Novel Grid Capabilities in GFDL's Dynamical Core FV3

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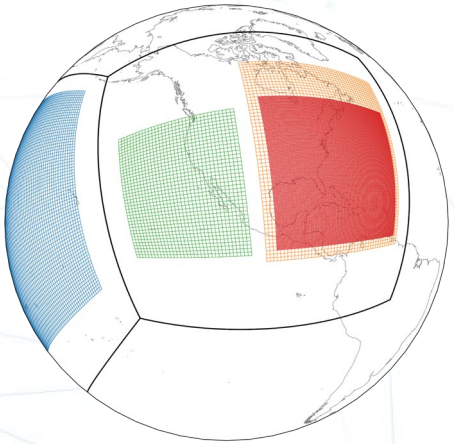
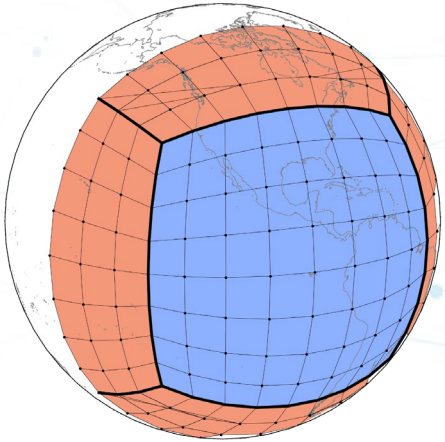
Novel Grid Capabilities in FV3

Multiple grid nesting



Duo-Grid



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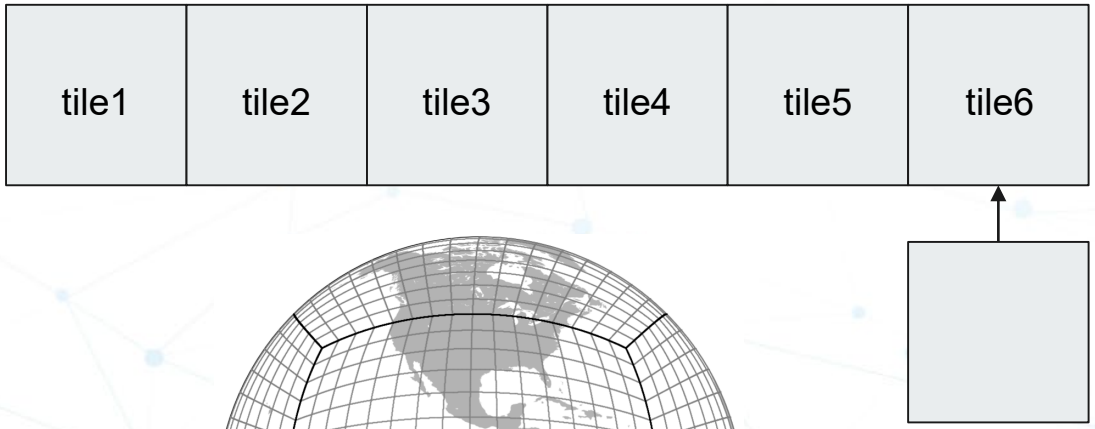
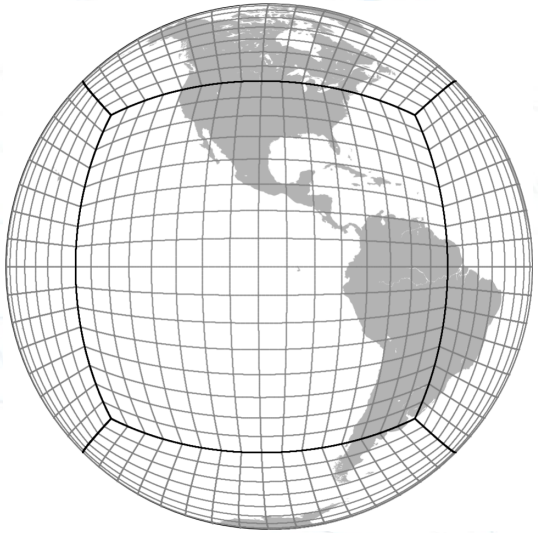
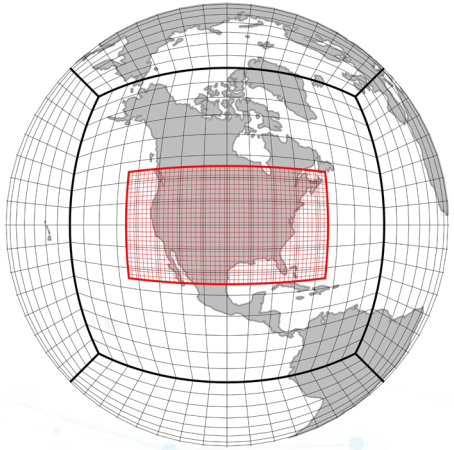
Nesting in FV3:

