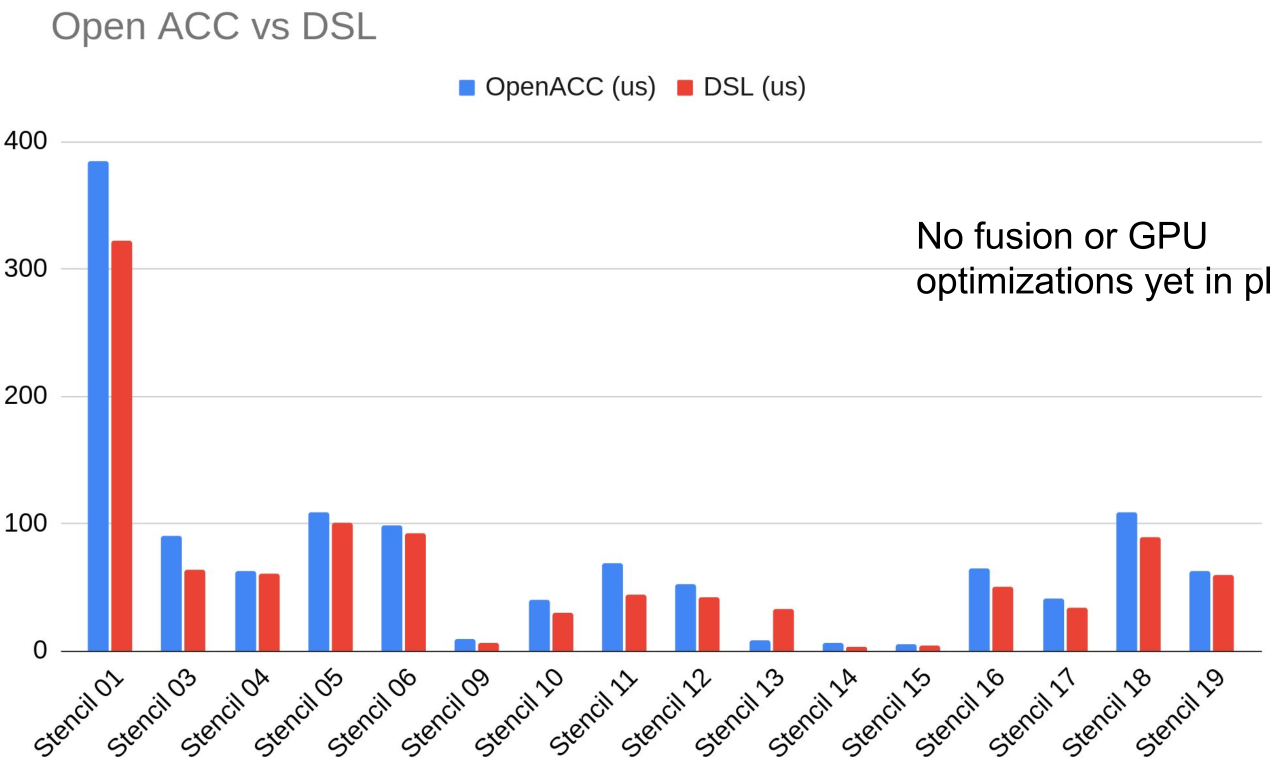
esiwace
CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE

Diffusion module translation - Performance



No fusion or GPU optimizations yet in place

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ESiWACE2 DSL Overview

- PSyclone and DAWN
- Demonstrators
    - ICON, IFS
    - NEMO, LFRic
- Comparison
    - NEMO Dwarf
    - PSyclone -> DAWN interoperability
- Training and dissemination
    - DSL training event
    - ESiWACE summer schools

