Various issues for fine-scale algorithms

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Issues

- Flexible geometry required
  - Unstructured grid
  - Grid generation
- Low Mach number flows
  - ‘Incompressible’ algorithm with elliptic solver
  - Conservation form not mandatory
    - Conservation required anyway?

Unstructured grids

- Finite volume or finite element
  - Compatibility with elliptic solver
  - Ability to represent state of rest in hydrostatic balance

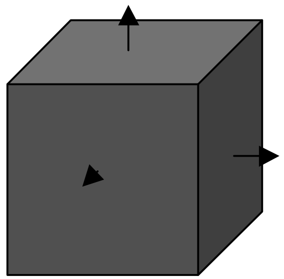
The latter rules out many engineering finite elements, including many with different polynomial interpolations for pressure and wind.

Compatibility with elliptic solver

Need compact stencil for pressure solver to avoid computational modes.

On regular finite difference grid get the 3-dimensional ‘C’ grid.

On unstructured mesh, need to hold normal velocity components at centroids of interfaces.



Alternative is to hold velocity potential at cell centres, with rotational part treated separately.

Conservation issues

- Conservation mandatory for high-speed flows, not the case here.
- Conservation of mass/ thermodynmaic quantities/moisture/tracers achievable with finite volume scheme and Galerkin finite element scheme.

Semi-lagrangian

- Semi-Lagrangian timestep advantage not relevant.

  no pole or polar night jet, accuracy requires CFL<1

- Semi-Lagrangian preserves Lagrangian parcel properties accurately.

  important for predicting phase changes/ reaction rates

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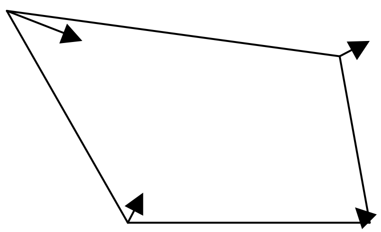
SL+conservation

- Problem with schemes which are genuinely multidimensional and compatible with elliptic solver.
- Prediction of evolution of control volume requires ‘cross-stream’ averaging.



Possible option

- Can achieve more conservative behaviour, but not formal conservation, with Eulerian discretisation of Lagrangian continuity equation.

$$\rho_a = \rho_d J$$

$$(\rho\theta)_a = (\rho\theta)_d \, J$$

$$J = \frac{\partial(x_d, y_d, z_d)}{\partial(x_a, y_a, z_a)}$$

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Semi-implicit options

- UM has to treat gravity waves implicitly, as well as sound waves
- Requires semi-implicit treatment of thermodynamic equation.
- Forces use of Eulerian form of continuity equation (but this gives exact mass conservation).
- More choices in fine-scale; as only sound waves have to be treated implicitly.

Solver issues

- Flexible geometry and variable coefficients will require solver for unsymmetric system.
- Met Office UM uses GCR(k).
- Flexible and general purpose.
- Key to success is preconditioning, as in other low-speed flow applications.

