Geostrophic adjustment process experiments with HYCOM

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Objectives

- **Representation of adjustment process by HYCOM**
  - **upwelling**
  - **coastal variability**

- **Influence of selection of vertical coordinates and sub-grid scale paramterization**

Motivation

- **Treatment of intersection of an isopycnal with bottom is robust in HYCOM (Bleck & Smith, 1990)**

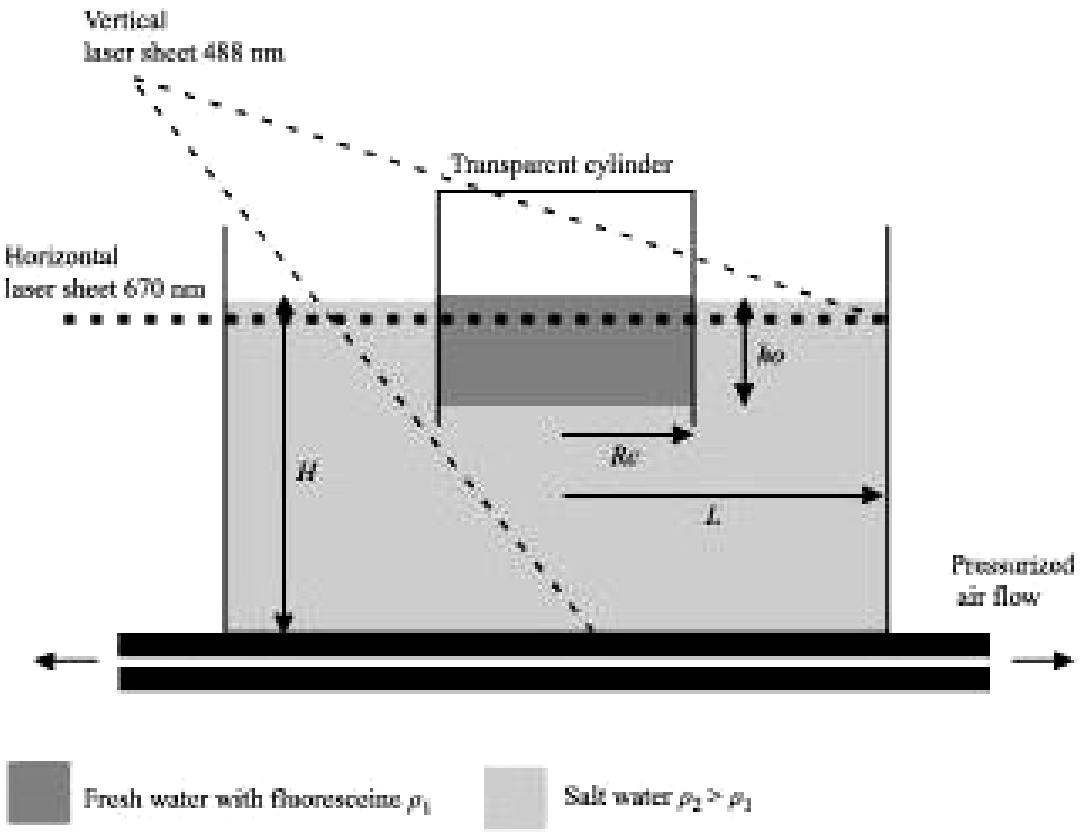
- **Is treatment of intersection of an isopycnal with the surface robust ?**

Geostrophic adjustment of mass anomaly

- **Laboratory experiment (*Stegner et al., JFM, 2004*)**
  - **Laboratory measurements of mass and velocity distributions.**
  - **Selected regimes are away from past experiments (barotropic wave modes, baroclinic unstable modes).**
  - **Suitable for quantitative comparison with numerical model simulation.**
  - **Process of adjustment will be reported later (*Stegner et al., in preparation*).**

Experiment Setup

$R_d^2 = (g^* h_o)/(2\,\Omega_o)^2$, where g^* => reduced gravity



Burger number:

$$Bu = \left(\frac{R_d}{R_c}\right)^2;$$

Vertical aspect ratio:

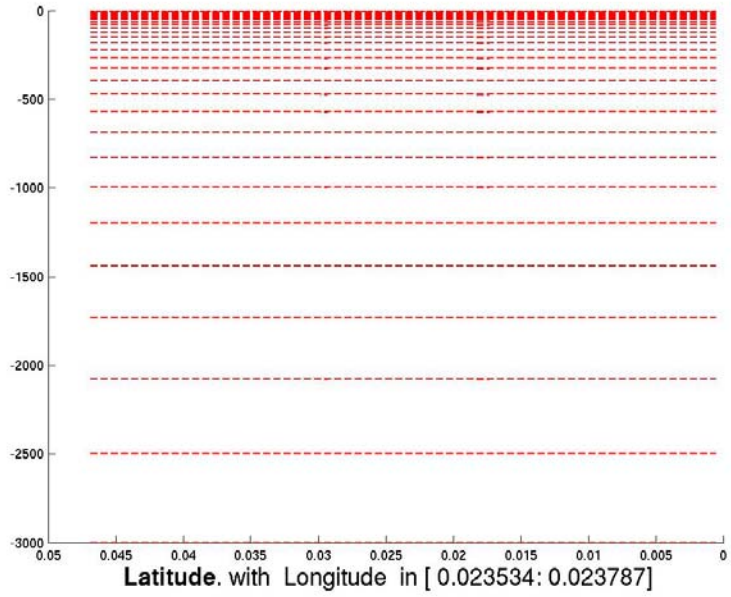
$$\delta = \frac{h_0}{H};$$

Front steepness:

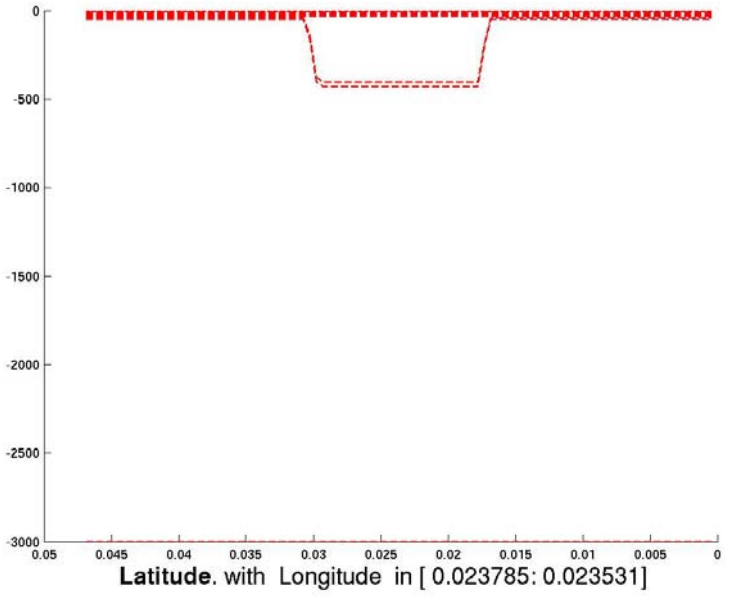
$$\alpha = \frac{h_0}{R_d}.$$

Model Setups

Z (480 x 480 x 30)