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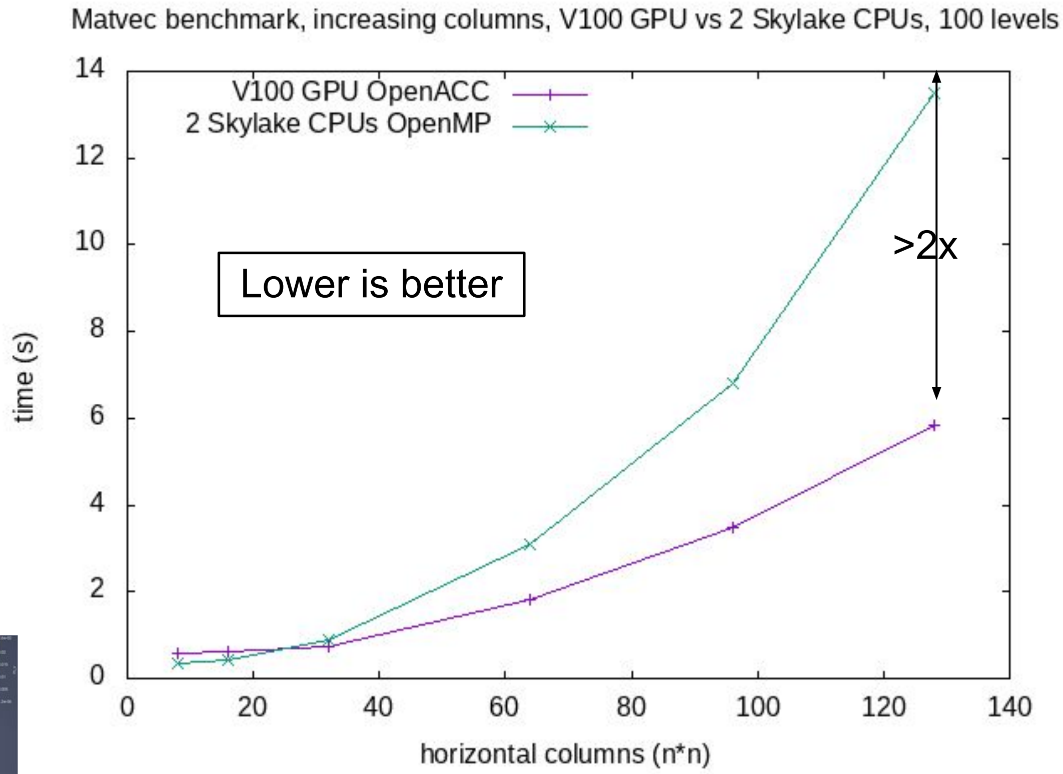
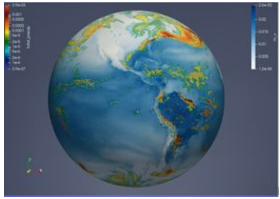
LFRic Matvec Benchmark

- Full model runs with MPI and OpenMP
- Working on OpenACC version
- Matvec responsible for 30% of model computational cost
- Manual restructure matvec to improve performance
- OpenMP performance 2x faster than original
- OpenACC implementation performs well with a large number of columns





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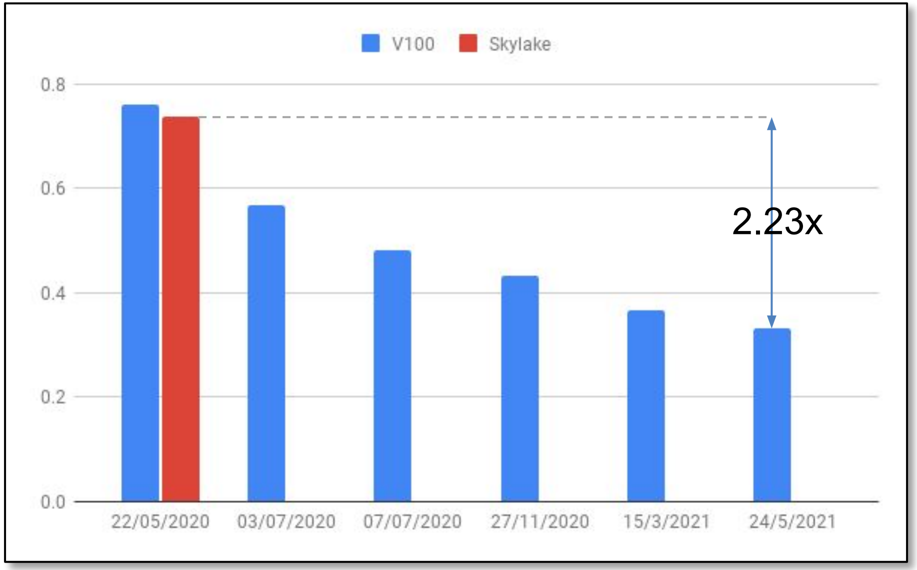
NEMO

- Full model runs on GPUs
- Concentrated on performance without sea-ice first
- ORCA1 Single GPU
- Multi-GPU ORCA12 running on Marconi but poor scaling. About to test on Juwels Booster.
- Start sea-ice optimisation next. Currently 75% time on GPU (cf 11% on CPU).

