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Preparing dawn for Weather and Climate Models on Triangular Grids

ENES, 26.05.2020

Matthias Röthlin

Dawn?

Dawn - Compiler toolchain to enable generation of high-level DSLs for geophysical fluid dynamics models

Agenda

- Motivation & Dawn Overview
- Summary of Developments so far
- Dawn for Triangular Meshes
- Outlook

Motivation

Model software development starts at numerical discretization of continuous quantities:

$$\underline{\nabla}_{\underline{n}}\psi(e) = \frac{\psi(c_1(e)) - \psi(c_0(e))}{\hat{l}}$$

Motivation

- (very) straight forward implementation
- "actual science" + mesh

```
DO jk = slev, elev
 DO je = i_startidx, i_endidx
   grad_norm_psi_e(je,jk) =
       (psi_c(iidx(je,2),jk)-psi_c(iidx(je,1),jk))/lhat(je)
 ENDDO
END DO
```

Motivation

- turns out mesh is too large for one machine, add blocks

```
DO jb = i_startblk, i_endblk
 CALL get_indices_e(ptr_patch, jb, i_startblk, i_endblk, &
                    i_startidx, i_endidx, rl_start, rl_end)
 DO jk = slev, elev
   DO je = i_startidx, i_endidx
     grad_norm_psi_e(je,jk,jb) =  &
       ( psi_c(iidx(je,jb,2),jk,iblk(je,jb,2)) -
         psi_c(iidx(je,jb,1),jk,iblk(je,jb,1)) )
       / ptr_patch%edges%lhat(je,jb)
   ENDDO
 END DO
END DO
```

Motivation

- code doesn't perform, add directives to exploit shared memory machines

```
#ifdef _OMP
!$OMP PARALLEL
!$OMP DO PRIVATE(jb, i_startidx, i_endidx, je, jk)
#endif
DO jb = i_startblk, i_endblk
 CALL get_indices_e(ptr_patch, jb, i_startblk, i_endblk, &
                    i_startidx, i_endidx, rl_start, rl_end)
 DO jk = slev, elev
   DO je = i_startidx, i_endidx
     grad_norm_psi_e(je,jk,jb) =  &
       ( psi_c(iidx(je,jb,2),jk,iblk(je,jb,2)) -
         psi_c(iidx(je,jb,1),jk,iblk(je,jb,1)) )
       / ptr_patch%edges%lhat(je,jb)
   ENDDO
 END DO
END DO
#ifdef _OMP
!$OMP END DO NOWAIT
!$OMP END PARALLEL
#endif
```

Motivation

- code needs to target another architecture...
- ... with different optimal memory layout

```
#ifdef _OMP
!$OMP ....
#else
!$ACC ....
#endif
DO jb = i_startblk, i_endblk
 CALL get_indices_e(ptr_patch, ...)
 #ifdef __LOOP_EXCHANGE
 DO je = i_startidx, i_endidx
   DO jk = slev, elev
 #else
   DO jk = slev, elev
     DO je = i_startidx, i_endidx
 #endif
     grad_norm_psi_e(je,jk,jb) =  &
       ( psi_c(iidx(je,jb,2),jk,iblk(je,jb,2)) -
         psi_c(iidx(je,jb,1),jk,iblk(je,jb,1)) )
       / ptr_patch%edges%lhat(je,jb)
   ENDDO
 END DO
END DO
#ifdef _OMP
!$OMP ...
#else
!$ACC ...
#endif
```


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Motivation

$$\underline{\nabla}_{\underline{n}}\psi(e) = \frac{\psi(c_1(e)) - \psi(c_0(e))}{\hat{l}}$$

```
#ifdef _OMP
!$OMP ....
#else
!$ACC ....
#endif
DO jb = i_startblk, i_endblk
 CALL get_indices_e(ptr_patch, ...)
 #ifdef __LOOP_EXCHANGE
 DO je = i_startidx, i_endidx
   DO jk = slev, elev
 #else
   DO jk = slev, elev
     DO je = i_startidx, i_endidx
 #endif
     grad_norm_psi_e(je,jk,jb) =  &
       ( psi_c(iidx(je,jb,2),jk,iblk(je,jb,2)) -
         psi_c(iidx(je,jb,1),jk,iblk(je,jb,1)) )
       / ptr_patch%edges%lhat(je,jb)
   ENDDO
 END DO
END DO
#ifdef _OMP
!$OMP ...
#else
!$ACC ...
#endif
```

Motivation

What if

- Requirements change, e.g. it turns out that this gradient should have been approximated using a higher order stencil?
- A third (fourth...) architecture needs to be supported?
- The mesh library needs to be replaced?

```
#ifdef _OMP
!$OMP ....
#else
!$ACC ....
#endif
DO jb = i_startblk, i_endblk
 CALL get_indices_e(ptr_patch, ...)
 #ifdef __LOOP_EXCHANGE
 DO je = i_startidx, i_endidx
   DO jk = slev, elev
 #else
   DO jk = slev, elev
     DO je = i_startidx, i_endidx
 #endif
     grad_norm_psi_e(je,jk,jb) =  &
       ( psi_c(iidx(je,jb,2),jk,iblk(je,jb,2)) -
         psi_c(iidx(je,jb,1),jk,iblk(je,jb,1)) )
       / ptr_patch%edges%lhat(je,jb)
   ENDDO
 END DO
END DO
#ifdef _OMP
!$OMP ...
#else
!$ACC ...
#endif
```

Motivation

Idea of dawn / DSLs in general

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

```
grad_norm_psi_e =
      reduce( psi_c,
              CELL > EDGE,
              [1/lhat, -1/lhat] )
```

OMP → **dawn**

```
!$OMP PARALLEL
!$OMP DO PRIVATE(jb, i_startidx, i_endidx, je, jk)
DO jb = i_startblk, i_endblk
 CALL get_indices_e(ptr_patch, ...)
 DO je = i_startidx, i_endidx
   DO jk = slev, elev
     grad_norm_psi_e(je,jk,jb) =  &
       ( psi_c(iidx(je,jb,2),jk,iblk(je,jb,2)) -
         psi_c(iidx(je,jb,1),jk,iblk(je,jb,1)) )
       / ptr_patch%edges%lhat(je,jb)
   ENDDO
 END DO
END DO
!$OMP END DO NOWAIT
!$OMP END PARALLEL
```

Motivation

Idea of dawn / DSLs in general

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

```
grad_norm_psi_e =
      reduce( psi_c,
              CELL > EDGE,
              [1/lhat, -1/lhat] )
```

Open ACC

dawn

```
!$ACC PARALLEL &
!$ACC PRESENT(ptr_patch, iidx, iblk, pci_c,
grad_...)
!$ACC LOOP GANG
DO jb = i_startblk, i_endblk
 CALL get_indices_e(ptr_patch, ...)
 DO jk = slev, elev
   DO je = i_startidx, i_endidx
     grad_norm_psi_e(je,jk,jb) =  &
       ( psi_c(iidx(je,jb,2),jk,iblk(je,jb,2)) -
         psi_c(iidx(je,jb,1),jk,iblk(je,jb,1)) )
       / ptr_patch%edges%lhat(je,jb)
   ENDDO
 END DO
END DO
!$ACC END PARALLEL
!$ACC END DATA
```


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Motivation

No FORTRAN Backend Exists, only for illustration purposes

Idea of dawn / DSLs in general

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

```
grad_norm_psi_e =
      reduce( psi_c,
              CELL > EDGE,
              [1/lhat, -1/lhat] )
```

