Overset Mesh Capability for BUB3D-RB

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DOD HPC MODERNIZATION PROGRAM

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Outline

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BUB3D-RB

SUGGAR

DiRTlib

Overset mesh implementation

Applications

- Sinking slab
- Buoyant cube surfacing

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Introduction

BUB3D-RB

- Only USN owned CFD code (Fortran) for Underwater Launch Analysis
  - Air-water interfaces / free surfaces
  - Wave dynamics
  - Cavitation
  - Bubble migration
  - Gas generation/bleed
  - Shallow depth explosion plumes
- 3DOF rigid body dynamics
  - Horizontal and vertical translation
  - Pitch

BUB3D-RB

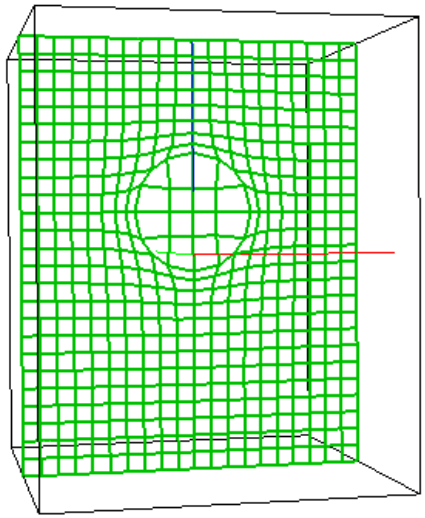
Inviscid Incompressible Generalized Hydrodynamic code

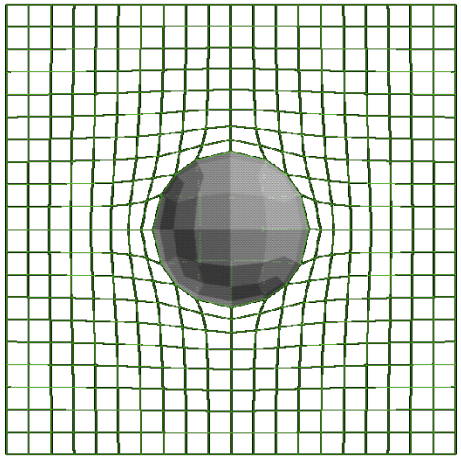
- Coordinate system attached to the rigid body
- Structured generalized curvilinear coordinate grid
- Time-split scheme
  - Mass & momentum convection (MUSCL)
  - Mass & momentum redistribution; Poisson equations for intermediate density and velocities (CICPCG)
  - Bubble update (merge, split, gas generation/bleed)
  - Virtual mass and rigid body accelerations
  - Pressure projection

BUB3D-RB

Mesh Capability

- Integrated Mesh Generation
- Limited to one (1) grid
- Mesh Conformal to Interior Boundaries
- Interior Solid BCs through “blocked cells”
- “Platform” and “Launch Tube” boundaries





Overset Mesh Capability

Enhancements

- Multiple meshes
    - Currently limited to 2 meshes, 1 moving
- Potential for Improved Geometric Flexibility
- Potential for Improved Motion Simulation