Hybrid (480 x 480 x 10)



- Hybrid (right) -- central experiment, 10 levels, alpha = 0.69, del = 0.077
- Pure Z (left) -- 30 levels
- Hybrid -- same as central, except sub grid scale parameterization

Observed Density (Vertical Cross-Section)

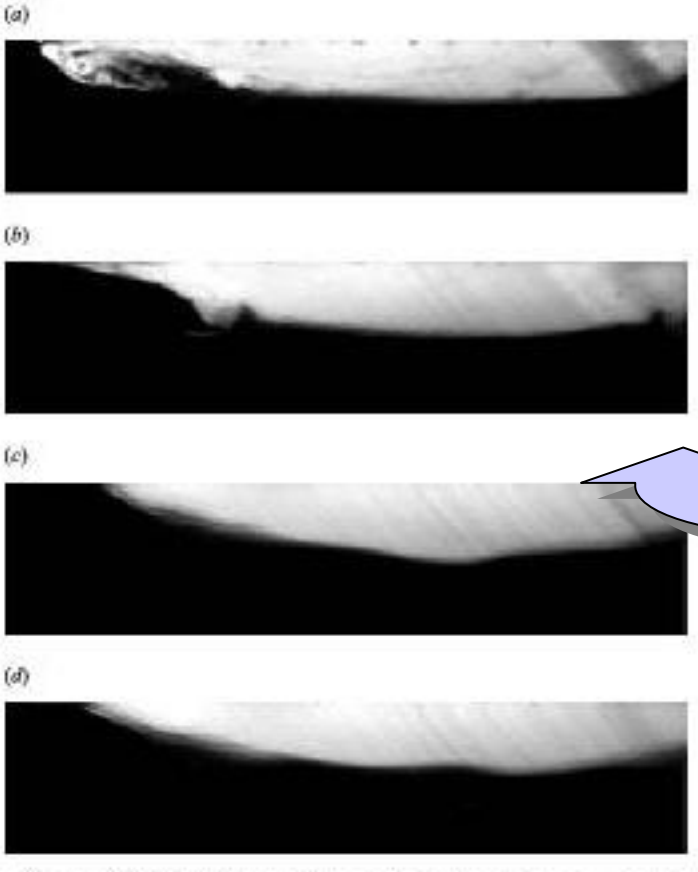
T_f = Inertial period