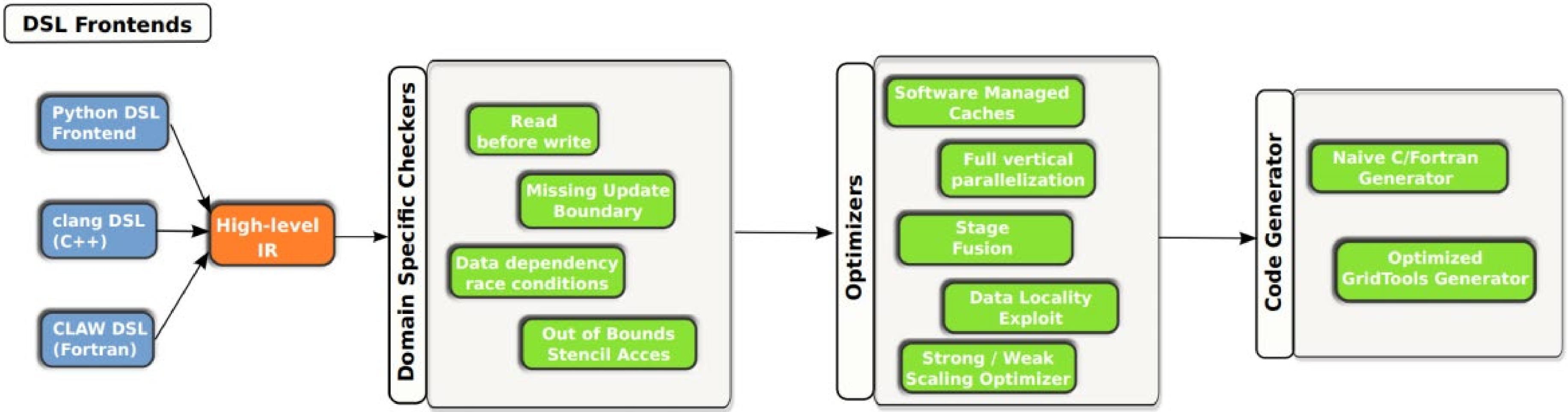
Open ACC

dawn

```
for(int k = 0 + 0; k < m_k_size; ++k) {
 for(auto const& loc : getEdges(LibTag{}, m_mesh)) {
   for(auto inner_loc :
     grad_norm_psi_e(loc, k + 0) = reduce(
         LibTag{}, m_mesh, loc, (::dawn::float_type)0.0,
         std::vector<dawn::LocationType>
         {dawn::Edges, dawn::Cells},
         [&](auto& lhs, auto red_loc1, auto const& weight)
         {
           lhs += weight * psi_c(red_loc1, k + 0);
           return lhs;
         },
         std::vector<::dawn::float_type>({-1.0 ,1.0});
   }
   grad_norm_psi_e(loc, k + 0) /= lhat_e(loc, k + 0)
 }
}
```

Dawn Overview

Dawn - A closer look

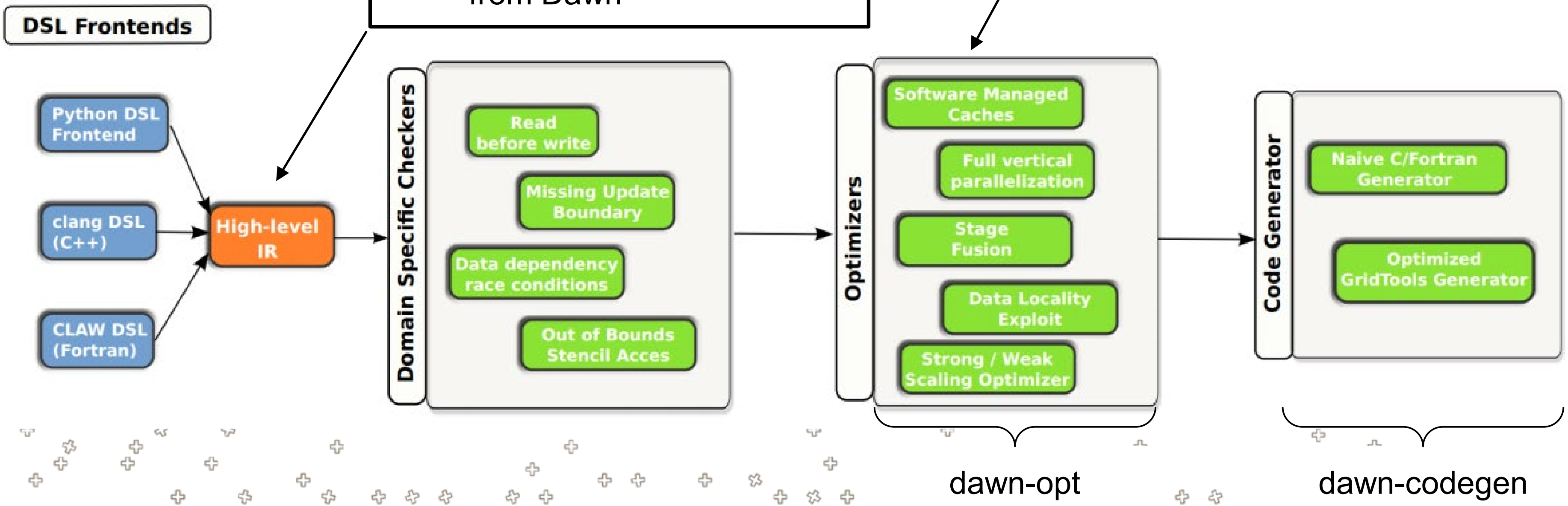


Dawn Overview

Dawn - A closer look

- High Level Intermediate Representation
- Decouples Front Ends from Dawn

- Various optimization passes
- Insertion of pragmas only very small subset of possibilities



Dawn - Developments Summary

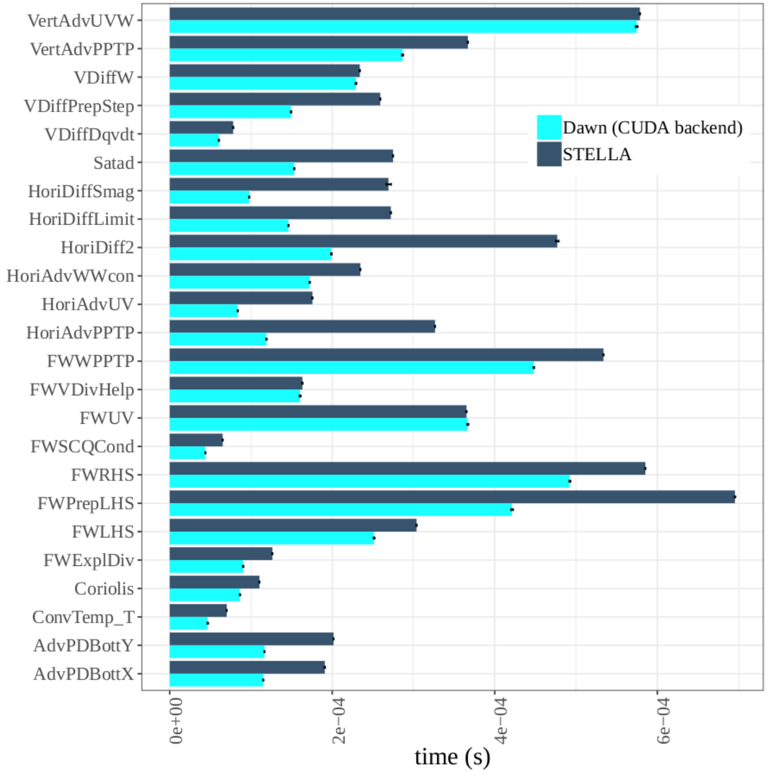
- Dawn currently ships with a frontend called "gtclang"
  - embedded into C++
  - complete w.r.t COSMO dycore in particular / Finite Differences in general
- Wide array of optimization strategies
- Various backends
  - C++ naive
  - gridtools MC / GPU
  - cuda

Dawn - Developments Summary

- Dawn was used to successfully translate the complete COSMO dycore
  - advection schemes
  - diffusion
  - tridiagonal solver
  - ...