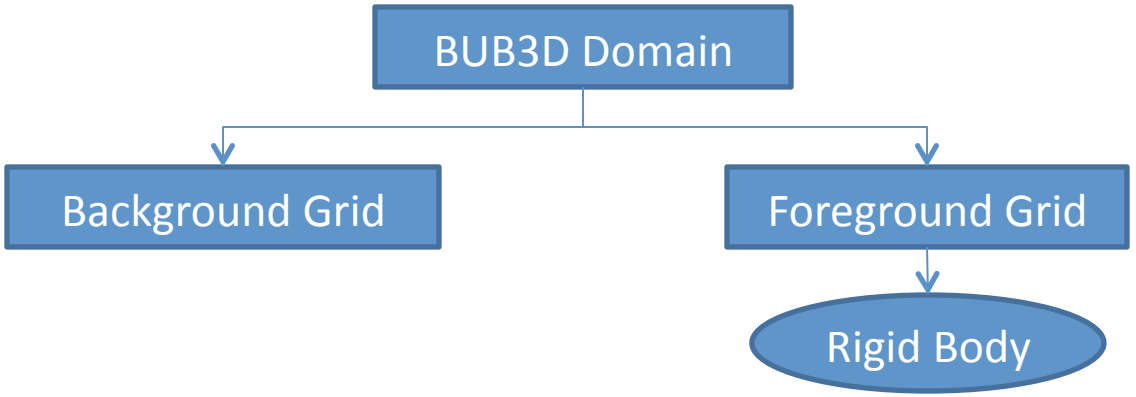
Modifications to I/O

- Modified mesh input file format
- Modified BUB3D input file to accommodate multiple meshes with associated boundary conditions and rigid body information
- Developed output routines for grid and flow visualization in plot3d format (at nodes) and for use with matplotlib (at cell centers)

SUGGAR

Structured, Unstructured & Generalized Grid AssembleR

- "Cuts holes" around the rigid body
- Defines interpolation stencils for information passing
- DCI file contains a list of field, out, fringe and orphan locations for all meshes
- Hierarchical organization of domain through XML input



DiRTlib

Donor Interpolation Receptor Transaction library

Call-back model

- Developed module of DiRTlib interface functions
  - Eases access to BUB3D data structures
  - Gathers data from the solver arrays
  - Interpolates donor values
  - Sends/Receives donor values
  - Distributes donor values to receptors
- Module is called at every time-step in order to load the updated DCI file

Overset mesh implementation

Data structure modifications

- Array dimensions extended to accommodate multiple grids
- Fortran module defined variables sent to DiRTlib

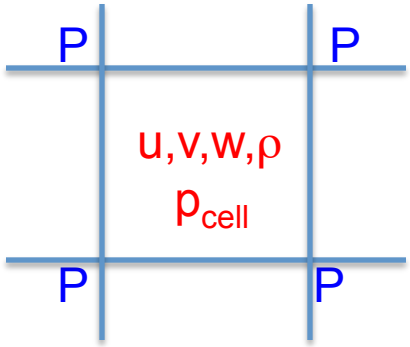
Flow control modifications

- Introduced a mesh loop, solver subroutines are called for each mesh; bubble effects applied after convection step and before pressure projection
- Global coordinates of the foreground grid are calculated at every time-step for interpolation and visualization purposes
- Time synchronization between meshes after convection step: time-step $\tau = \min(\tau_{\text{mesh } j})$

Overset mesh implementation

Information passing

- DiRTlib set to cell centered variables
- Pressure interpolated from nodes to cell centers and back

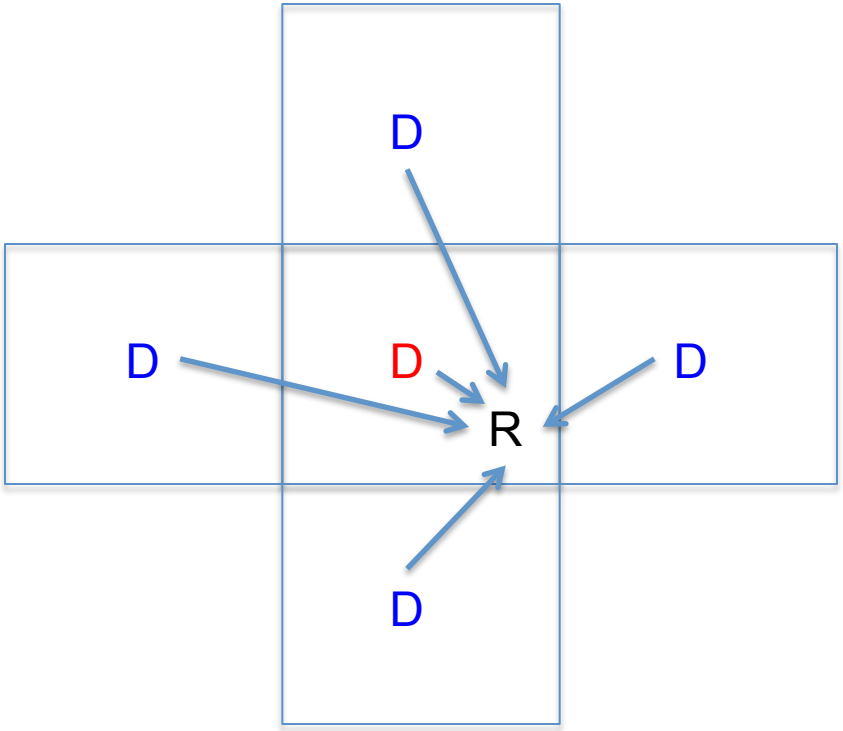


- Solver still calculates vector quantities within each mesh in the local, attached system.
- Transformation of foreground (moving) velocity and coordinates to the background (stationary) system is required