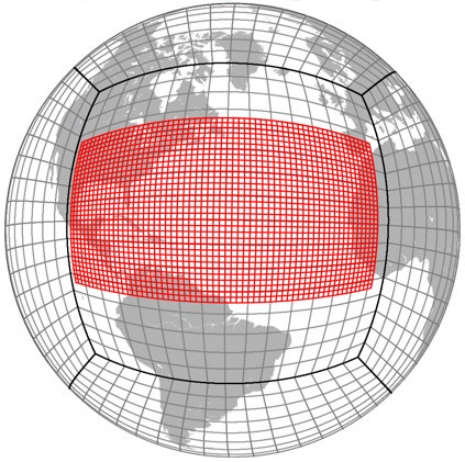




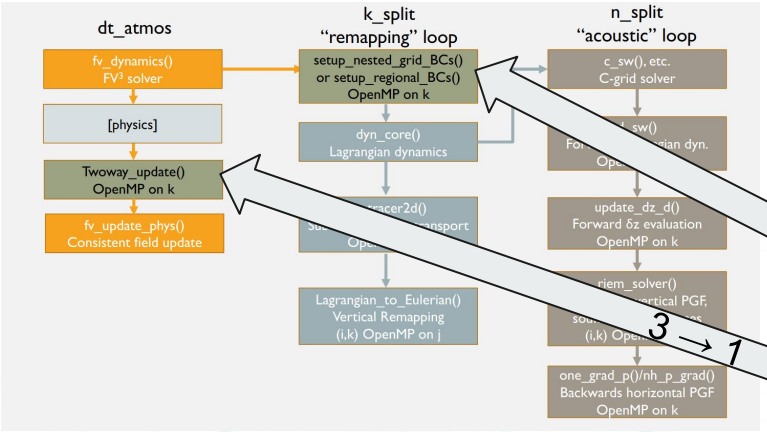
C-SHiELD: C768n5:
13-2.5km Severe Weather Prediction

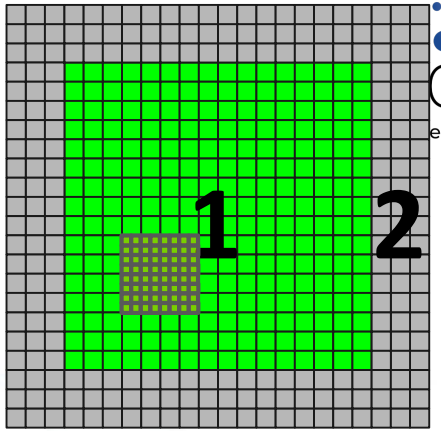


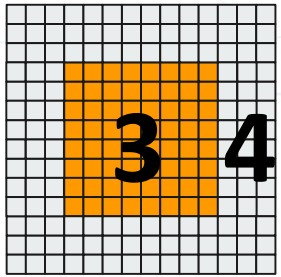
T-SHiELD: C768n4:
13-3km Tropical Cyclone



Grid nesting in FV3:





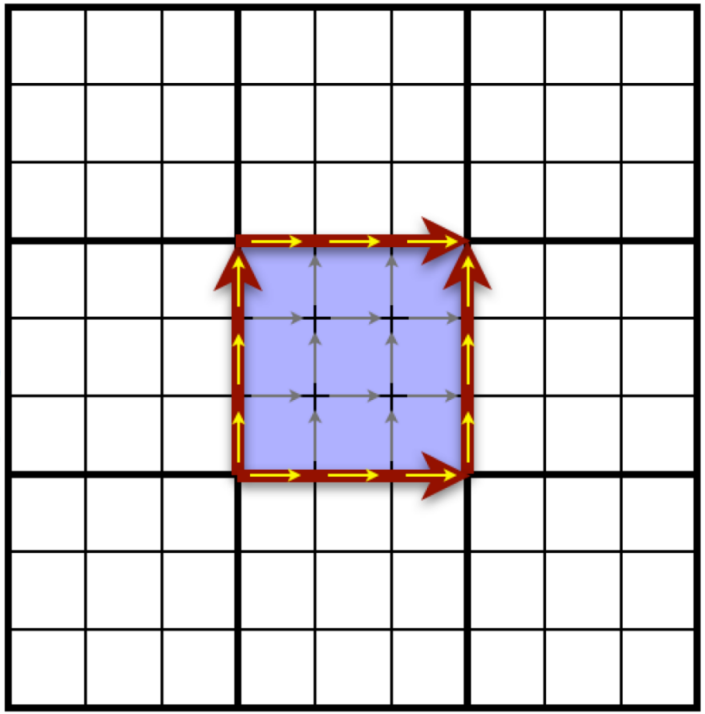


- To update nest BCs (1→ 4), <u>all variables</u> are linearly interpolated in space
- Nest BCs are also linearly extrapolated in time every acoustic timestep (n_split) then updated from the coarse grid every vertical remapping timestep (k_split)
- Each nested grid runs on a specific list of processors, allowing concurrent timestepping which eases the computational load of each grid which also has its own name list, thus, could be configured differently.
- Only the temperature and the three wind components are used for the twoway updates. Therefore, there is no violation of mass conservation during this process on the coarse grid.