- Outperforms previous efforts of translating the COSMO dycore using DSLs, at a fraction of the lines of code

Dawn - Developments Summary



Dawn for Triangular Meshes

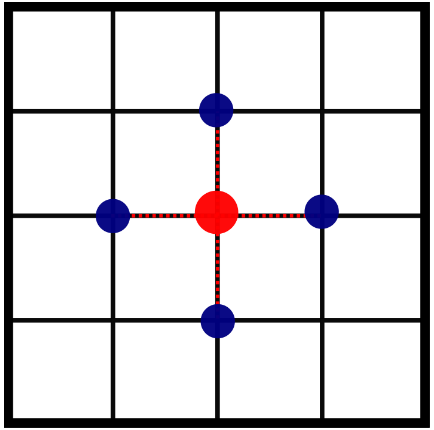
- Dawn is to be used to translate the ICON dycore
- Switch from Finite Differences on a Cartesian mesh to more general computations on a icosahedral triangle mesh
- New concepts are required to map these kind of computations, starting from the frontend all throughout the tool chain until code generation

Dawn for Triangular Meshes

Basic Idea: Reductions instead of "North-East-South-West" accesses

```
field lapl, u
lap(i,j) = -4*u(i,j)
          + u(i-1,j) + u(i+1,j)
          + u(i,j-1) + u(i,j+1)
```

cartesian access



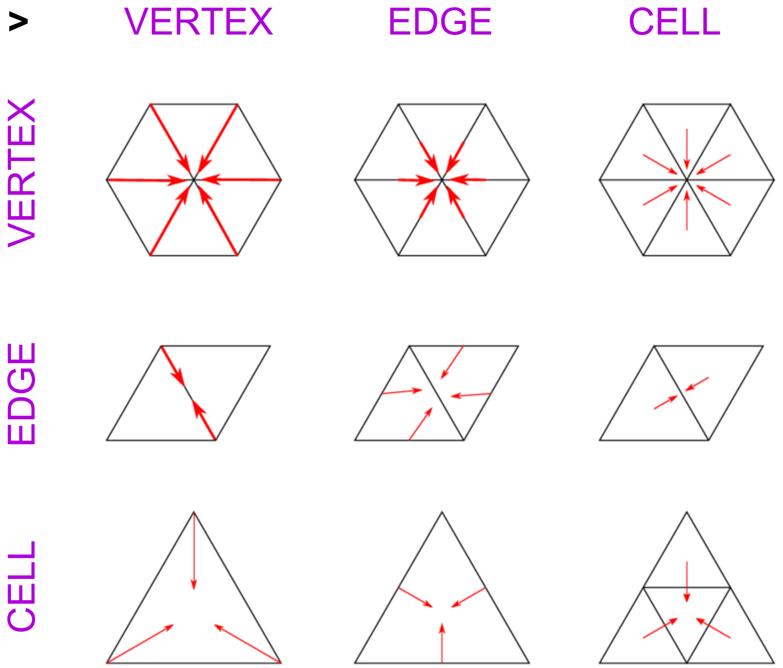
```
VertxField lapl, u
lapl = reduce( VERTEX>VERTEX
               u )
lapl = lapl - 4*u
```

unstr. access

Dawn for Triangular Meshes

Basic Idea: Reductions

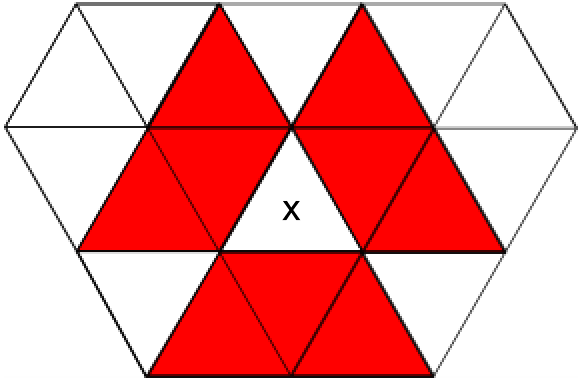
```
cellField div_c;
edgeField flux, n;
div_c = reduce(
          CELL>EDGE,
          flux*n)
```

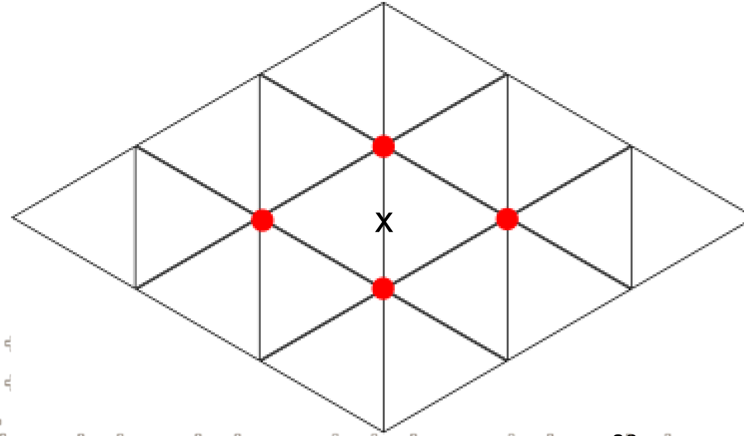


Dawn for Triangular Meshes

Typical computations in ICON are more general

- **larger neighborhoods** / "wider" stencils
- weighted reductions (e.g. gradients)
- "sparse dimensions"
  - arrays of higher rank which store values for each neighbor in the reduction





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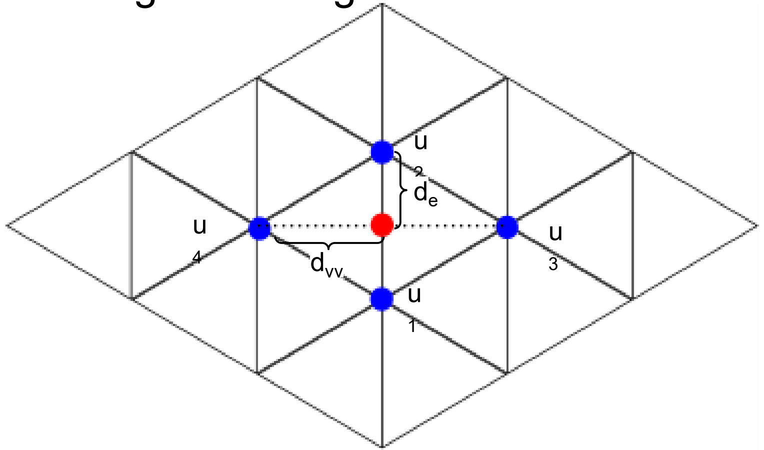
Dawn for Triangular Meshes

Worked Example - Laplacian Finite Difference Stencil on a hexagonal triangle mesh

$$\nabla^2(u) \approx \frac{u_1 + u_2 - 2 \cdot u}{d_e^2} + \frac{u_3 + u_4 - 2 \cdot u}{d_{vv}^2}$$