$t = 0.5T_f$

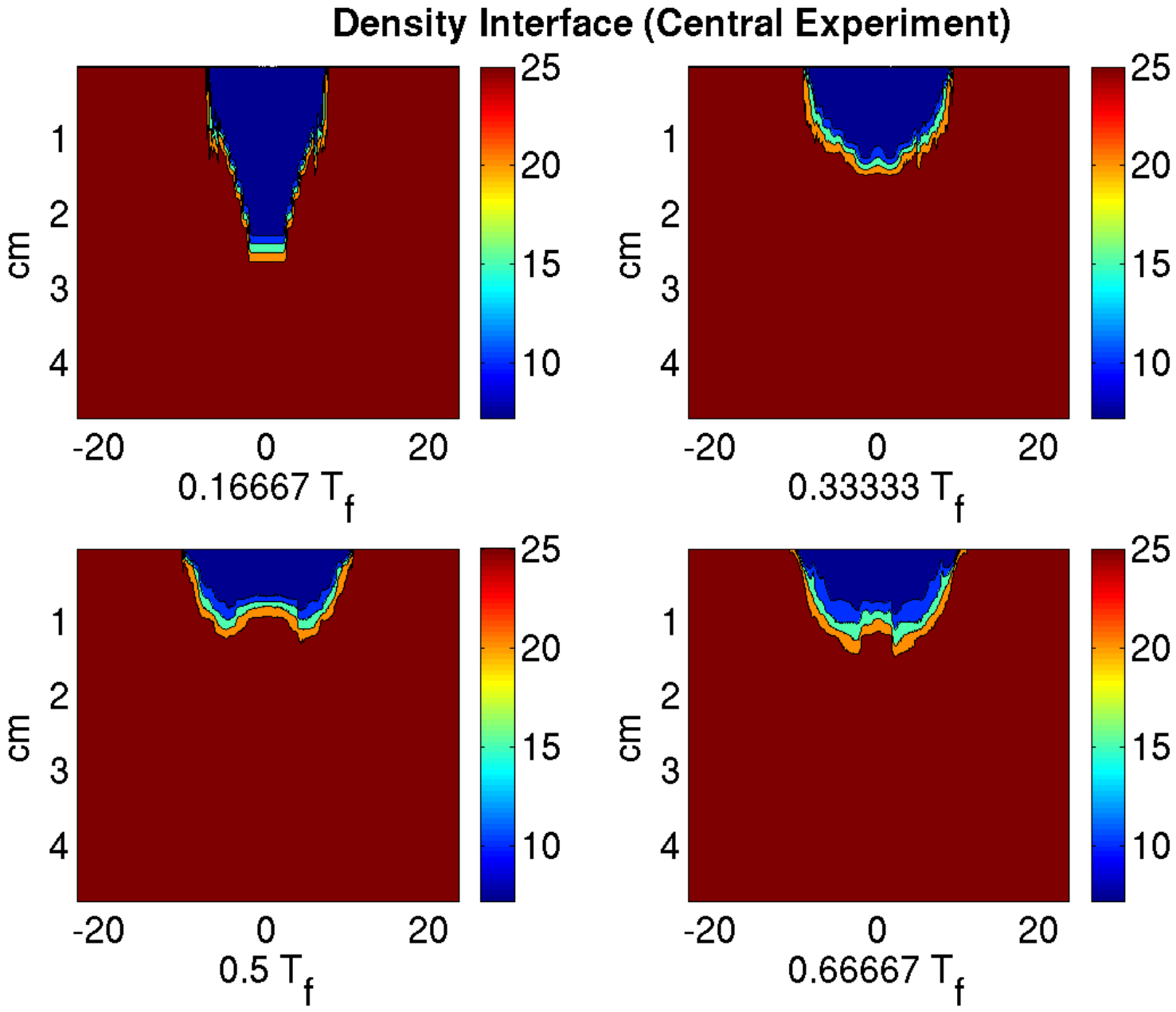
$t = 0.8T_f$

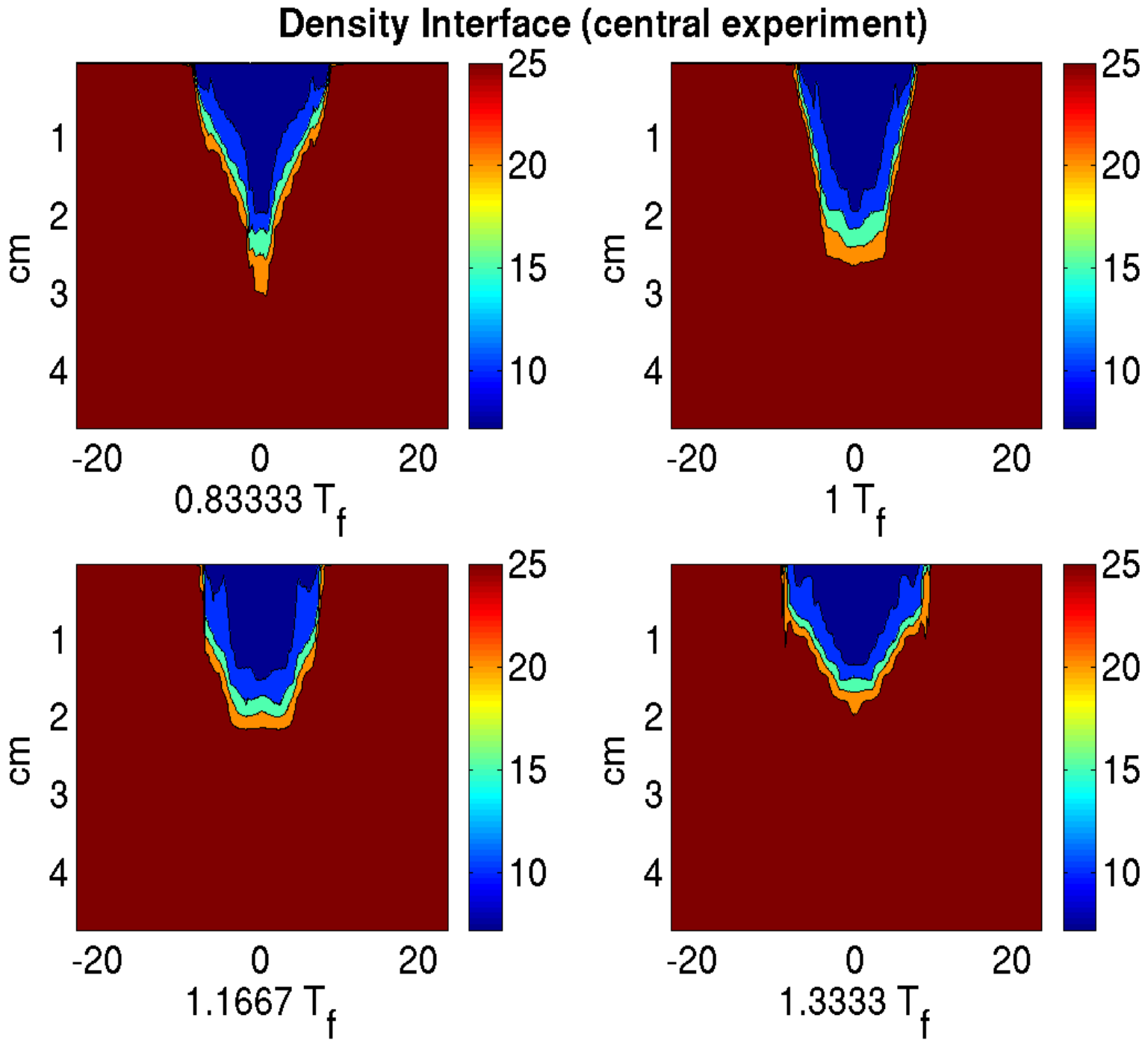
$t = 3.0T_f$

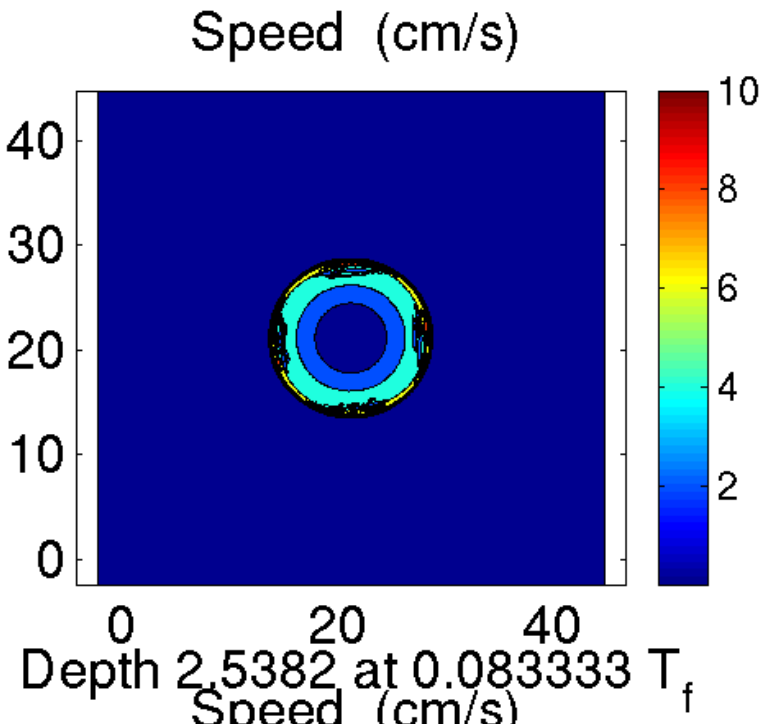
$t = 3.4T_f$

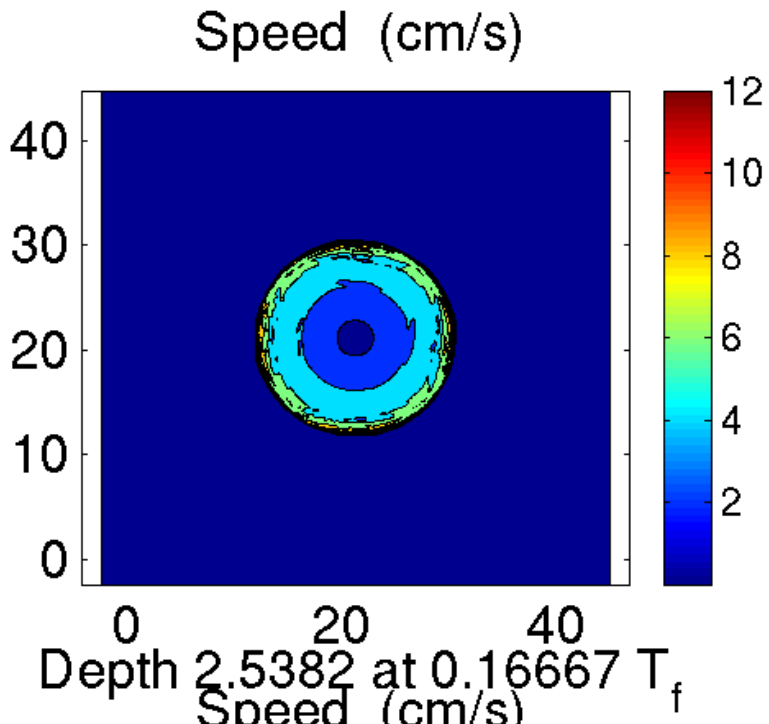


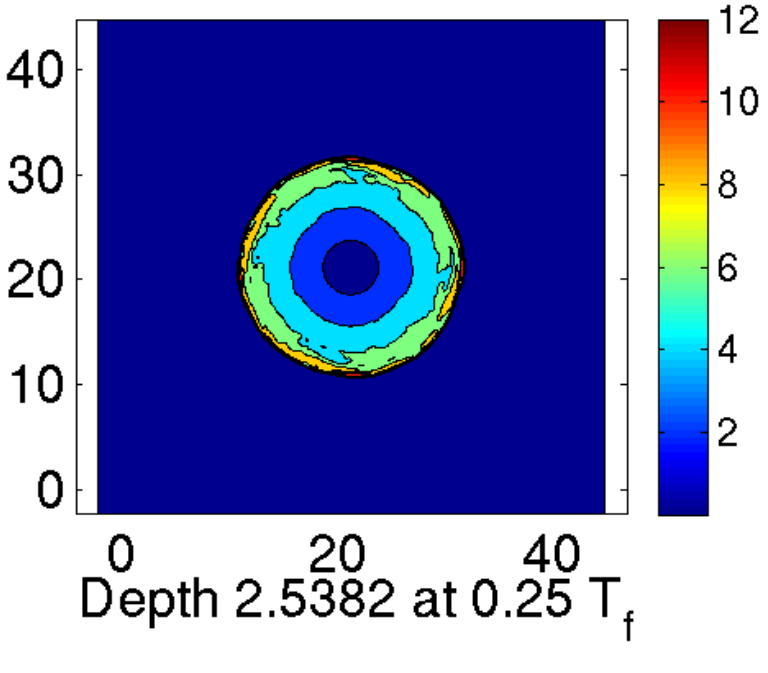
Axis of symmetry