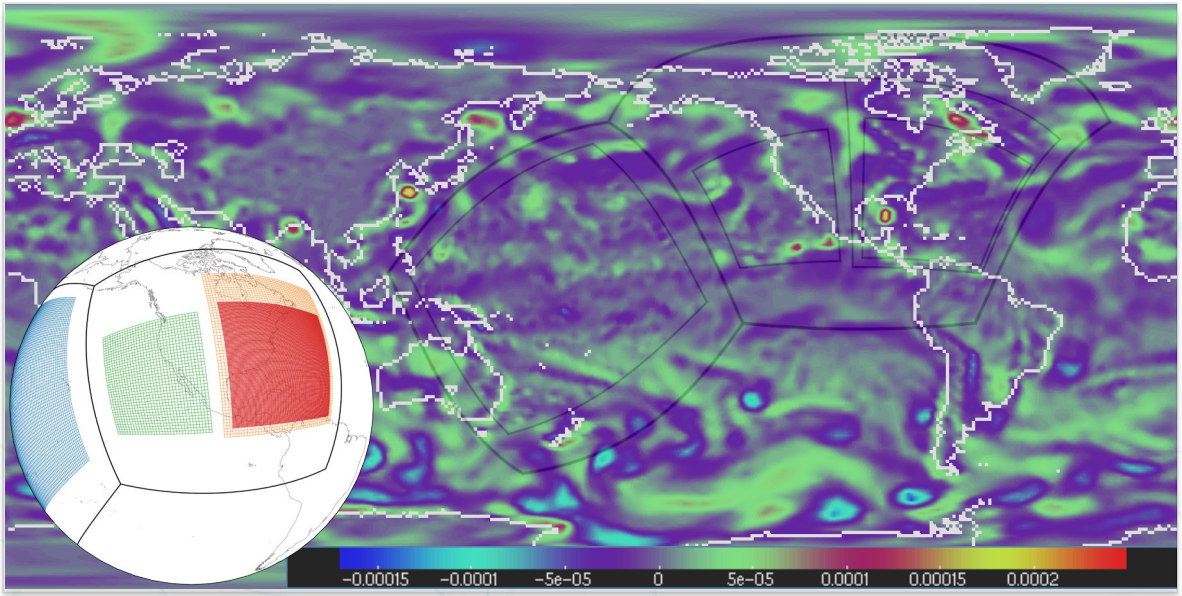
Two way updates:

- For cell-mean scalars, the value in the shaded coarse-grid cell (heavy lines) is replaced by the area-weighted average of the values on the coinciding nested-grid cells (thin lines).
- The winds tangential to this coarse-grid cell (red arrows) are updated using the length-weighted average of coinciding nested-grid cell boundaries (yellow arrows). This conserves vorticity.

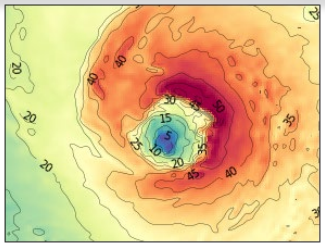
Note: Cubed-sphere grid cells are not squares. Could be applied to any non-orthogonal quadrilateral grid



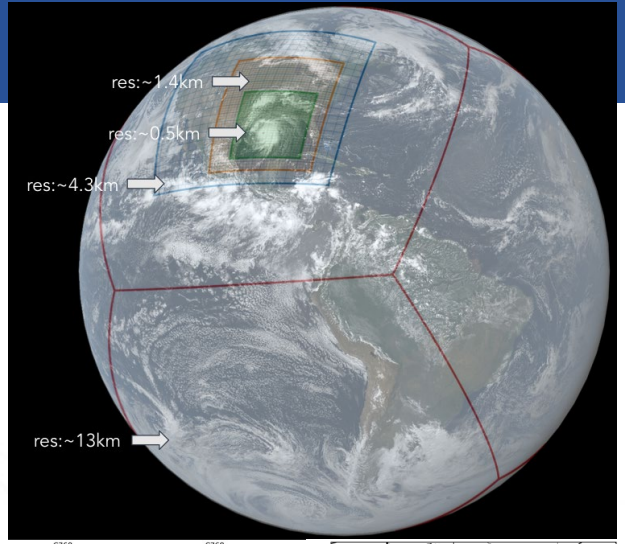
Towards kilometer -scale and eddy -scale