Overset mesh implementation

Interpolation methods

- Nearest donor (or zero order)
- Inverse distance, p=3 $$w_i(\vec{x}) = \frac{1}{|(\vec{x} - \vec{x}_i)|^p \sum_j w_j}$$



Application: sinking slab

Slab properties

- Dimensions (ft): 0.4x0.4x2.0 (x,y,z)
- Mass (lbm): ~40
- Initial depth (ft): 100
- Initial orientation: ~5^{o} off vertical

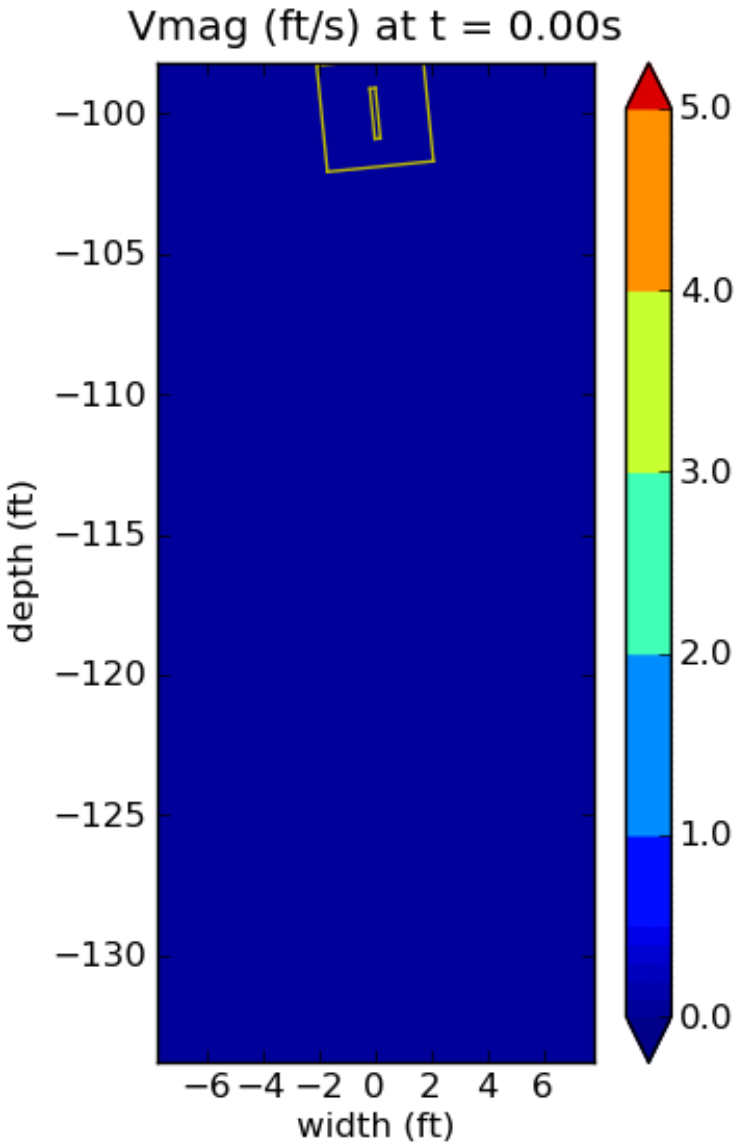
Foreground mesh

- Dimensions (ft): 4x4x4 (x,y,z)
