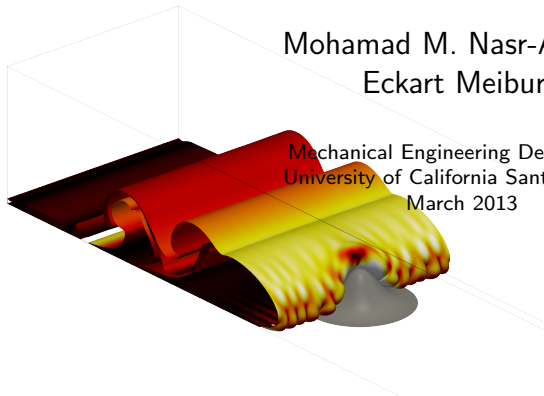


Introduction to TURBINS

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engineering

What is TURBINS?

- **TURB**idity currents via **I**mmersed-boundary **N**avier-**S**tokes
- Three-dimensional DNS parallel solver
- C-code using MPI-based parallelism
- Solves density-driven currents: particles, salinity, temperature gradients
- Can handle any complex topography
- TURBINS-2D: only serial

Nasr-Azadani, M. M. and Meiburg, E. (2011), *Computers & Fluids* 45 (1), 14-28.

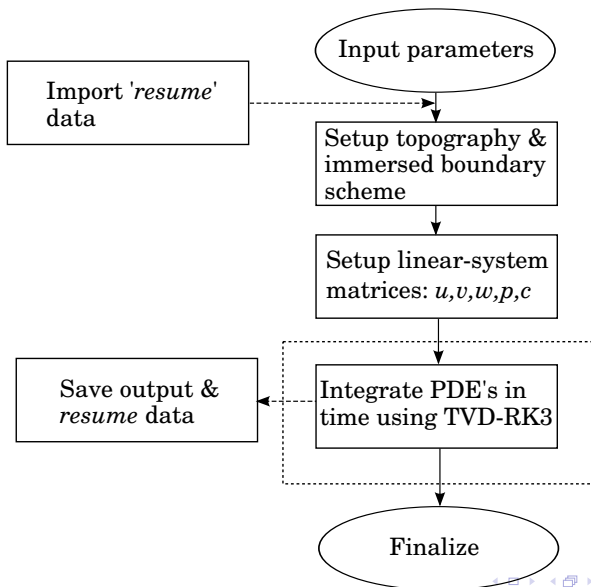
Numerical method

- Viscous terms: Implicit second-order finite difference scheme
- Convective terms: Third-order ENO
- Time integration: Third-order TVD Runge-Kutta method
- To impose a divergence-free velocity field: A fractional projection method
- Complex topography: Immersed boundary method with direct forcing

TURBINS: requirements

- PETSc (<http://www.mcs.anl.gov/petsc/>)
- HyPre (<http://acts.nersc.gov/hypre/>)
- MPICH (or any compatible MPI-package)
- ParaView (or Visit) for visualization (post-processing stage)

Code components



Time integration flowchart

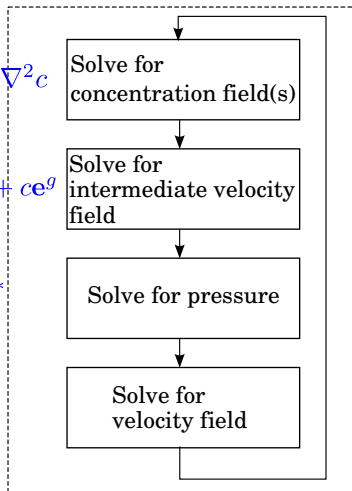
$$\frac{\partial c}{\partial t} + (\mathbf{u} + u_s^i \mathbf{e}^g) \cdot \nabla c = \frac{1}{Pe} \nabla^2 c$$

$$\frac{\partial \mathbf{u}^*}{\partial t} + \mathbf{u}^* \cdot \nabla \mathbf{u}^* = \frac{1}{Re} \nabla^2 \mathbf{u}^* + c \mathbf{e}^g$$

$$\nabla^2 \phi = \frac{1}{\Delta t} \nabla \cdot \mathbf{u}^*$$

$$\frac{\mathbf{u} - \mathbf{u}^*}{\Delta t} = -\nabla \phi$$

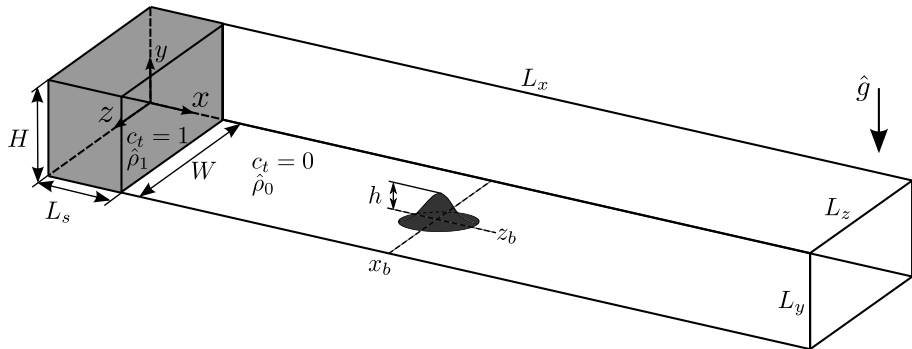
TVD-RK sub-step



Post-processing

- Raw-binary data is saved during simulation runtime
- A data-converter is run separately to convert data into VTK format
- VTK format can be visualized in: **ParaView** and **Visit**
- Other data analysis: simply use MATLAB, Python, etc