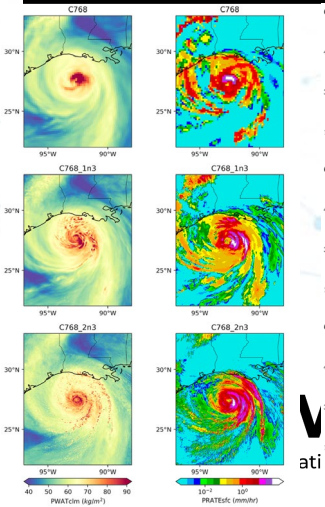


Laura 2020 at 200/50/12km

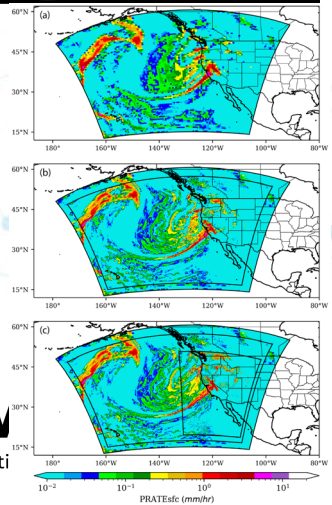


Laura at 1km taken from 13/4/1





Global-nest moisture and rainfall at 13/4/1

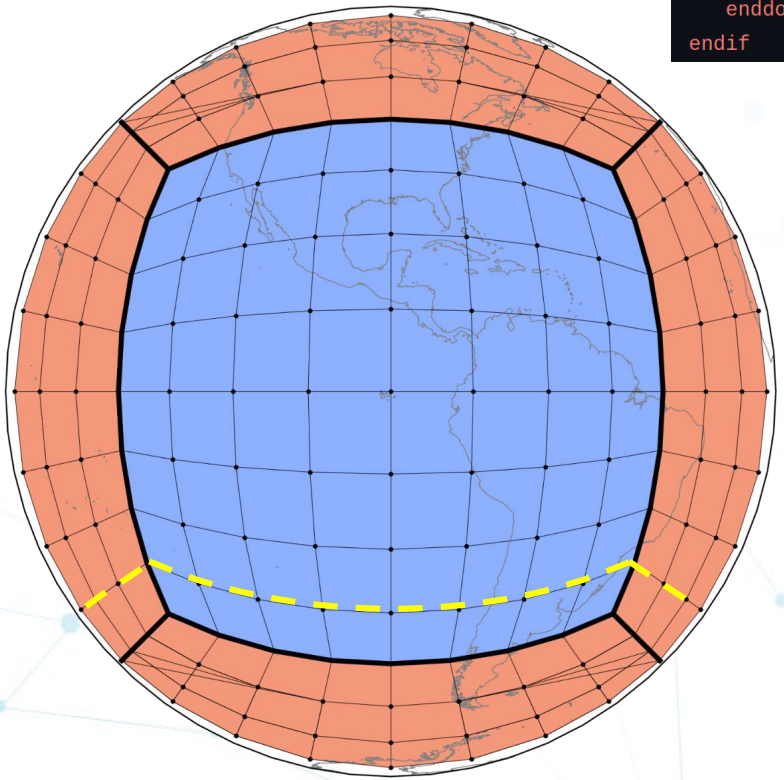


AR 2021 Regional-nest precipitation 50/17/6

Multiple same-level and telescoping nesting in GFDL's dynamical core *(Mouallem et al. 2022, GMD)*

HSUP-funded project transferred to HAFS.

Edges and corners



```
if ( (je+1)==npy ) then
   do i=is,ie+1
      vb(i,npy) = dt5*(vt(i-1,npy)+vt(i,npy)) ! corner values are incorrect
   enddo
endif
```

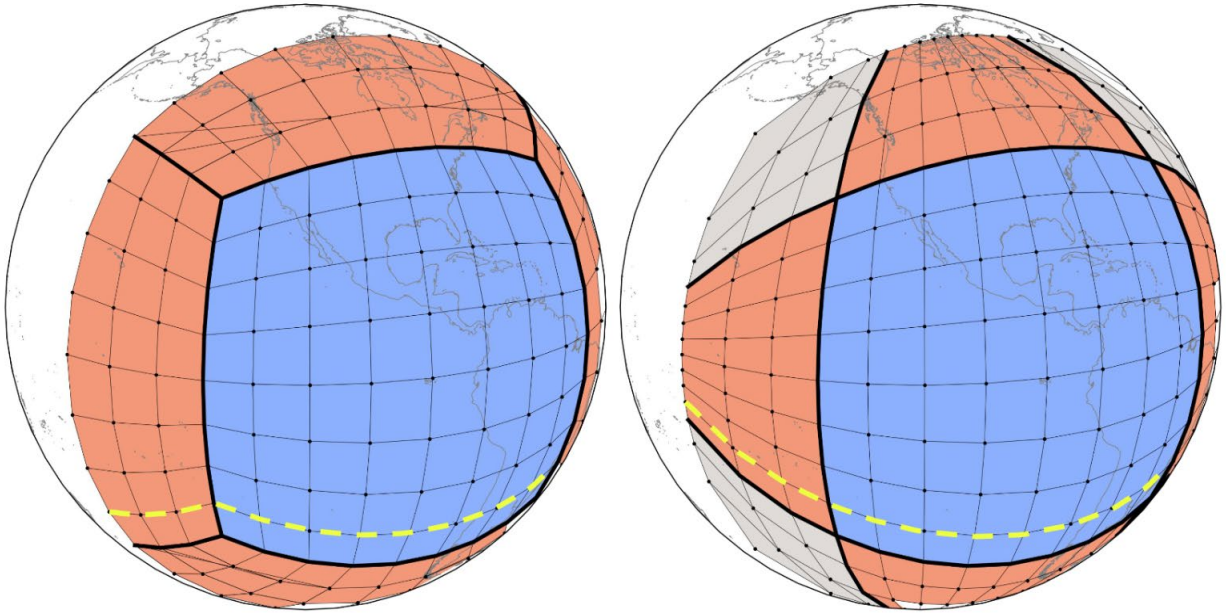
```
! East edge:
      if ( (ie+1)==npx ) then
         do j=jsd,jed
            if ( uc(npx,j)*dt > 0. ) then
               ut(npx,j) = uc(npx,j) / sin_sg(npx-1,j,3)
            else
               ut(npx,j) = uc(npx,j) / sin_sg(npx,j,1)
            endif
         enddo

          do j=max(3,js), min(npy-2,je+1)
             vt(npx-1,j) = vc(npx-1,j) - 0.25*cosa_v(npx-1,j)*   &
                           (ut(npx-1,j-1)+ut(npx,j-1)+ut(npx-1,j)+ut(npx,j))
             vt(npx,j) = vc(npx,j) - 0.25*cosa_v(npx,j)*   &
                         (ut(npx,j-1)+ut(npx+1,j-1)+ut(npx,j)+ut(npx+1,j))
          enddo
      endif
```

```
if ( se_corner ) then
     i = npx
     ke(i,1) = dt6*( (ut(i,1) + ut(i,  0)) * u(i-1,1) + &
                     (vt(i,1) + vt(i-1,1)) * v(i,  1) + &
                     (ut(i,1) - vt(i-1,1)) * u(i,  1) )
endif
```

```
if ( fill_c ) call fill_corners(divg_d, npx, npy, FILL=XDir, BGRID=.true.)
```