- Resolution (ft): 0.2

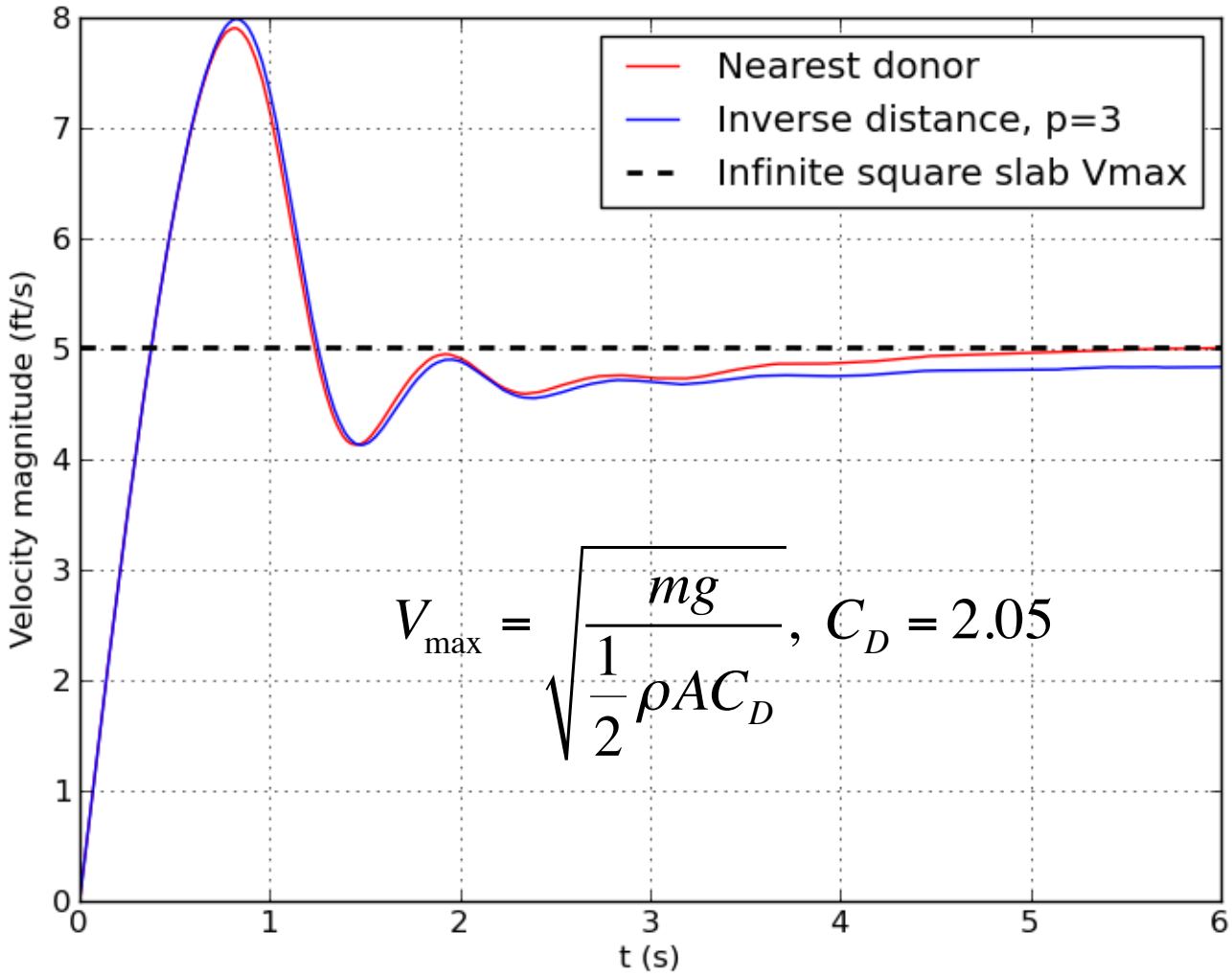
Background mesh

- Dimensions (ft): 16x8x36 (x,y,z)
- Resolution (ft): 0.4

Results: sinking slab



Results: sinking slab



$$V_{\max} = \sqrt{\frac{mg}{\frac{1}{2}\rho A C_D}}, \; C_D = 2.05$$

Application: buoyant cube surfacing

Cube properties

- Dimensions (ft): 0.8x0.8x0.8 (x,y,z)
- Mass (lbm): ~20
- Initial depth (ft): 6
- Initial orientation: vertical, in launch tube