General setup: lock-exchange configuration



Input parameters

- Basic information should be passed to TURBINS via **input.inp**
- Several fine-tuning parameters should be set in **Input.c**
- Bottom topography should be described in **Grid.c**, function **Grid_describe_interface(...)**

Input parameters: example 'input.inp'

```
*****
*****1-Geometrical Parameters:*****
Number of Cells in x-direction:
50
Number of Cells in y-direction:
30
Number of Cells in z-direction:
5
Minimum x:
0.0
Maximum x:
5.0
Minimum y:
0.0
Maximum y:
1.5
Minimum z:
0.0
Maximum z:
0.1
*****
*****2-Grid:*****
Is X-Grid Uniform (YES/NO)?:
YES
Is Y-Grid Uniform (YES/NO)?:
YES
.
```

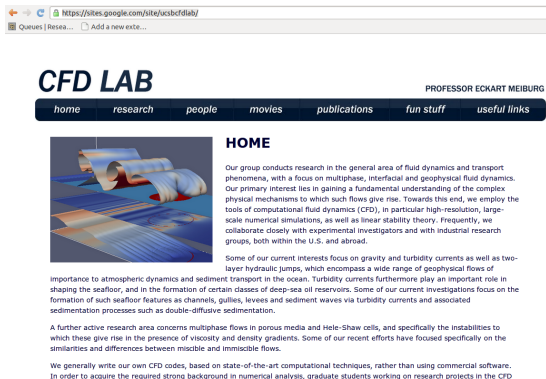
```
Is Z-Grid Uniform (YES/NO)?:
YES
Import Grid From File (YES/NO)?:
NO
*****
*****3-Flow Parameters:*****
Reynolds Number:
2200.0
Number of Concentration Fields:
1
Peclet Number(s):
2200.0
Initial Maximum Volume Fraction of Each Concentration Field:
1.0
Particle Settling Velocity(ies)(in y-direction):
0.02
Physical Particle Volume Fraction(s):
0.0
*****
*****4-Runtime Parameters:*****
Maximum Simulation Time:
35.0
Saving Output Results Time-Step:
0.2
*****
*****5-Lock Parameters:*****
Initial x Position of Lock:
1.0
```

Acknowledgment

- Dr. Brendon Hall
- PETSc team
- CSDMS: Beach, Janus supercomputing facility

Contact

- TURBINS is a research code: still evolving
- Contact me for installation, job submission and more
mmnasr@engineering.ucsb.edu
- Check CFD-lab website for more updates
<https://sites.google.com/site/ucsbcfdlab/>



The screenshot shows the homepage of the UCSB CFD Lab website. At the top, there is a navigation bar with links: home, research, people, movies, publications, fun stuff, and useful links. Below the navigation bar is a large image of a turbulent flow simulation. To the right of the image is the heading "HOME" and a paragraph of text about the group's research focus. Below the paragraph is another paragraph about current interests. At the bottom, there is a paragraph about the group's research area and a footer with contact information.

CFD LAB

PROFESSOR ECKART MEIBURG

home research people movies publications fun stuff useful links

HOME

Our group conducts research in the general area of fluid dynamics and transport phenomena, with a focus on multiphase, interfacial and geophysical fluid dynamics. Our primary interest lies in gaining a fundamental understanding of the complex physical mechanisms to which such flows give rise. Towards this end, we employ the tools of computational fluid dynamics (CFD), in particular high-resolution, large-scale numerical simulations, as well as linear stability theory. Frequently, we collaborate closely with experimental investigators and with industrial research groups, both within the U.S. and abroad.

Some of our current interests focus on gravity and turbidity currents as well as two-layer hydraulic jumps, which encompass a wide range of geophysical flows of importance to atmospheric dynamics and sediment transport in the ocean. Turbidity currents furthermore play an important role in shaping the seafloor, and in the formation of certain classes of deep-sea oil reservoirs. Some of our current investigations focus on the formation of such seafloor features as channels, gullies, levees and sediment waves via turbidity currents and associated sedimentation processes such as double-diffusive sedimentation.

A further active research area concerns multiphase flows in porous media and Hele-Shaw cells, and specifically the instabilities to which these give rise in the presence of viscosity and density gradients. Some of our recent efforts have focused specifically on the similarities and differences between miscible and immiscible flows.

We generally write our own CFD codes, based on state-of-the-art computational techniques, rather than using commercial software. In order to acquire the required strong background in numerical analysis, graduate students working on research projects in the CFD