Kinked Grid

Extended Grid



- Continuous integration along great circle lines => No other edge/corner handling code is required!
- The halo remapping algorithm and Duo extension are directly implemented into tiles' halo update message passing calls.
- Minimize data movement on CPU/GPU hybrid systems
  => Stepping stone for future FV3 developments on GPUs

Mouallem and Harris (under review)

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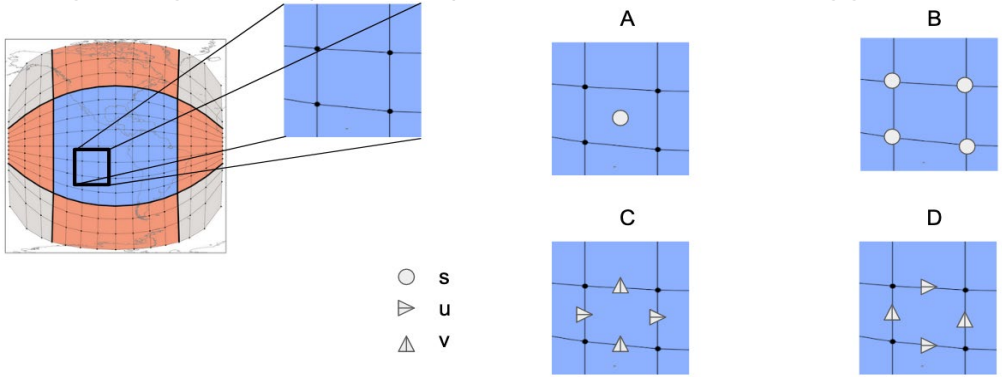
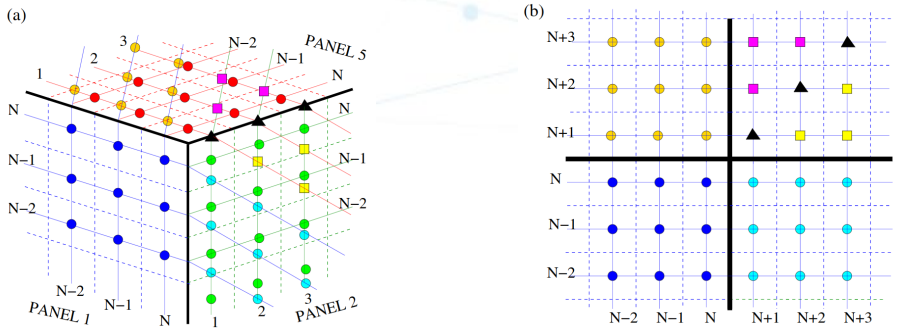
Challenges

- Extend the non-staggered LMARS duo grid algorithm (Xi, 2020) to support all FV3 staggered/unstaggered variables