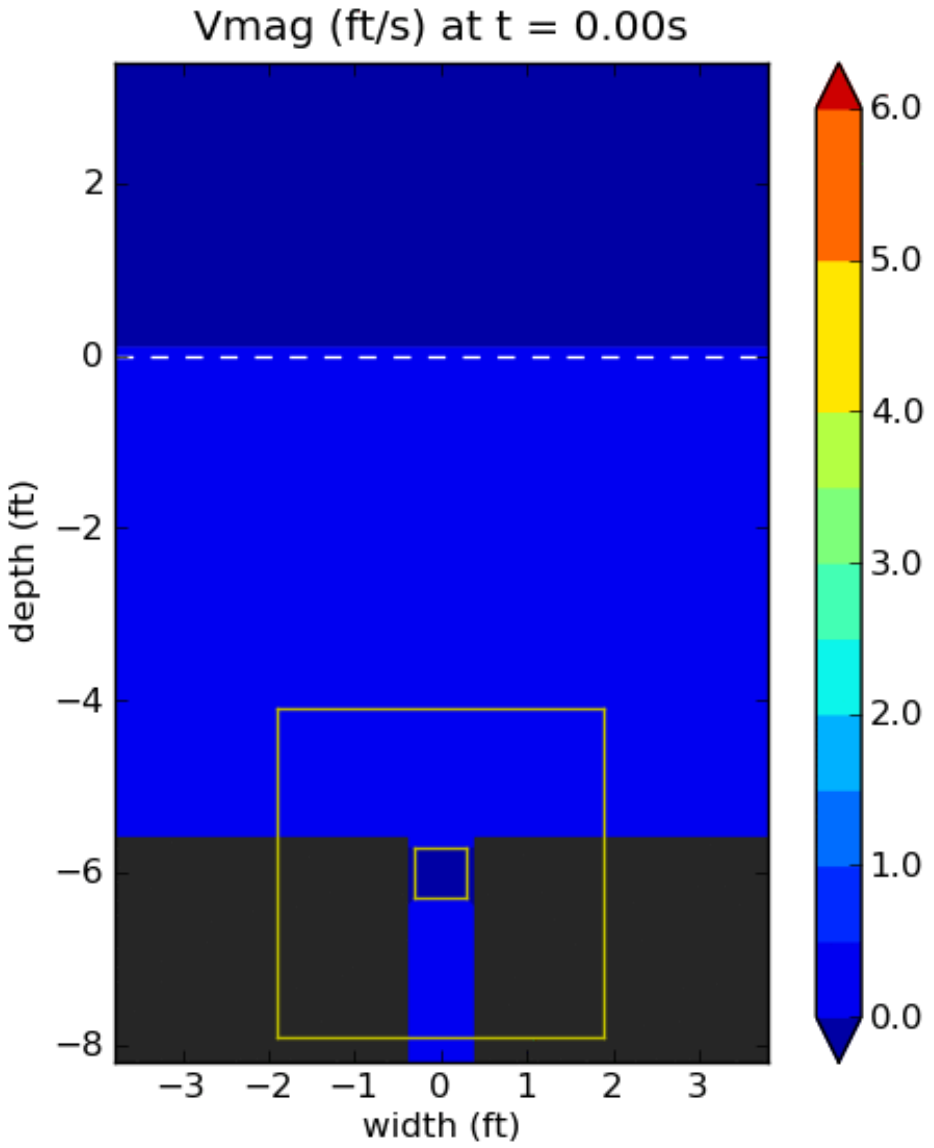
Foreground mesh

- Dimensions (ft): 4x4x4 (x,y,z)
- Resolution (ft): 0.2

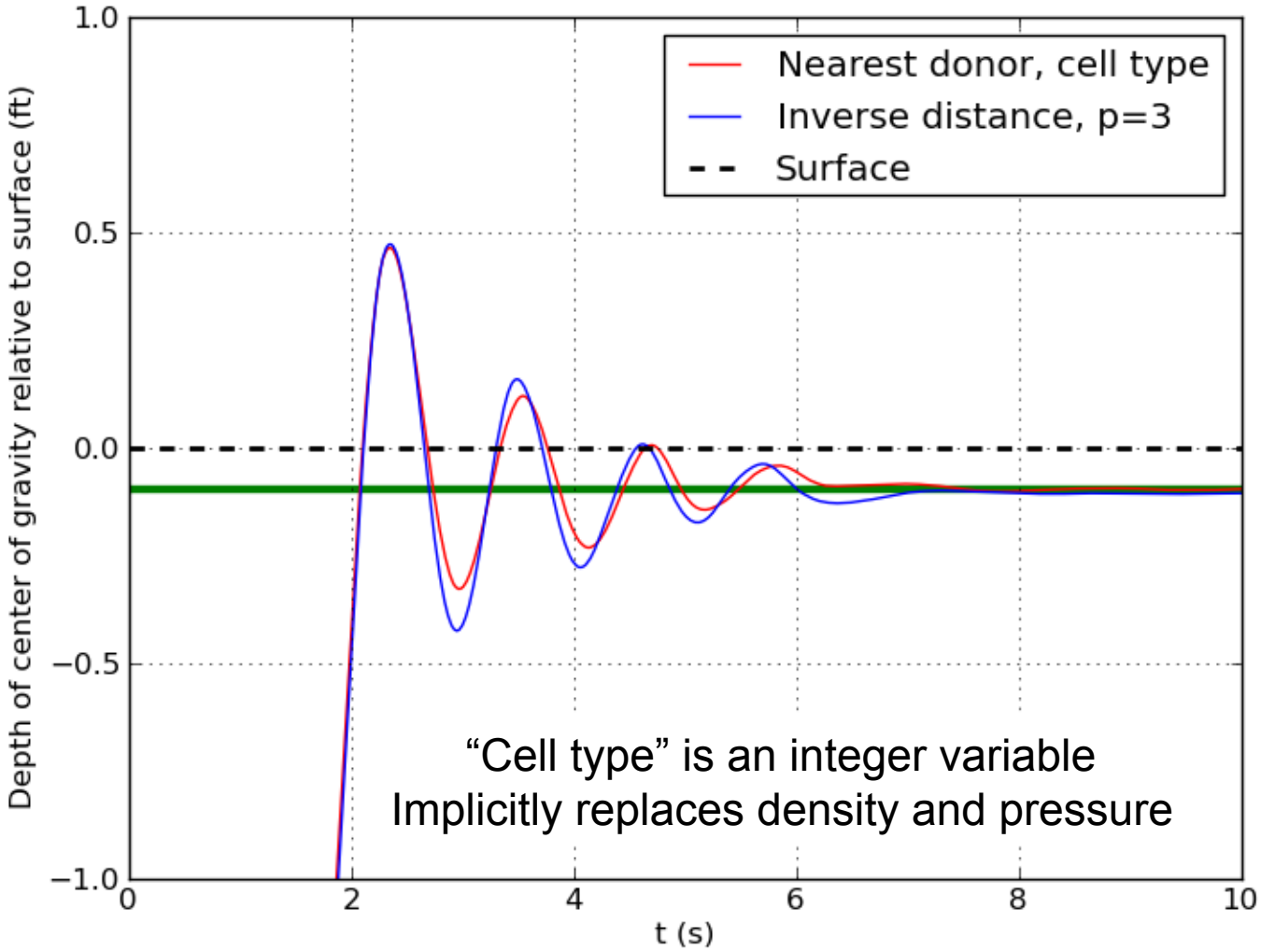
Background mesh

- Dimensions (ft): 8x8x12 (x,y,z)
- Resolution (ft): 0.2

Results: buoyant cube surfacing



Results: buoyant cube surfacing



Conclusions

Overset Mesh capability was added to BUB3D-RB

- Currently accommodates single moving grid
- Extension is straight-forward

Information passed correctly between meshes

- In the presence of air-water interfaces passing of the "cell type" variable, rather than density and pressure appears to improve behavior

Different interpolation techniques compared

- Nearest donor
- Inverse distance method

Future Work

Further Enhancements Needed to address General Underwater Launch Scenarios

- Separation of Flow Solver and Mesh Generator
- Allow Multiple Overset Grids with Possible Multi-block Grids
- Dynamic Coupling with Grid Assembler
- Full, 6DOF Motion
- Parallel Execution

Acknowledgement

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