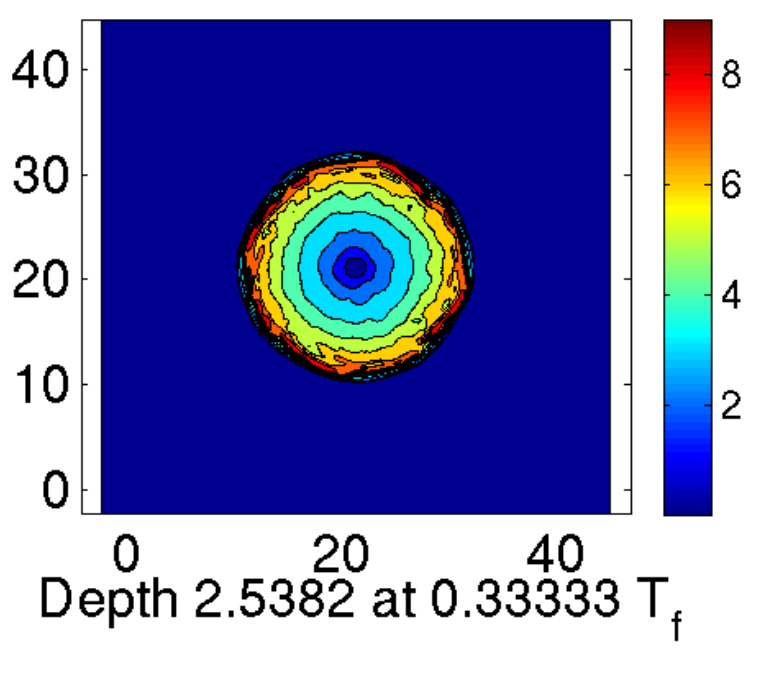

Density Interface (Central Experiment)
cm
1
2
3
4
-20
0
20
25
20
15
10
0.16667 T_f
0.33333 T_f
0.5 T_f
0.66667 T_f

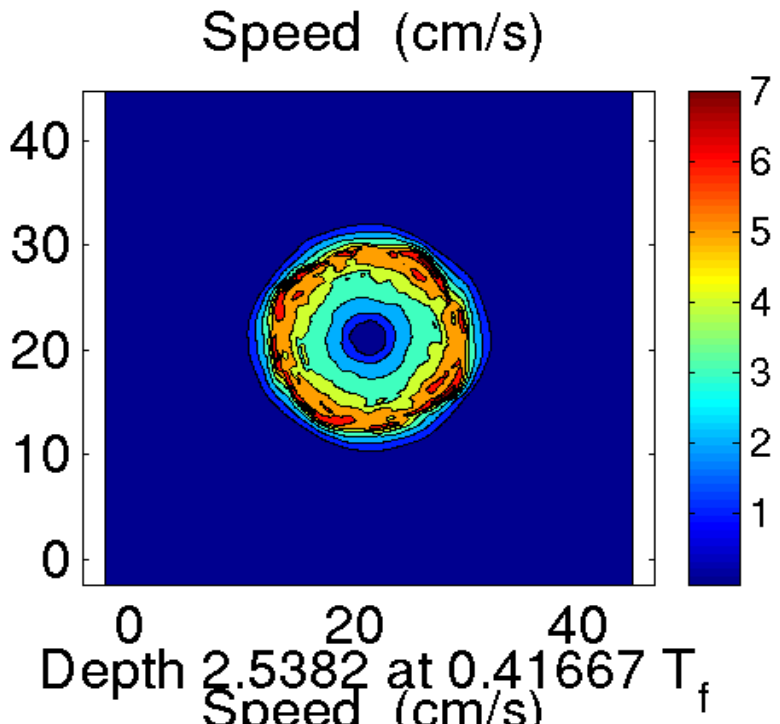

Density Interface (central experiment)
cm
1
2
3
4
-20
0
20
25
20
15
10
0.83333 T_f
1 T_f
1.1667 T_f
1.3333 T_f