"Too good to be true" – Andreas Mueller ECMWF 2019



Lower is better

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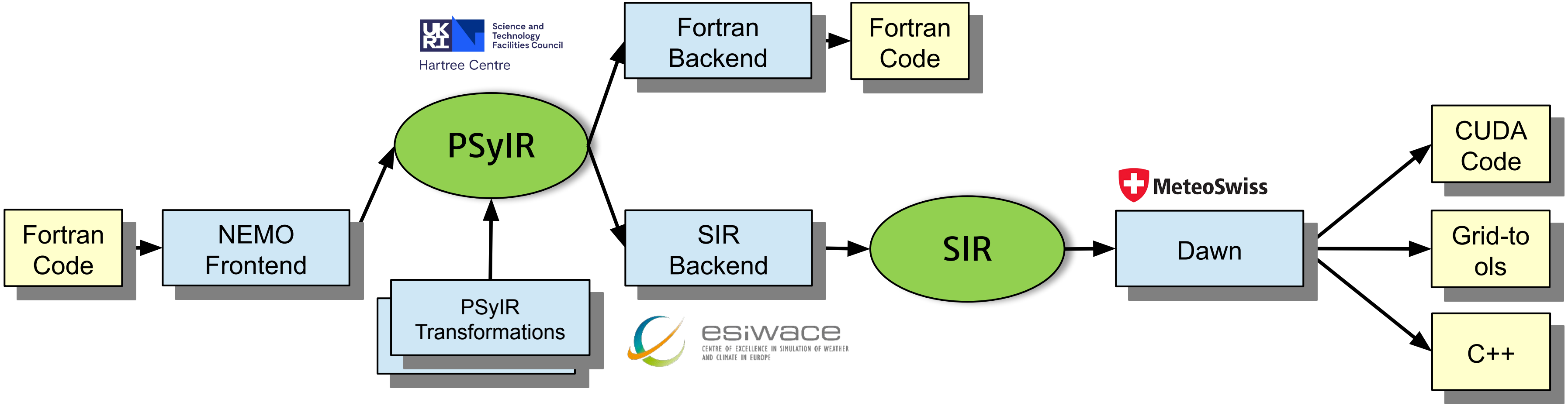
DSL Interoperability

- Different DSL front ends (and probably back ends)
- Compatible IRs?
- Evaluate PSyclone to DAWN via PSyIR and SIR



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DSL Interoperability

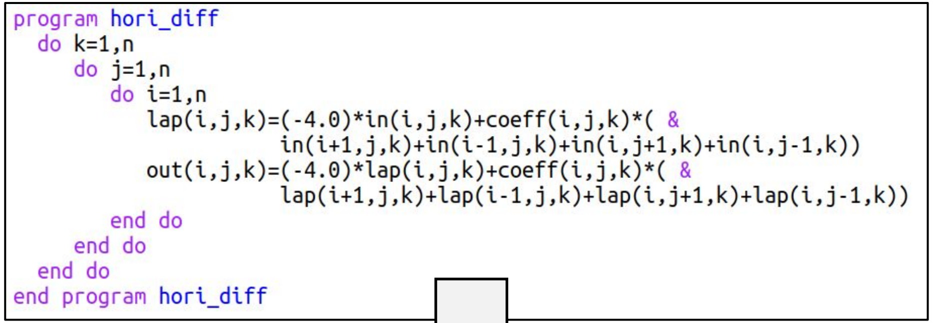
- NEMO Dwarf – tracer advection
- PSyclone transforms
  - Intrinsics