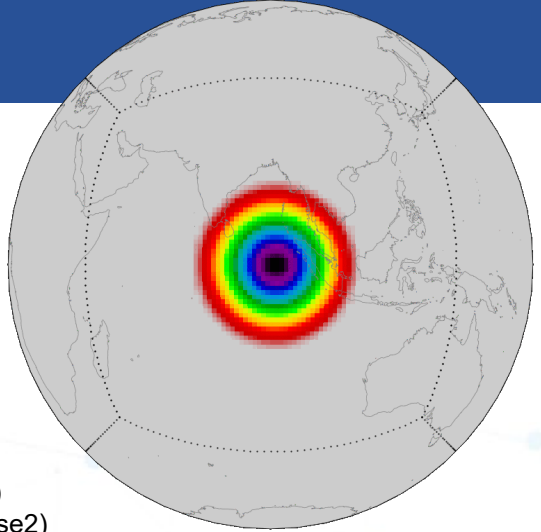


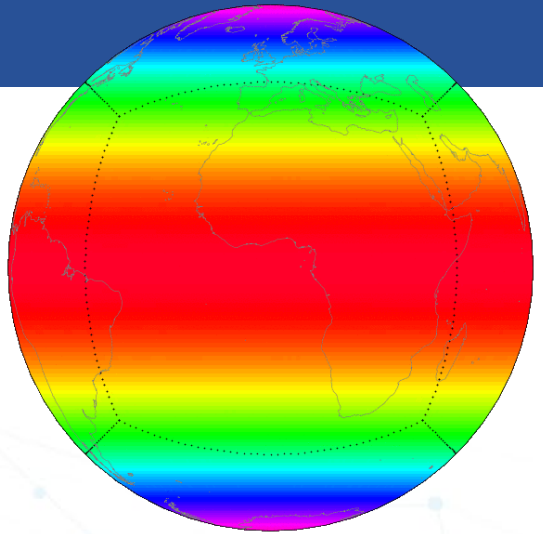
- Implement a corner handling algorithm (ZA et al., 2022) since the 2D FFSL transport scheme reaches the corner region



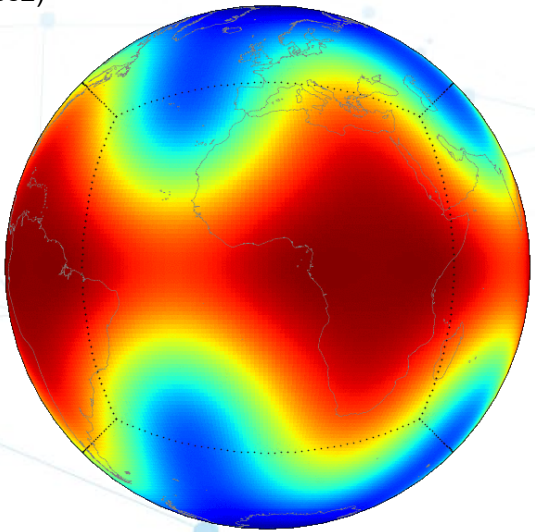
- Break down complex and optimized subroutines (such as d_sw) to apply flux averaging on different components used to assemble the time advanced quantities

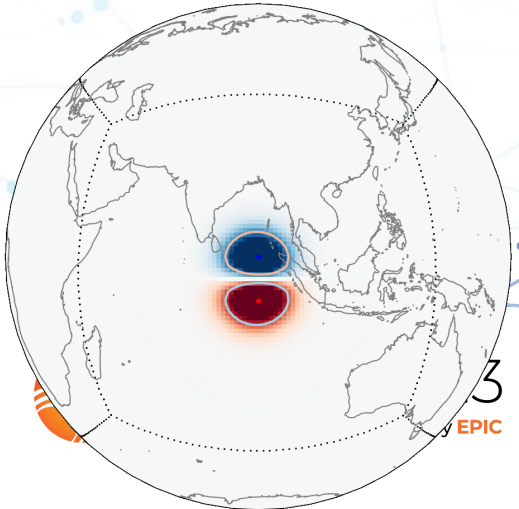
SW Results





- Advection of a cosine bell (case1)
- Steady state geostrophic flow (case2)
- Rossby wave (case6)
- Colliding modons