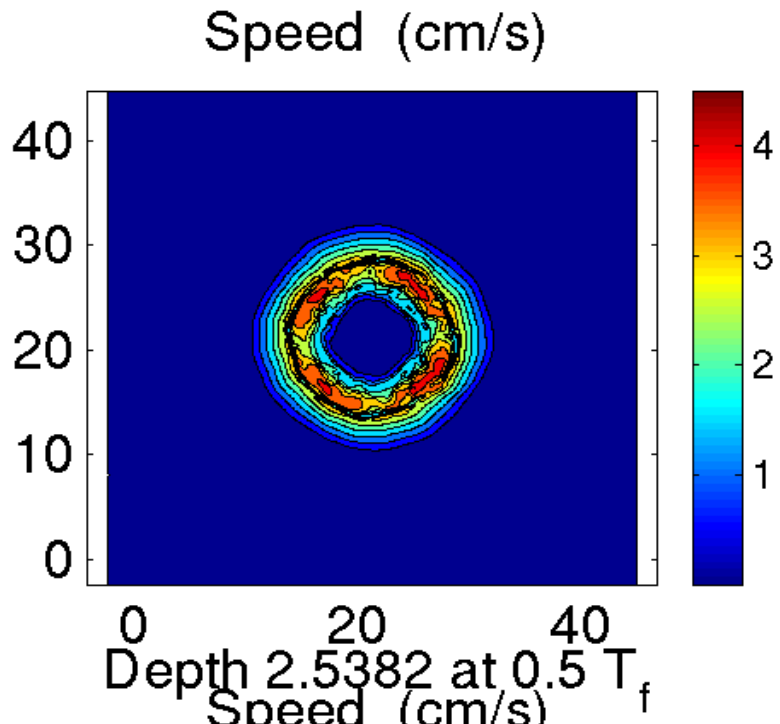

Speed (cm/s)
40
30
20
10
0
0
20
40
10
8
6
4
2
Depth 2.5382 at 0.083333 T_f

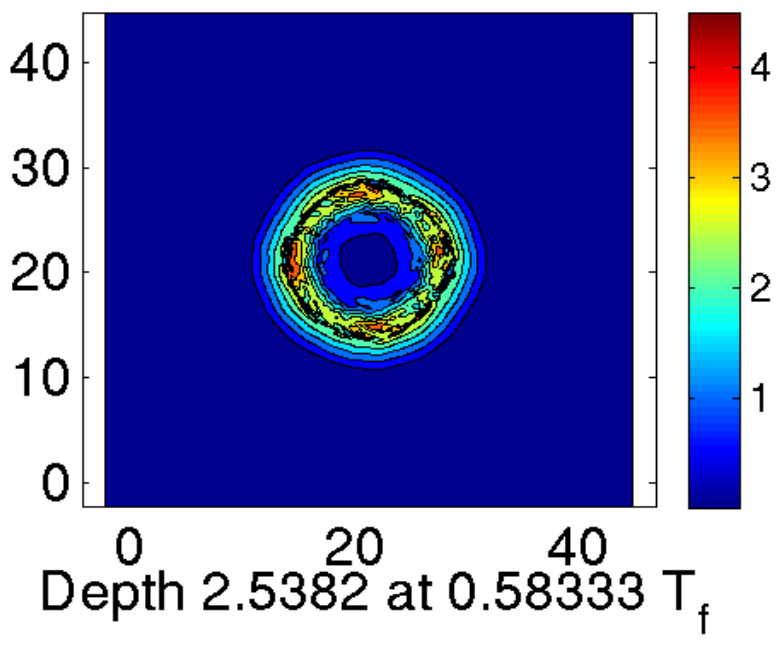

Speed (cm/s)
40
30
20
10
0
0
20
40
12
10
8
6
4
2
Depth 2.5382 at 0.16667 T_f

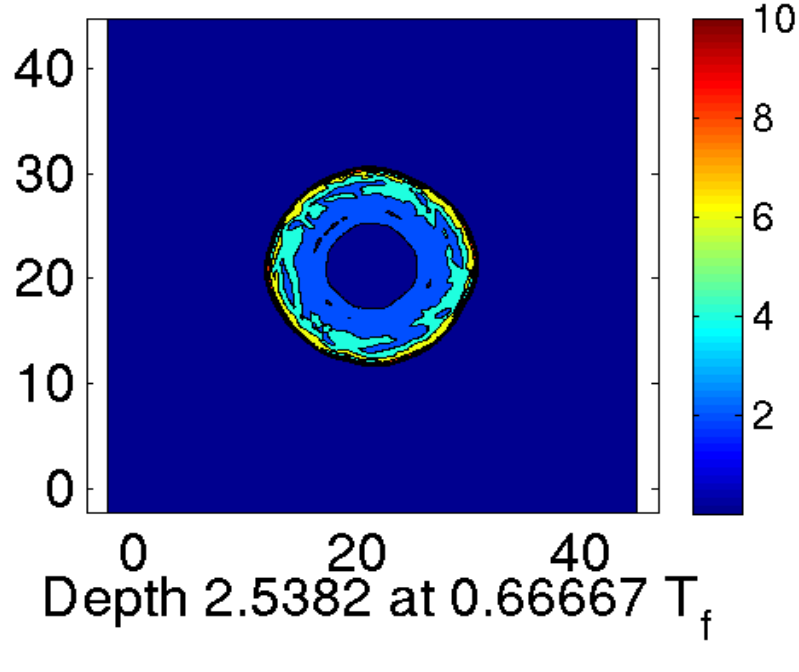

Speed (cm/s)
40
30
20
10
0
0
20
40
12
10
8
6
4
2
Depth 2.5382 at 0.25 T_f


Speed (cm/s)
40
30
20
10
0
0
20
40
8
6
4
2
Depth 2.5382 at 0.33333 T_f