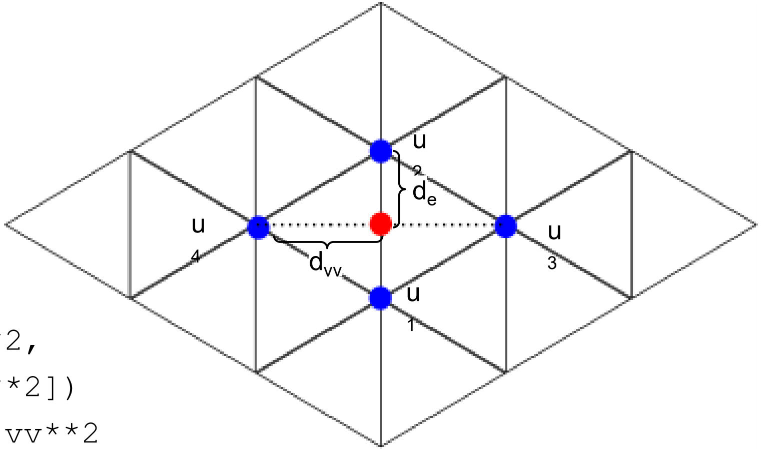


Dawn for Triangular Meshes

Worked Example - Formula to DSL

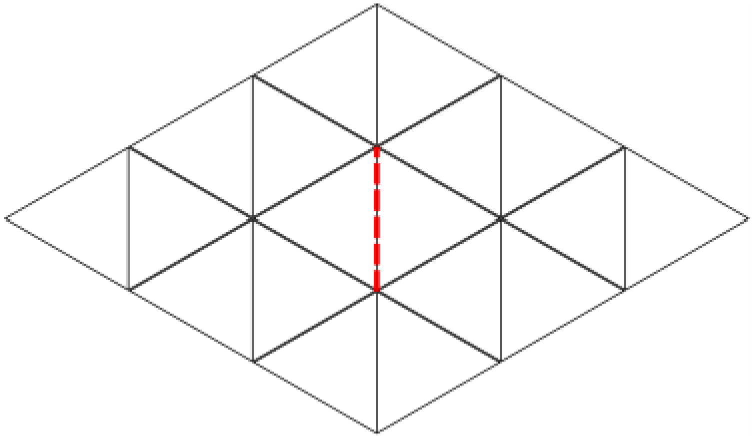
$$\nabla^2(u) \approx \frac{u_1 + u_2 - 2 \cdot u}{d_e^2} + \frac{u_3 + u_4 - 2 \cdot u}{d_{vv}^2}$$

```
vertexField u;
edgeField lapl;
lapl = reduce(EDGE>CELL>VERTEX,
              u,
              [1/d_e**2 , 1/d_e**2,
               1/d_vv**2, 1/d_vv**2])
lapl = lapl - 2*u/d_e**2 - 2*u/d_vv**2
```



Dawn for Triangular Meshes

Worked Example - Building a the reductions "Neighbor Chain"



EDGE>CELL>VERTEX

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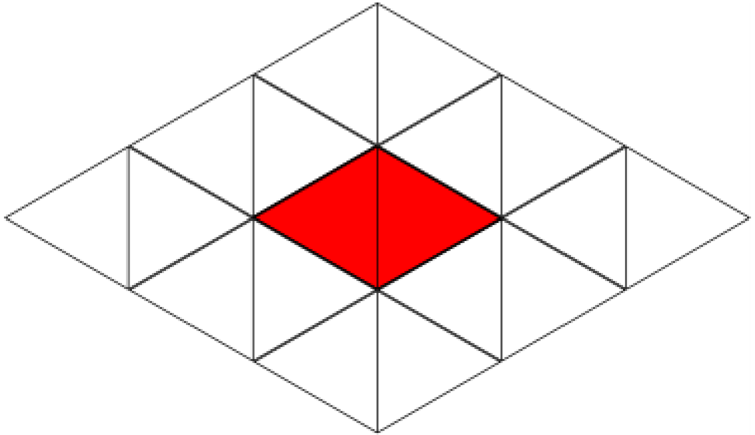
Dawn for Triangular Meshes

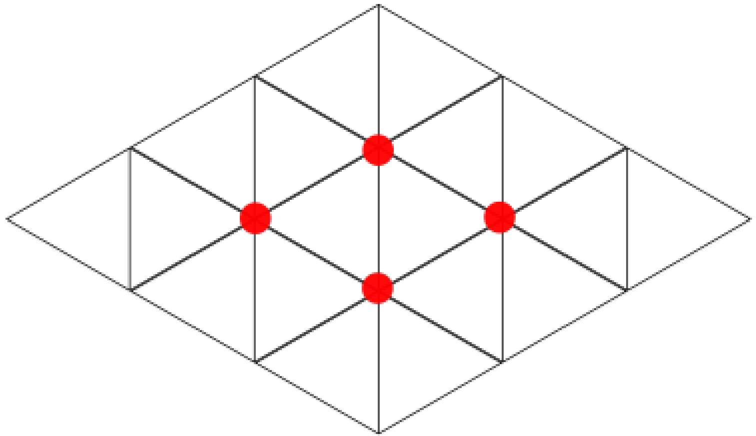
Worked Example - Building a the reductions "Neighbor Chain"



EDGE>**CELL**>VERTE
X

Dawn for Triangular Meshes

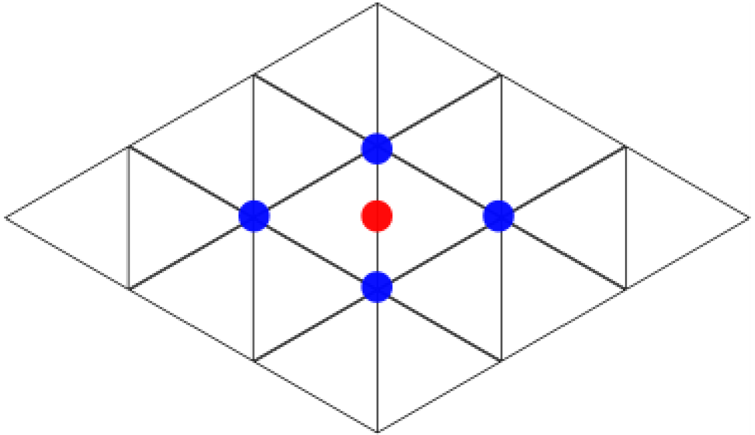
Worked Example - Building a the reductions "Neighbor Chain"



EDGE>CELL>**VERTE**
X

Dawn for Triangular Meshes

Worked Example - Building a the reductions "Neighbor Chain"



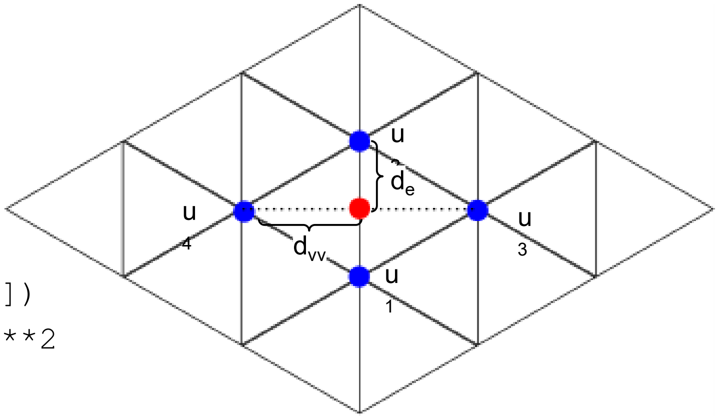
EDGE>CELL>VERTE
X

Dawn for Triangular Meshes

Worked Example - Formula to DSL

$$\nabla^2(u) \approx \frac{u_1 + u_2 - 2 \cdot u}{d_e^2} + \frac{u_3 + u_4 - 2 \cdot u}{d_{vv}^2}$$

```
vertexField u;
edgeField lapl;
lapl = reduce(EDGE>CELL>VERTEX,
              u,
              [1/d_e**2 , 1/d_e**2,
               1/d_vv**2, 1/d_vv**2])
lapl = lapl - 2*u/d_e**2 - 2*u/d_vv**2
```