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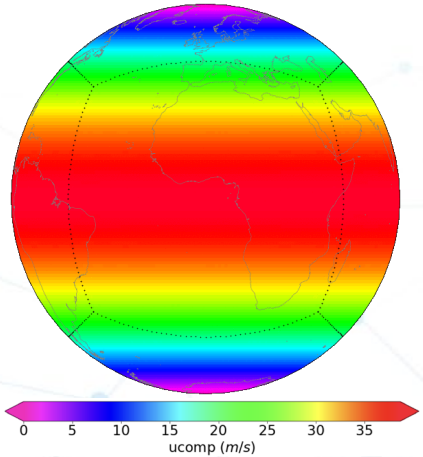
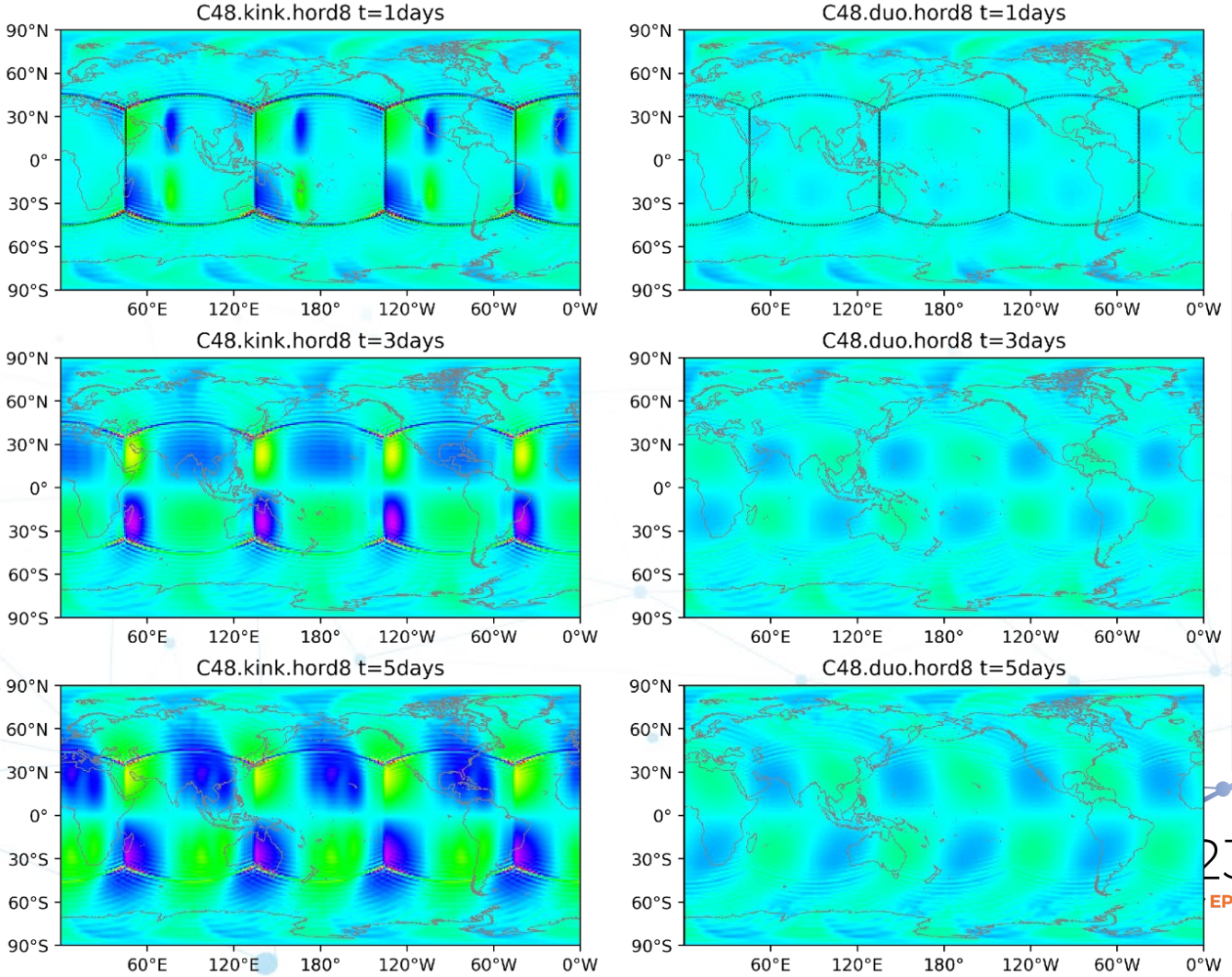
Case 2