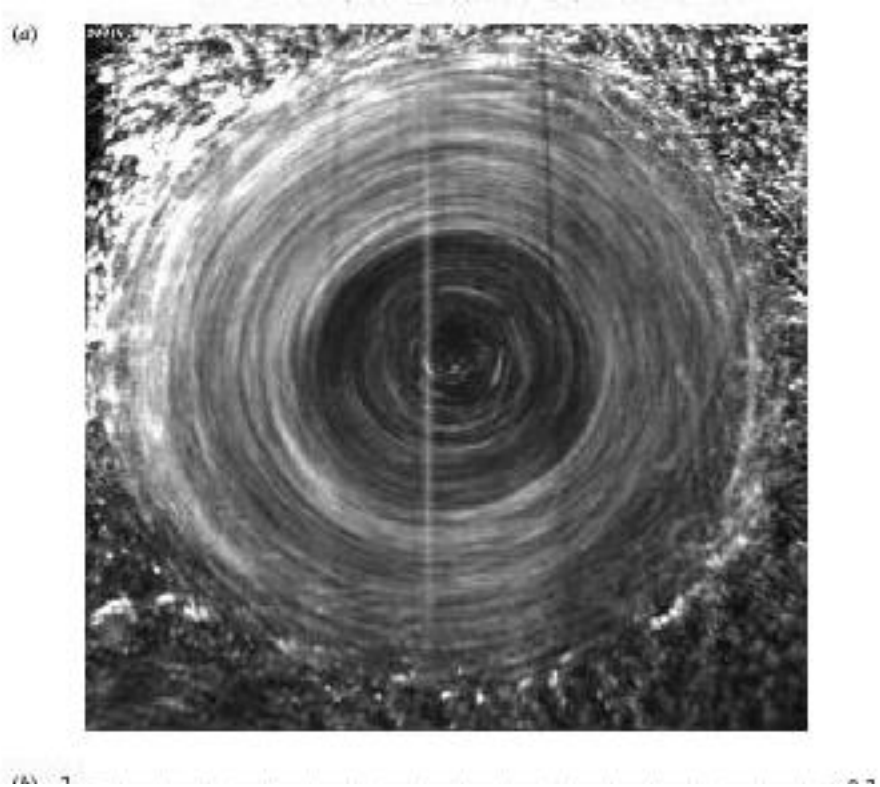

Speed (cm/s)
40
30
20
10
0
0
20
40
7
6
5
4
3
2
1
Depth 2.5382 at 0.41667 T_f


Speed (cm/s)
40
30
20
10
0
0
20
40
4
3
2
1
Depth 2.5382 at 0.5 T_f


Speed (cm/s)
40
30
20
10
0
0
20
40
4
3
2
1
Depth 2.5382 at 0.58333 T_f


Speed (cm/s)
40
30
20
10
0
0
20
40
10
8
6
4
2
Depth 2.5382 at 0.66667 T_f

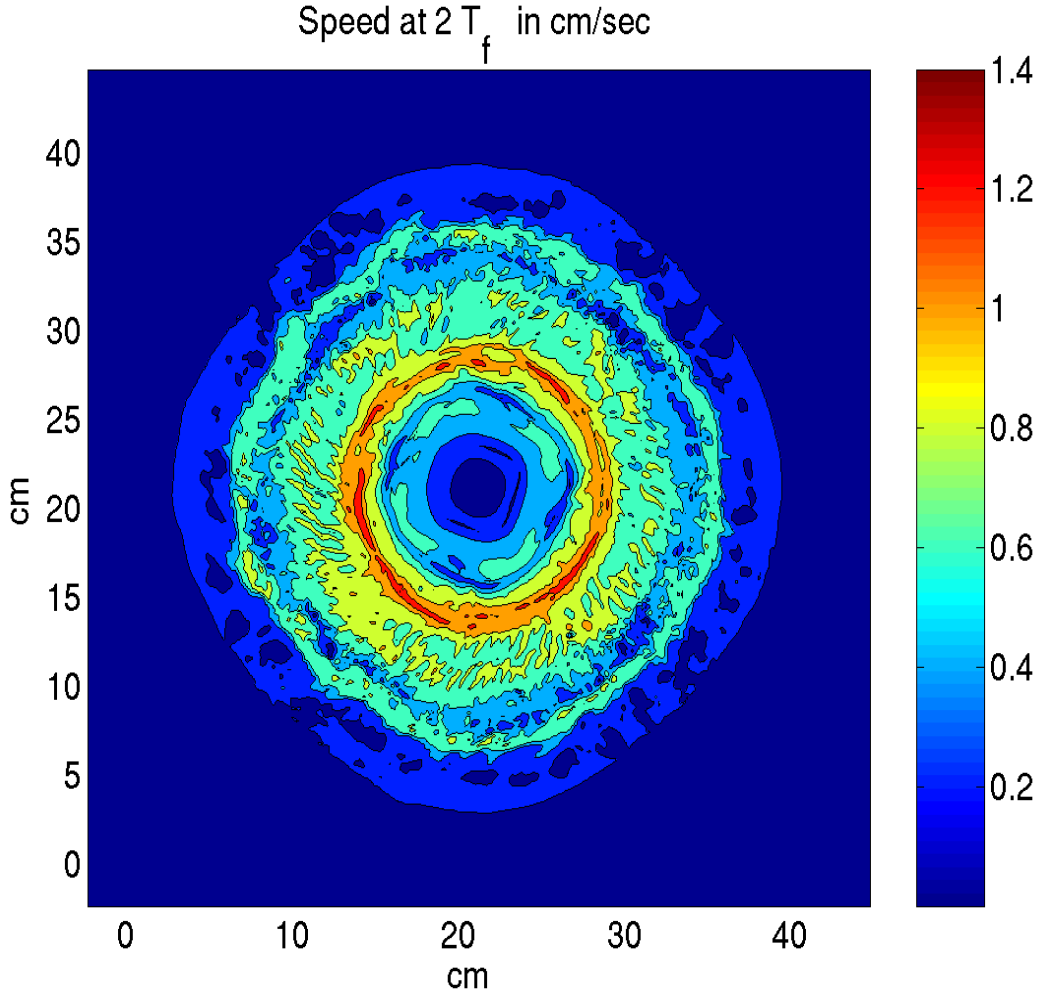
Particle trajectories