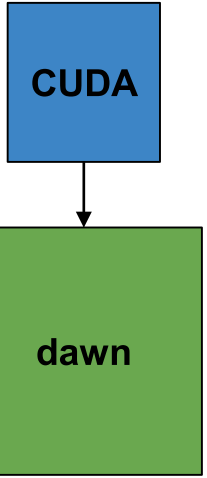


Worked Example - DSL to Codegen

```
vertexField u;
edgeField lapl;
lapl = reduce(EDGE>CELL>VERTEX,
              u,
              [1/d_e**2 , 1/d_e**2,
               1/d_vv**2, 1/d_vv**2])
lapl = lapl - 2*u/d_e**2 - 2*u/d_vv**2
```

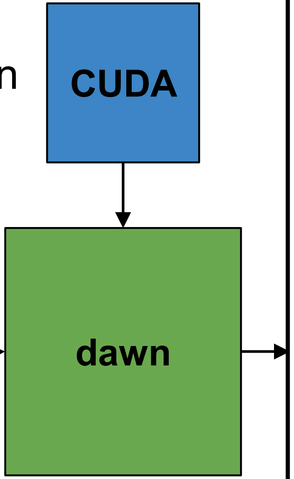
Worked Example - DSL to Codegen

```
vertexField u;
edgeField lapl;
lapl = reduce(EDGE>CELL>VERTEX,
              u,
              [1/d_e**2 , 1/d_e**2,
               1/d_vv**2, 1/d_vv**2])
lapl = lapl - 2*u/d_e**2 - 2*u/d_vv**2
```



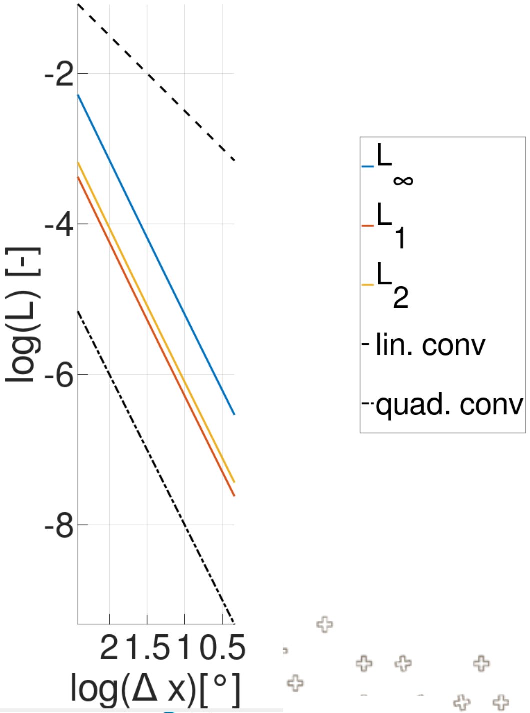
Worked Example - DSL to Codegen

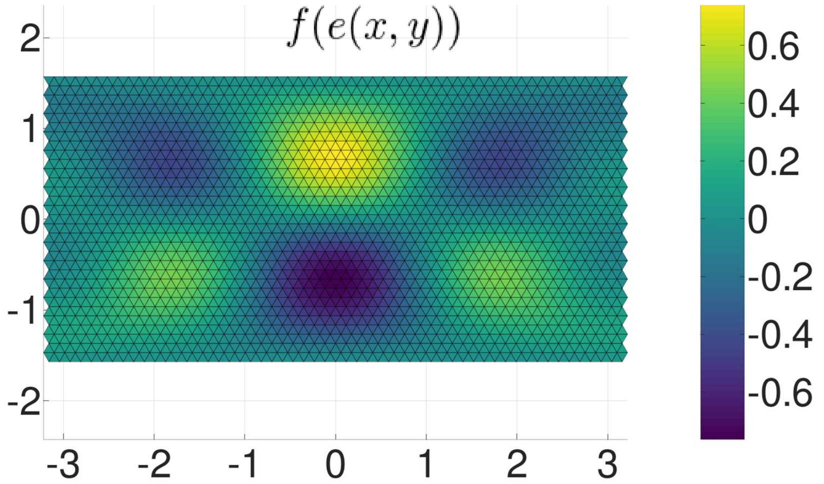
```
vertexField u;
edgeField lapl;
lapl = reduce(EDGE>CELL>VERTEX,
              u,
              [1/d_e**2 , 1/d_e**2,
               1/d_vv**2, 1/d_vv**2])
lapl = lapl - 2*u/d_e**2 - 2*u/d_vv**2
```

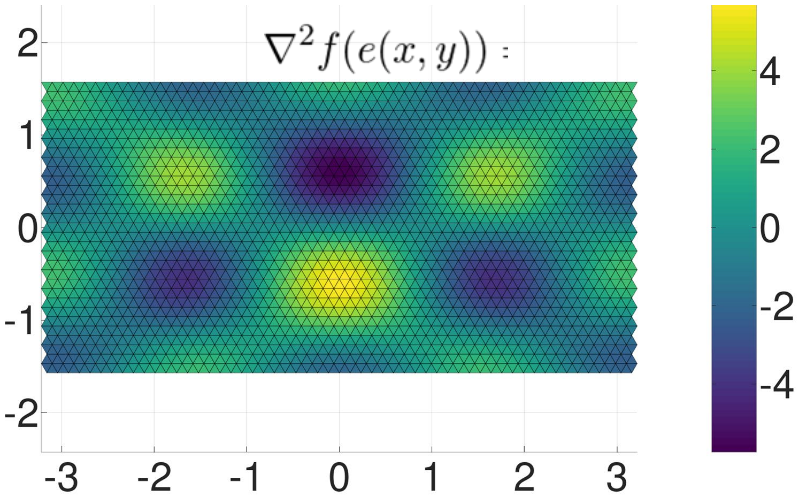



```
template <int E_C_V_SIZE>
__global__ void ICON_laplacian__ms439_s466_kernel(
   int NumEdges, int NumVertices, int kSize, const int*
ecvTable,
   const ::dawn::float_type* __restrict__ u,
    ::dawn::float_type* __restrict__ lapl) {
 unsigned int pidx = blockIdx.x * blockDim.x + threadIdx.x;
 unsigned int kidx = blockIdx.y * blockDim.y + threadIdx.y;
 int klo = kidx * LEVELS_PER_THREAD;
 int khi = (kidx + 1) * LEVELS_PER_THREAD;
 if(pidx >= NumEdges) {return;}
 for(int kIter = klo; kIter < khi; kIter++) {
   int offsetIdx = kIter * NumEdges + pidx;
   ::dawn::float_type weights[4] = {
       1. / d_e[offsetIdx] **2,  1. / d_e[offsetIdx] **2,
       1. / d_vv[offsetIdx] **2, 1. / d_vv[offsetIdx] **2};
   for(int nbhIter = 0; nbhIter < E_C_V_SIZE; nbhIter++) {
     int nbhIdx = kIter * NumVertices +
                       ecvTable[pidx * E_C_V_SIZE + nbhIter];
     if(nbhIdx == DEVICE_MISSING_VALUE) {continue;}
     lapl[offsetIdx] += u[nbhIdx] * weights[nbhIter];
   }
   lapl[offsetIdx] =
       lapl[offsetIdx] - 2*u[offsetIdx]/d_e[offsetIdx]
                       - 2*u[offsetIdx] / d_vv[offsetIdx]
 }
}
```

$$\begin{cases} u(x,y) := \frac{1}{4}\sqrt{\frac{105}{2\pi}} \cos 2x \cos^2 y \sin y \ , \\ v(x,y) := -\frac{1}{2}\sqrt{\frac{15}{2\pi}} \cos x \cos y \sin y \ . \end{cases}$$







