Mimetic postprocessing for LFRic

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LFRic Melbourne Workshop 20-23 Feb 2018

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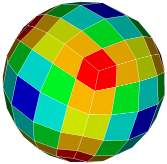
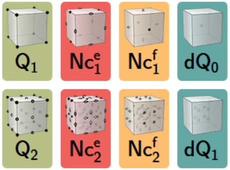
Why we need to worry about pre-/post-processing

Not business as usual

1. GungHo's horizontal grid is unstructured. Iris handles structured grids only.
2. Grid cells are non-orthogonal. Watch out for code that implicitly assumes orthogonality.
3. Fields are on nodes, edges, faces and cells (mixed finite elements) $\rightarrow$ UGRID fields.
4. Support for high order finite elements. There is no standard!





Mimetic discretization impacts many areas of pre- and post-processing

- Regridding/remapping
  - Scientists want to see results in lat-lon space
- Visualization
  - E.g. streamlines need to compute the velocity
- Transport of tracers
  - Langragian formulation $\equiv$ interpolate field at previous position
- Computation of fluxes

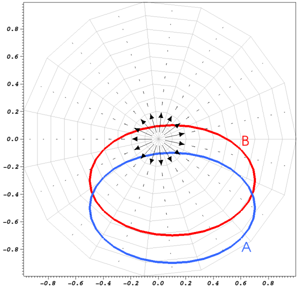
All the above need interpolation in one form or another

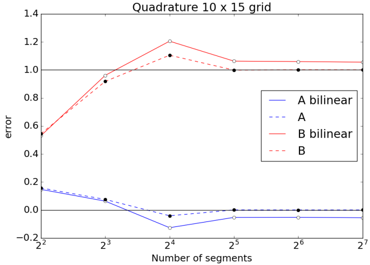
The price of not doing it right

- Regridding/remapping: Cannot compare models, cannot interface, etc.
- Visualization: Cannot debug, community cannot see the benefits of the GungHo approach
- Transport of tracers: Lack of conservation
- Computation of fluxes: Spurious inaccuracy

Example 1: Getting fluxes right

Using W_1 finite elements as interpolating functions returns the correct flux whilst a nodal interpolation an error dependent on the grid resolution and the number of segments.

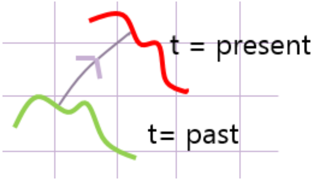




Example 2: transport (advection) of fields

$\partial_t + \mathcal{L}_v$ takes many forms but all these cases can be handled by the same interpolation procedure

- $\partial_t + v \cdot \nabla \star$ for nodal fields
- $\partial_t + (\nabla \times \star) \times v + \nabla(v \cdot \star)$ for edge fields
- $\partial_t + \nabla \times (\star \times v) + \nabla \cdot (v \cdot \star)$ for face fields
- $\partial_t + \nabla \cdot (v \star)$ for cell fields

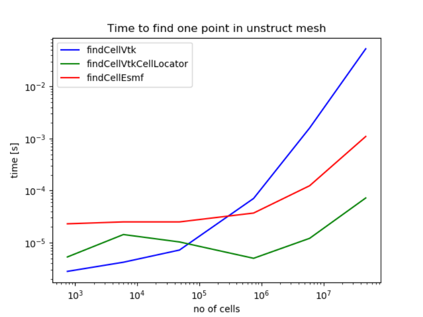


Results

Comparing software for locating a cell

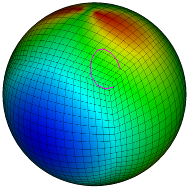
All interpolation methods need to quickly locate cell containing a point

- findCellVtk: VTK method vtkUnstructured
- findcellEsmf: ESMF software
- findCellVtkCellLocator: octree based search. Search time is nearly independent of grid size!. Average number of cells per bucket is 100.

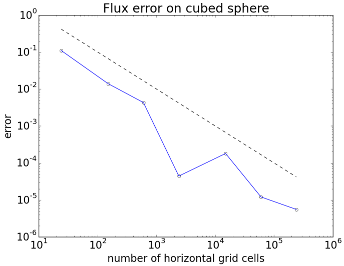


Proposed approach works on the cubed-sphere

- Test $v = \nabla\psi \times \nabla r$; ψ : analytic stream function of lat-lon
- Flux only depends on start/end points. Zero error if start/end points fall on nodes
- Some cells have 120 deg angle between edges



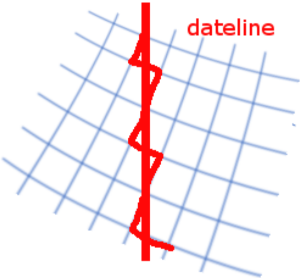
Integration path/surface



Error is $\sim h^2$

Problem of dateline when using lat-lon coordinates so ended up using Cartesian coordinates

- Dateline cannot cross cells
- Jagged dateline
- Cell at the pole has a cut



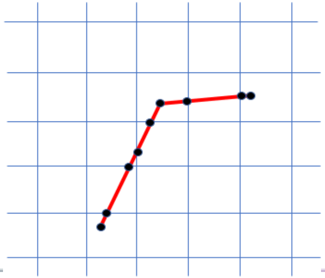
Recommended work plan

Step 1: develop a standalone mini-app that takes a collection of points and returns cells and barycentric coordinates for each cell

- Necessary step for interpolation
- The only step need to do nodal interpolation
- Can use off the shelf software (e.g. VTK)
- Does not depend much on other developments (can proceed in parallel)
- Could work with scientist who needs the work

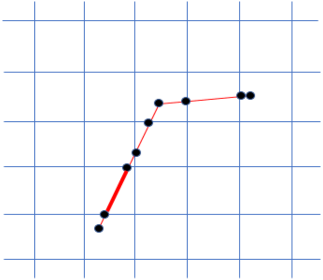
Step 2: compute the collision of source and target grids

- Requires step 1 to be completed
- Result is a map of target elements $\rightarrow$ set of source grid elements and parametric coords
- Custom code (?), API (?)



Step 3: evaluate the interpolation weights/integrals

- Requires step 2 to be completed
- Fairly straightforward but laborious for high order finite elements
- Exact!



Goal is to apply the rigour of dynamical cores to pre- and post-processing tools. Overtime we expect the distinction between dynamical core and pre-/post-processing to diminish.

Thank You

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