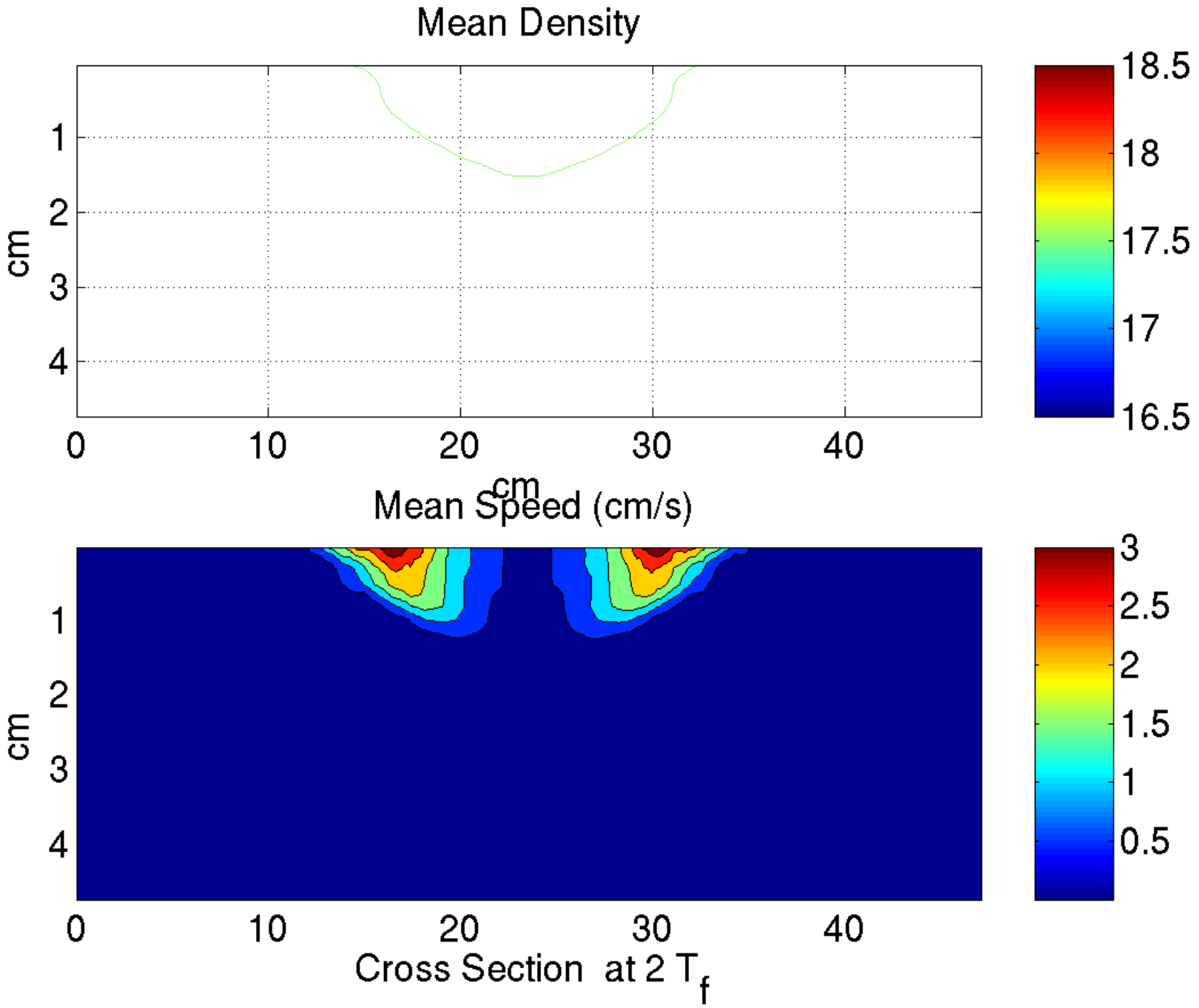


Bu=0.4, δ=0.008, α=0.69

T_f (Inertial Period) = 2

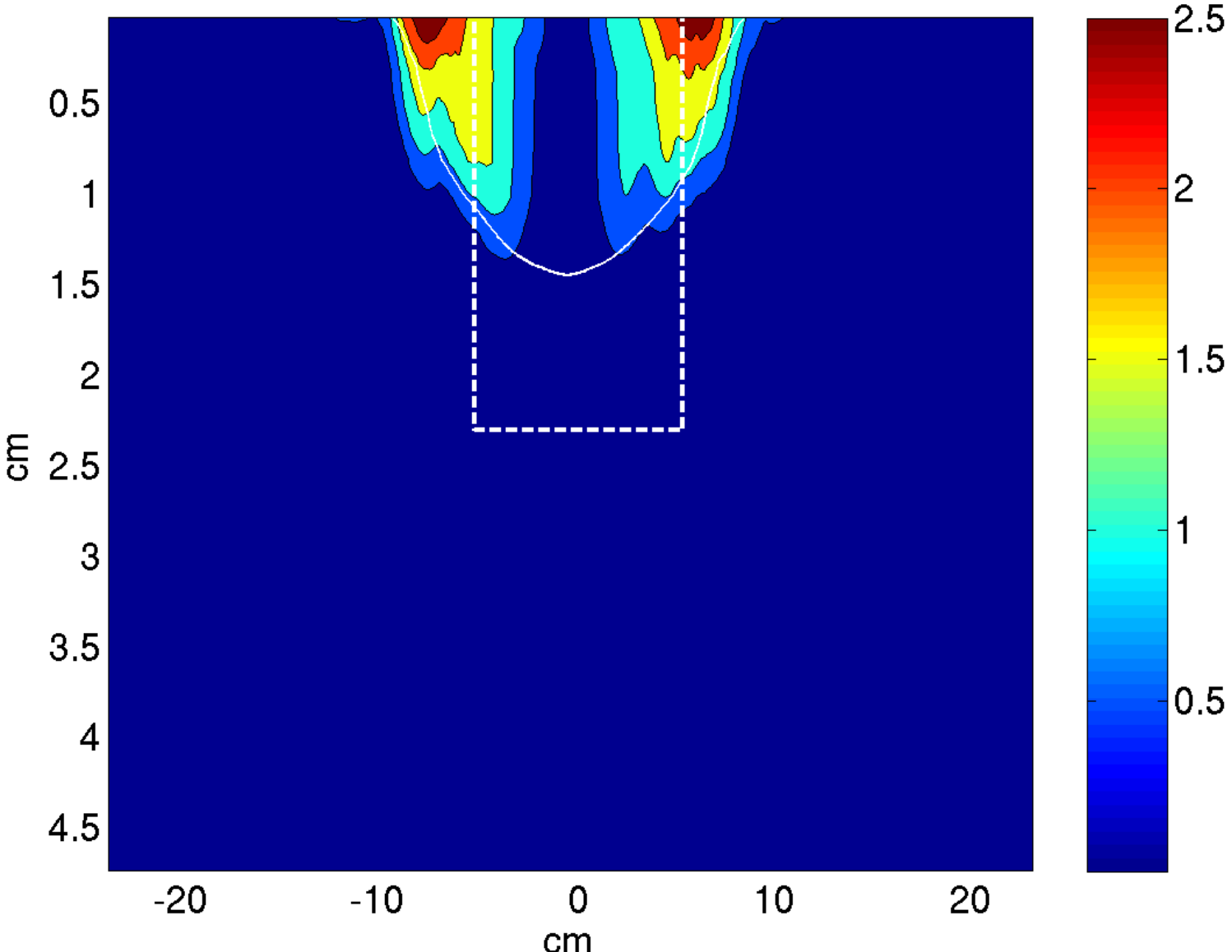
Simulated speed

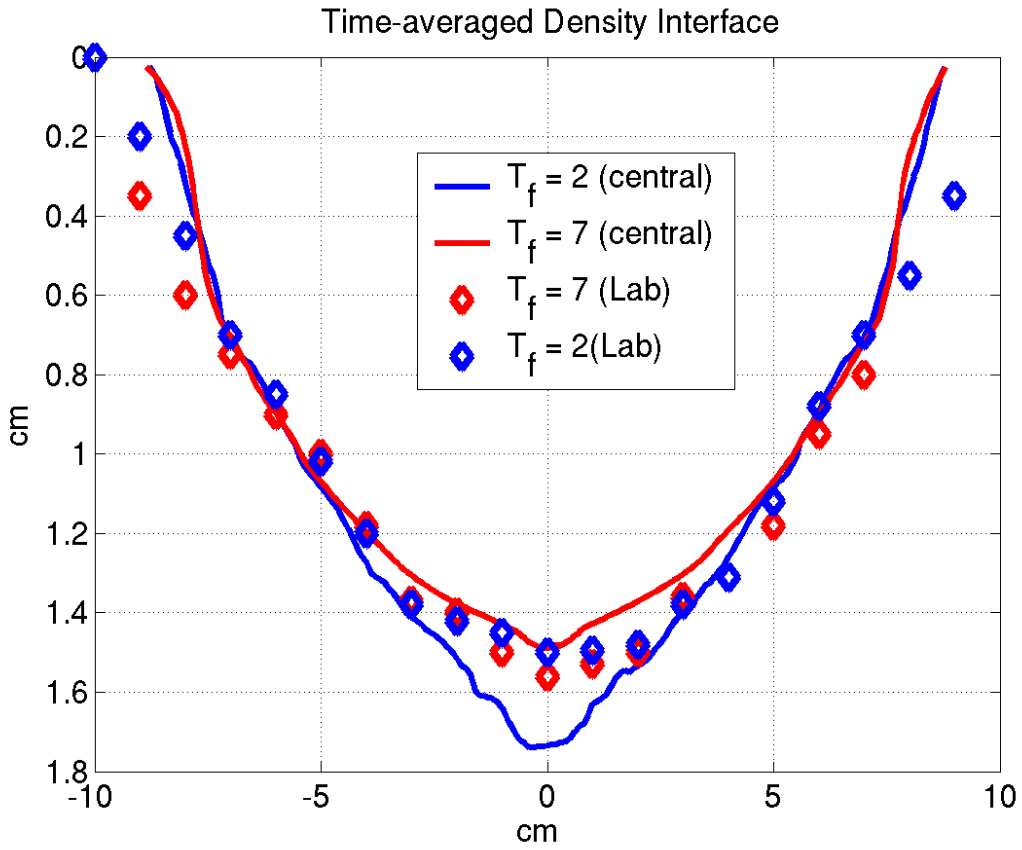



Mean Density
cm
1
2
3
4
0
10
20
30
40
cm
18.5
18
17.5
17
16.5
Mean Speed (cm/s)
cm
1
2
3
4
0
10
20
30
40
Cross Section at 2 T_f
3
2.5
2
1.5
1
0.5

Mean Speed and Density at 7 T_f

(initial profile is given by dashed contour)