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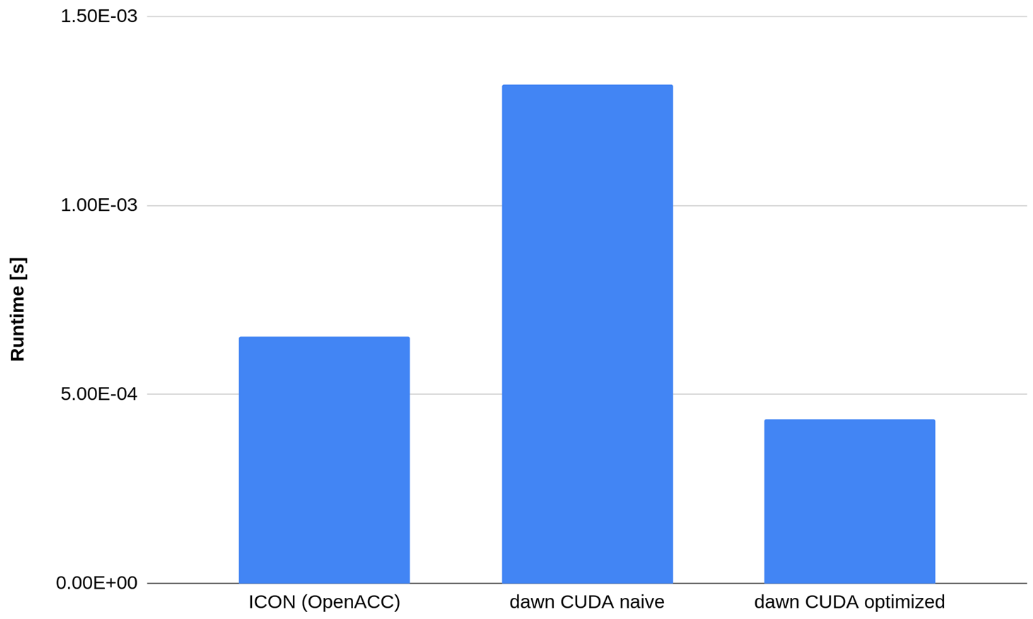
Dawn for Triangular Meshes

Worked Example - Timings: Tesla P100, Single GPU, 1.3M Edges, Laplacian + Smagorinsky Diffusion



Dawn - Outlook

- Short to Midterm: Translate functional subunits of the ICON dycore using the DSL
- Long Term: Translate entire ICON dycore using the DSL
  - Efficiently target pre-exascale machines
  - Keep code readable
  - Ensure code can be further developed scientifically

- dawn is open source / open development: github

BACKUP

Example of a CUDA Optimization Strategy: Fuse Reductions

```
# dvt_tang for smagorinsky
dvt_tang = reduce(
    u_vert * dual_normal_x + v_vert * dual_normal_y,
    Edge > Cell > Vertex,
    [-1.0, 1.0, 0.0, 0.0],
)

# dvt_norm for smagorinsky
dvt_norm = reduce(
    u_vert * dual_normal_x + v_vert * dual_normal_y,
    Edge > Cell > Vertex,
    [0.0, 0.0, -1.0, 1.0],
)
```

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```
# dvt_tang for smagorinsky
float lhs_495 = 0.0;
float weights_495[4] = {-1.0, 1.0, 0.0, 0.0};
for(int nbhIter = 0; nbhIter < E_C_V_SIZE; nbhIter++) {
  int nbhIdx = ecvTable[pidx * E_C_V_SIZE + nbhIter];
  if(nbhIdx == DEVICE_MISSING_VALUE) {continue;}
  int denseIdx = kIter * NumVertices + nbhIdx;
  int sparseIdx = kIter * NumEdges * E_C_V_SIZE + ...
  lhs_495 += weights_495[nbhIter] *
             (u_vert[denseIdx] * dual_normal_x[sparseIdx] +
              v_vert[denseIdx] * dual_normal_y[sparseIdx]);
}
dvt_tang[denseIdx] = lhs_495;
# dvt_norm for smagorinsky
float lhs_517 = 0.0;
float weights_517[4] = {0.0, 0.0, -1.0, 1.0};
for(int nbhIter = 0; nbhIter < E_C_V_SIZE; nbhIter++) {
  int nbhIdx = ecvTable[pidx * E_C_V_SIZE + nbhIter];
  if(nbhIdx == DEVICE_MISSING_VALUE) {continue;}
  int denseIdx = kIter * NumVertices + nbhIdx;
  int sparseIdx = kIter * NumEdges * E_C_V_SIZE + ...
  lhs_517 += weights_495[nbhIter] *
             (u_vert[denseIdx] * dual_normal_x[sparseIdx] +
              v_vert[denseIdx] * dual_normal_y[sparseIdx]);
}
dvt_norm[denseIdx] = lhs_517;
```

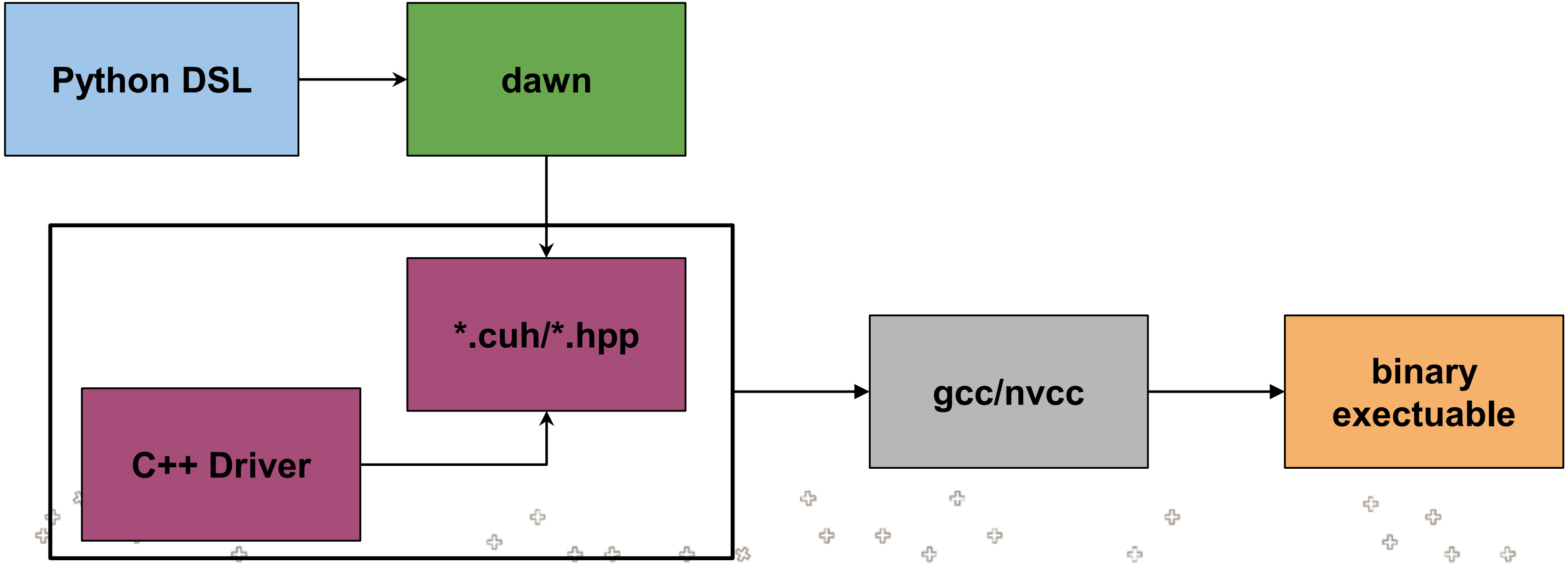
```
# dvt_tang for smagorinsky
dvt_tang = reduce(
    u_vert * dual_normal_x + v_vert * dual_normal_y,
    Edge > Cell > Vertex,
    [-1.0, 1.0, 0.0, 0.0],
)
```