    ✔ABS, SIGN, MIN
  - Perfectly-nested triple loops

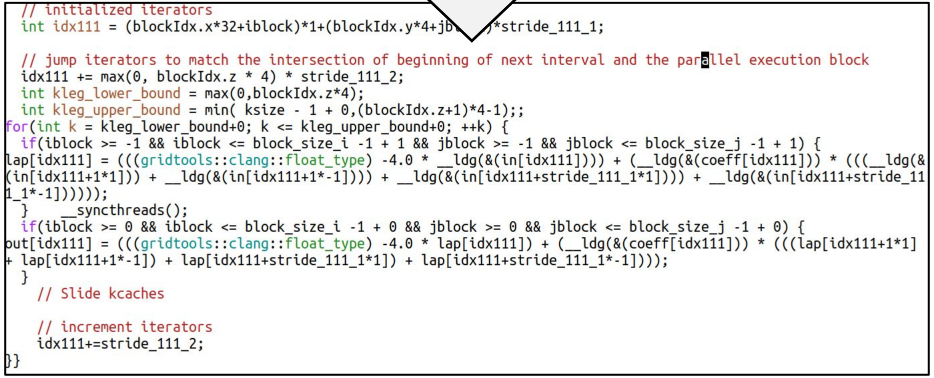
    ✔Array assignment -> loops

    ✔Single array index -> loops

    ⚠ Loop invariant scalars
- □ 2D arrays



```
program hori_diff
  do k=1,n
     do j=1,n
        do i=1,n
           lap(i,j,k)=(-4.0)*in(i,j,k)+coeff(i,j,k)*( &
                      in(i+1,j,k)+in(i-1,j,k)+in(i,j+1,k)+in(i,j-1,k))
           out(i,j,k)=(-4.0)*lap(i,j,k)+coeff(i,j,k)*( &
                      lap(i+1,j,k)+lap(i-1,j,k)+lap(i,j+1,k)+lap(i,j-1,k))
        end do
     end do
  end do
end program hori_diff
```



```
  // initialized iterators
  int idx111 = (blockIdx.x*32+iblock)*1+(blockIdx.y*4+jblock)*stride_111_1;

  // jump iterators to match the intersection of beginning of next interval and the parallel execution block
  idx111 += max(0, blockIdx.z * 4) * stride_111_2;
  int kleg_lower_bound = max(0,blockIdx.z*4);
  int kleg_upper_bound = min( ksize - 1 + 0,(blockIdx.z+1)*4-1);;
for(int k = kleg_lower_bound+0; k <= kleg_upper_bound+0; ++k) {
  if(iblock >= -1 && iblock <= block_size_i -1 + 1 && jblock >= -1 && jblock <= block_size_j -1 + 1) {
lap[idx111] = (((gridtools::clang::float_type) -4.0 * __ldg(&(in[idx111]))) + (__ldg(&(coeff[idx111])) * (((__ldg(&
(in[idx111+1*1])) + __ldg(&(in[idx111+1*-1]))) + __ldg(&(in[idx111+stride_111_1*1]))) + __ldg(&(in[idx111+stride_11
1_1*-1])))));
  }    __syncthreads();
  if(iblock >= 0 && iblock <= block_size_i -1 + 0 && jblock >= 0 && jblock <= block_size_j -1 + 0) {
out[idx111] = (((gridtools::clang::float_type) -4.0 * lap[idx111]) + (__ldg(&(coeff[idx111])) * (((lap[idx111+1*1]
+ lap[idx111+1*-1]) + lap[idx111+stride_111_1*1]) + lap[idx111+stride_111_1*-1])));
  }
    // Slide kcaches

    // increment iterators
    idx111+=stride_111_2;
}}
```

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Summary

- ESiWACE will extend the HPCW Benchmarks and apply them to various systems.
- ESiWACE made PSyclone and GridTools / DAWN work in/with production mode models.
- A full dry-dycore of ICON atmosphere was implemented within ESiWACE2. Early stage, but performance (wallclock time) is already promising.
- NEMO can be parsed by PSyclone.
- The interoperability demonstration of ESiWACE2 will allow to share backends/frontends being developed for different models.
- Automatic integration into Fortran allows to easily “escape” the DSL language for non performance critical operations or non DSL supported patterns -> allows to “port what you need”

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ESiWACE2 is on Zenodo, the Open Access repository for scientific results
https://zenodo.org/communities/esiwace

Interested in getting in touch?
Twitter: https://twitter.com/esiwace
Website: www.esiwace.eu

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