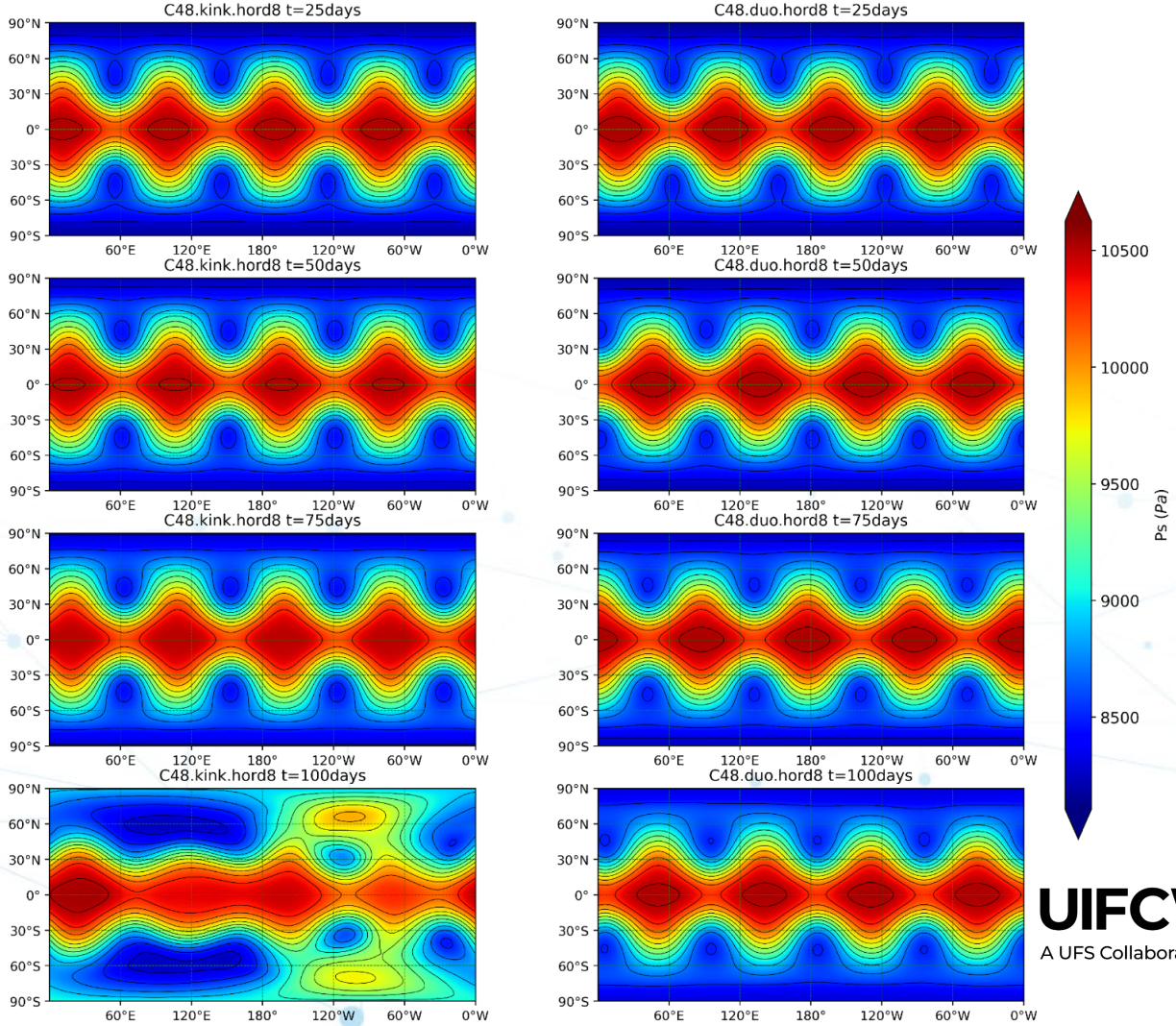
Geostrophic balance flow





Case 6

Rossby-Haurwitz wave



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Baroclinic wave (Case 13)

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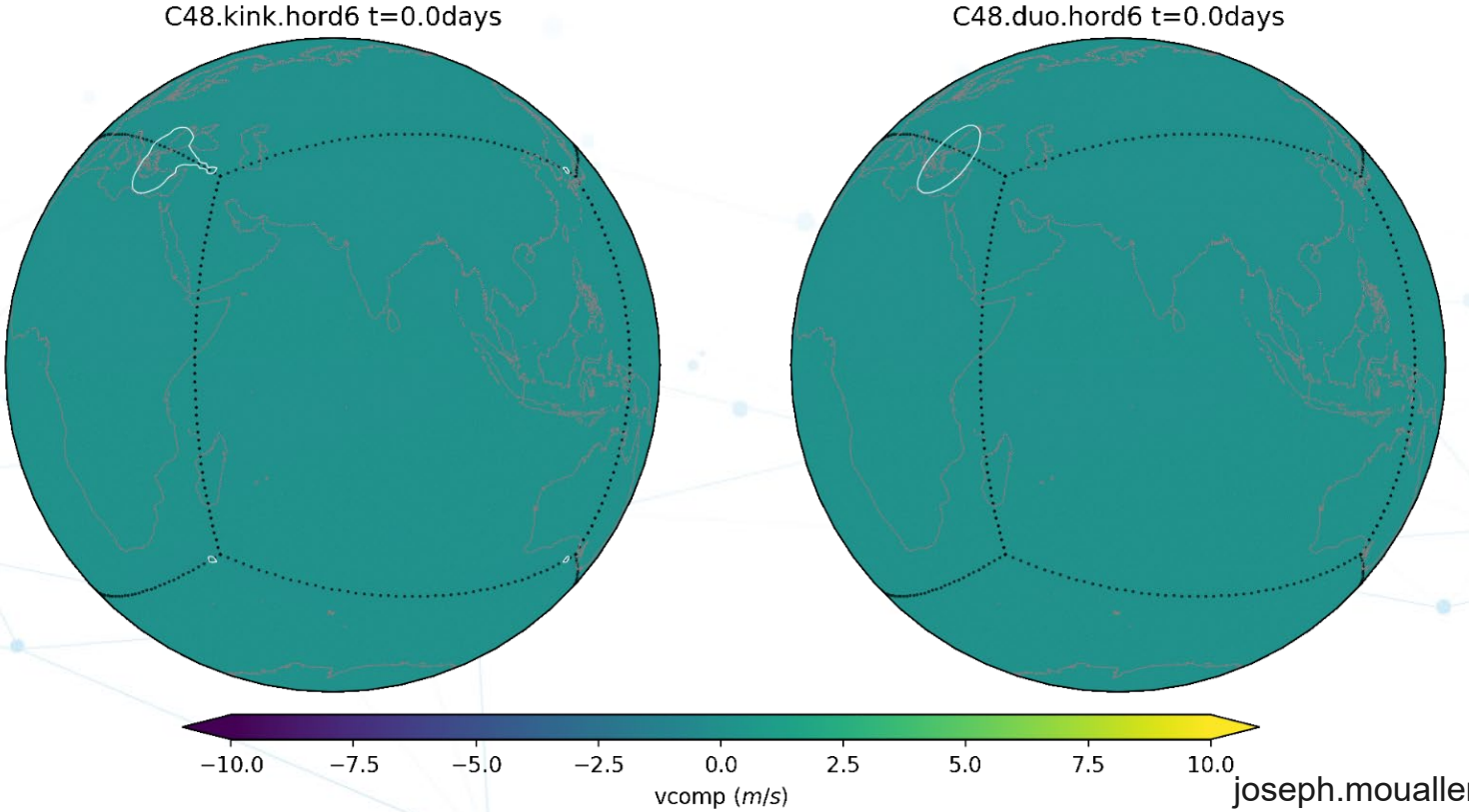

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