```
# dvt_norm for smagorinsky
dvt_norm = reduce(
    u_vert * dual_normal_x + v_vert * dual_normal_y,
    Edge > Cell > Vertex,
    [0.0, 0.0, -1.0, 1.0],
)
```

```
# fused reductions
float lhs_495 = 0.0;
float lhs_517 = 0.0;
float weights_495[4] = {-1.0, 1.0, 0.0, 0.0};
float weights_517[4] = {0.0, 0.0, -1.0, 1.0};
for(int nbhIter = 0; nbhIter < E_C_V_SIZE; nbhIter++) {
  int nbhIdx = ecvTable[pidx * E_C_V_SIZE + nbhIter];
  if(nbhIdx == DEVICE_MISSING_VALUE) {continue;}
  int denseIdx = kIter * NumVertices + nbhIdx;
  int sparseIdx = kIter * NumEdges * E_C_V_SIZE + ...
  float rhs = (u_vert[denseIdx] * dual_normal_x[sparseIdx] +
               v_vert[denseIdx] * dual_normal_y[sparseIdx]);
  lhs_495 += weights_495[nbhIter] * rhs;
  lhs_517 += weights_517[nbhIter] * rhs;
}
dvt_tang[denseIdx] = lhs_495;
dvt_norm[denseIdx] = lhs_517;
```

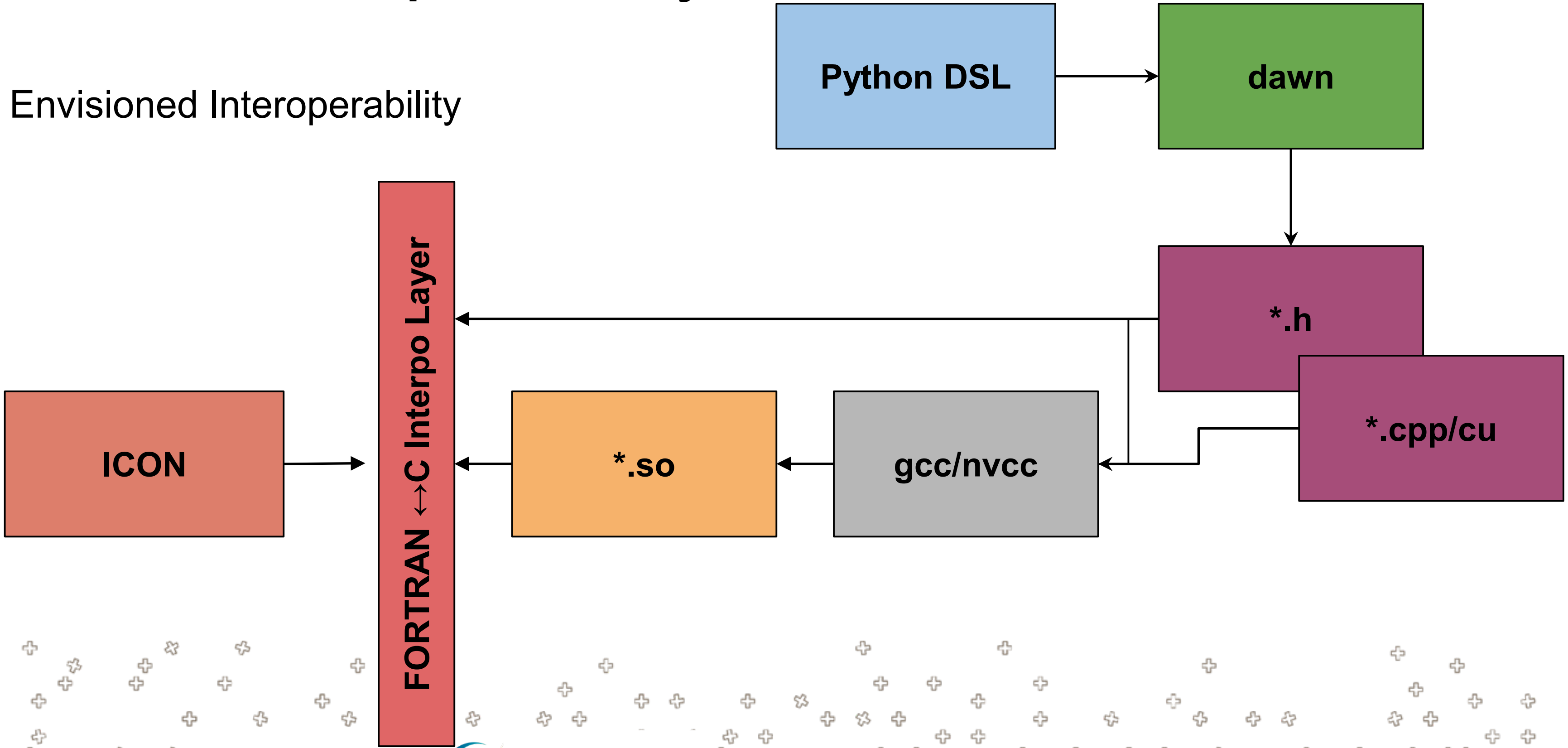
Interoperability

Current work flow:



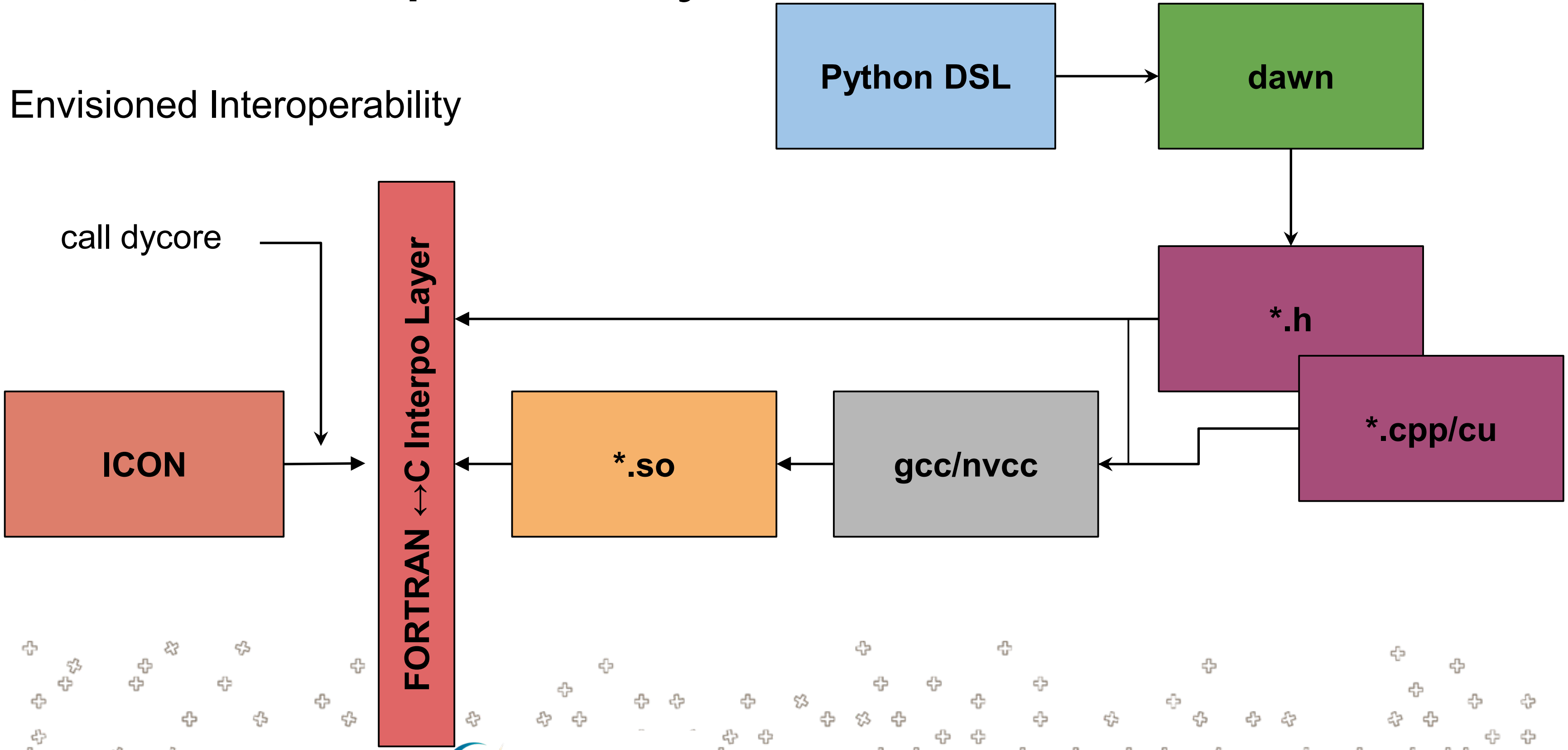
Interoperability

Envisioned Interoperability



Interoperability

Envisioned Interoperability



Interoperability

```
SUBROUTINE vn_adv_horizontal(
           p_vn, p_vort, p_delp_c,
           pt_patch, pt_int,
           p_ddt_vn, p_kin, p_vt,
           p_delp_v,
           opt_rlstart, opt_rlend  )
! <SNIP>
!===========================================
! Calculate the gradient of kinetic energy,
! and accumulate velocity tendency
!===========================================

 CALL grad_fd_norm( p_kin, pt_patch,
              z_tmp_e, opt_rlstart=4 )
```

```
SUBROUTINE grad_fd_norm(
       psi_c, ptr_patch, grad_norm_psi_e,
       opt_slev, opt_elev, opt_rlstart,
       opt_rlend )
TYPE(t_patch), TARGET, INTENT(in) :: ptr_patch
! <SNIP>
!$ACC DATA ....          &
!$ACC
!$OMP PARALLEL
!$OMP DO PRIVATE(jb,i_startidx,i_endidx,je,jk)
 DO jb = i_startblk, i_endblk
 CALL get_indices_e(ptr_patch, jb, i_startblk, i_endblk, &
                    i_startidx, i_endidx, rl_start, rl_end)
   !$ACC PARALLEL IF( i_am_accel_node .AND. acc_on )
   !$ACC LOOP GANG
   DO je = i_startidx, i_endidx
     !$ACC LOOP VECTOR
     DO jk = slev, elev
      grad_norm_psi_e(je,jk,jb) =  &
         &  ( psi_c(iidx(je,jb,2),jk,iblk(je,jb,2)) - &
         &    psi_c(iidx(je,jb,1),jk,iblk(je,jb,1)) )  &
         &  * ptr_patch%edges%inv_dual_edge_length(je,jb)
     ENDDO
   END DO
   !$ACC END PARALLEL
 END DO
! <SNIP>
```

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Interoperability

```
SUBROUTINE vn_adv_horizontal(
           p_vn, p_vort, p_delp_c,
           pt_patch, pt_int,
           p_ddt_vn, p_kin, p_vt,
           p_delp_v,
           opt_rlstart, opt_rlend  )
! <SNIP>
!===========================================
! Calculate the gradient of kinetic energy,
! and accumulate velocity tendency
!===========================================

 CALL grad_fd_norm( p_kin, pt_patch,
              z_tmp_e, opt_rlstart=4 )
```

Stencil is rewritten using our DSL

```
grad_norm_psi_e =
      reduce( psi_c,
              C > E,
              [1/lhat, -1/lhat] )
```

Interoperability

```
SUBROUTINE vn_adv_horizontal(
           p_vn, p_vort, p_delp_c,
           pt_patch, pt_int,
           p_ddt_vn, p_kin, p_vt,
           p_delp_v,
           opt_rlstart, opt_rlend  )
! <SNIP>
!===========================================
! Calculate the gradient of kinetic energy,
! and accumulate velocity tendency
!===========================================

 CALL grad_fd_norm( p_kin, pt_patch,
              z_tmp_e, opt_rlstart=4 )
```

Code is generated using dawn

Header

```
void grad_fd_norm_dawn(
  dawn::cell_field_t<double>& psi_c,
  dawn::edge_field_t<double>& grad_norm_psi_e,
  dawn::edge_field_t<double>& inf_edge_length);
```

Implementation

```
void grad_fd_norm_dawn(
  dawn::cell_field_t<double>& psi_c,
  dawn::edge_field_t<double>& grad_norm_psi_e,
  dawn::edge_field_t<double>& inf_edge_length)
 for(int k = 0; k < k_size; ++k) {
   for(auto const& loc : getEdges(m_mesh)) {
     for(auto inner_loc :
       grad_norm_psi_e(loc, k) = reduce(...
```

Interoperability

```
SUBROUTINE vn_adv_horizontal(
           p_vn, p_vort, p_delp_c,
           pt_patch, pt_int,
           p_ddt_vn, p_kin, p_vt,
           p_delp_v,
           opt_rlstart, opt_rlend  )
! <SNIP>
!===========================================
! Calculate the gradient of kinetic energy,
! and accumulate velocity tendency
!===========================================

 CALL grad_fd_norm( p_kin, pt_patch,
               z_tmp_e, opt_rlstart=4 )
```

Compile into library

Header

```
void grad_fd_norm_dawn(
  dawn::cell_field_t<double>& psi_c,
  dawn::edge_field_t<double>& grad_norm_psi_e,
  dawn::edge_field_t<double>& inf_edge_length);
```

*.so

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Interoperability

```
SUBROUTINE vn_adv_horizontal(
           p_vn, p_vort, p_delp_c,
           pt_patch, pt_int,
           p_ddt_vn, p_kin, p_vt,
           p_delp_v,
           opt_rlstart, opt_rlend  )
! <SNIP>
!==========================================
! Calculate the gradient of kinetic energy,
! and accumulate velocity tendency
!==========================================

 CALL grad_fd_norm_dsl( p_kin, pt_patch,
              z_tmp_e, opt_rlstart=4 )
```

Call FORTAN Interop layer

```
MODULE grad_fd_norm_dsl( p_kin,...
! Pack / transform fields for C/C++
!
CALL grad_fd_norm_dawn

!
! Unpack Fields
```

```
void
grad_fd_norm_daw
n(...
```

*.so

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