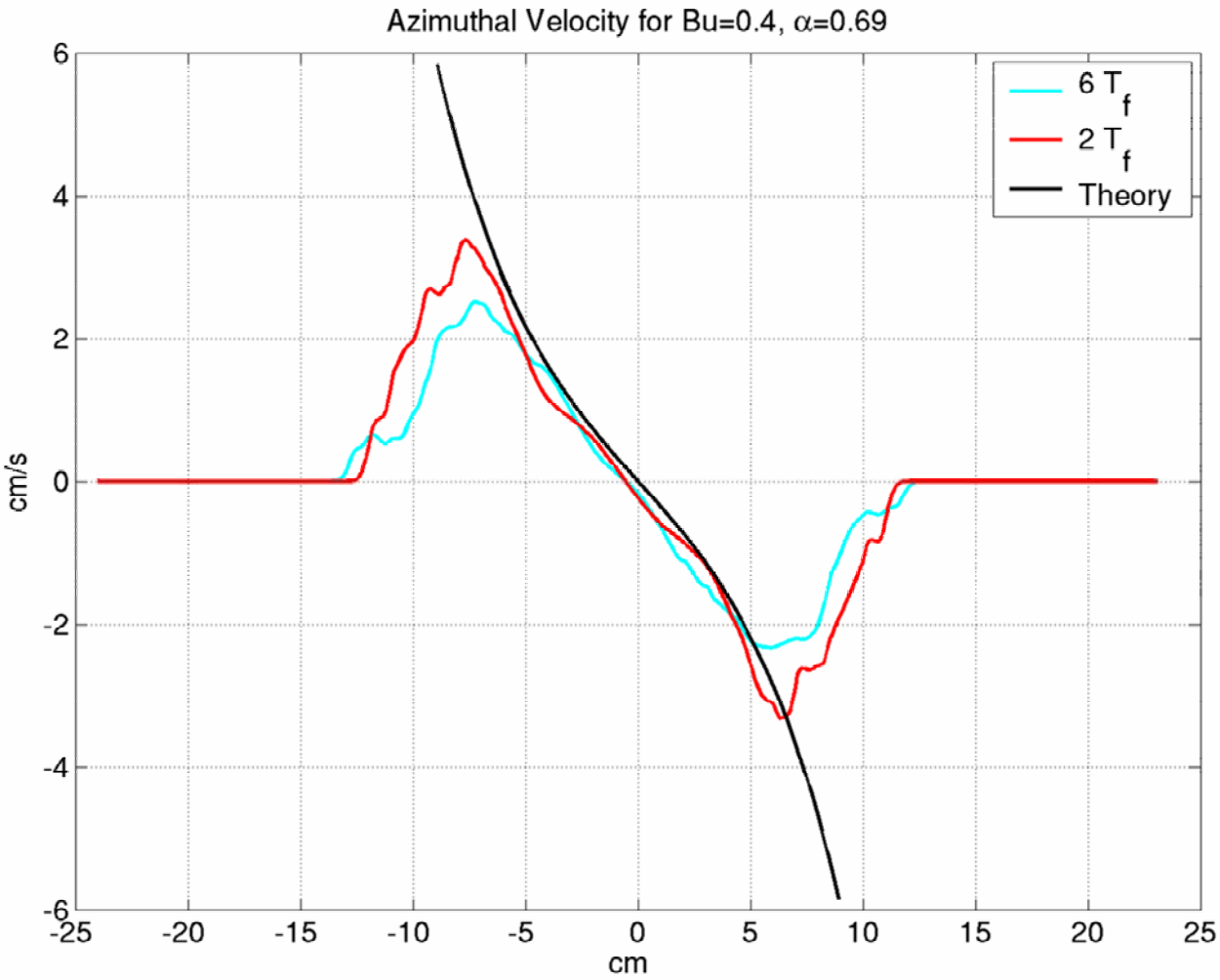


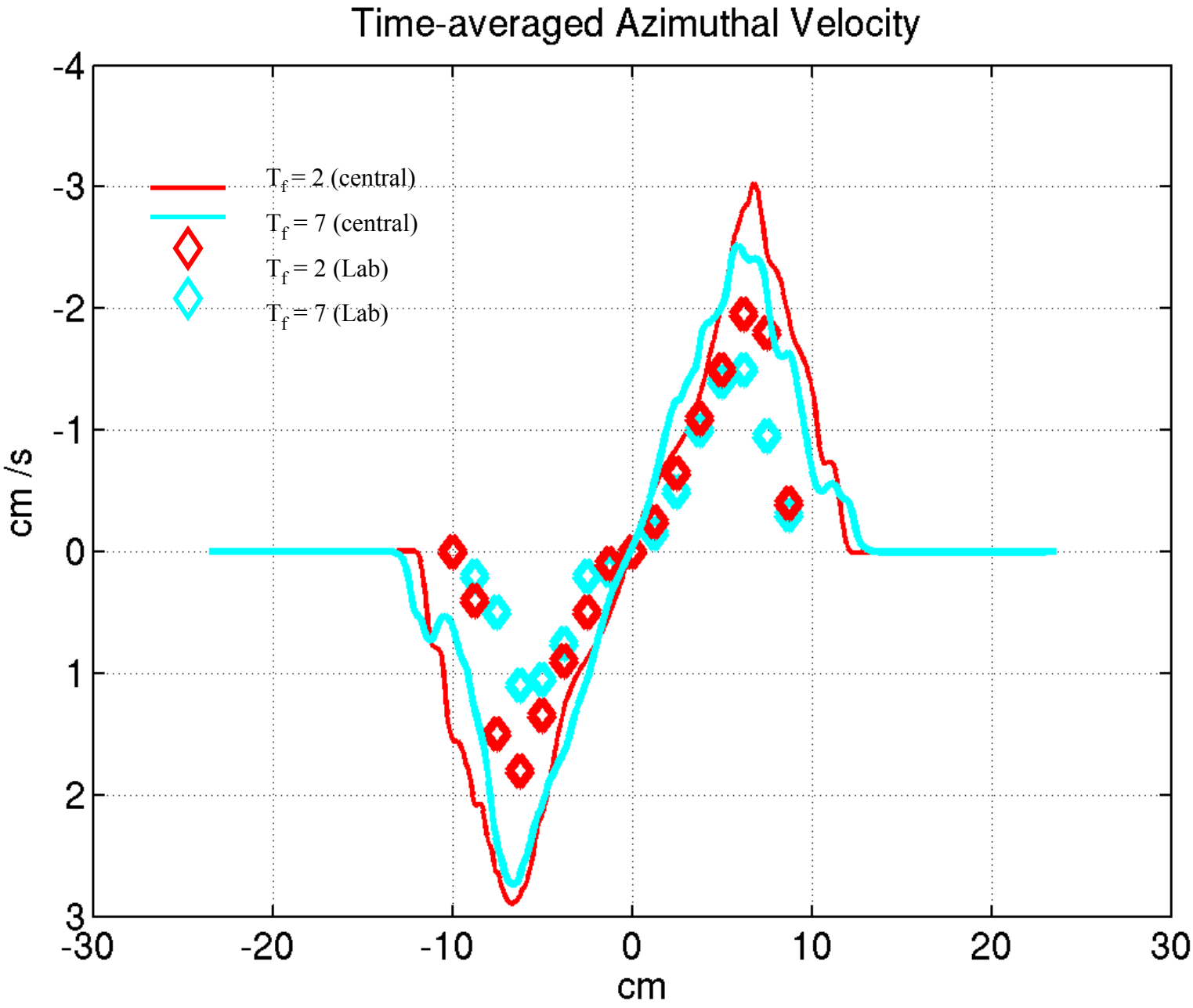


Central: Hybrid 10 levels

- Little change in mean density profiles from 2 to 7 T_f
- Viscous effects at center, outer edges

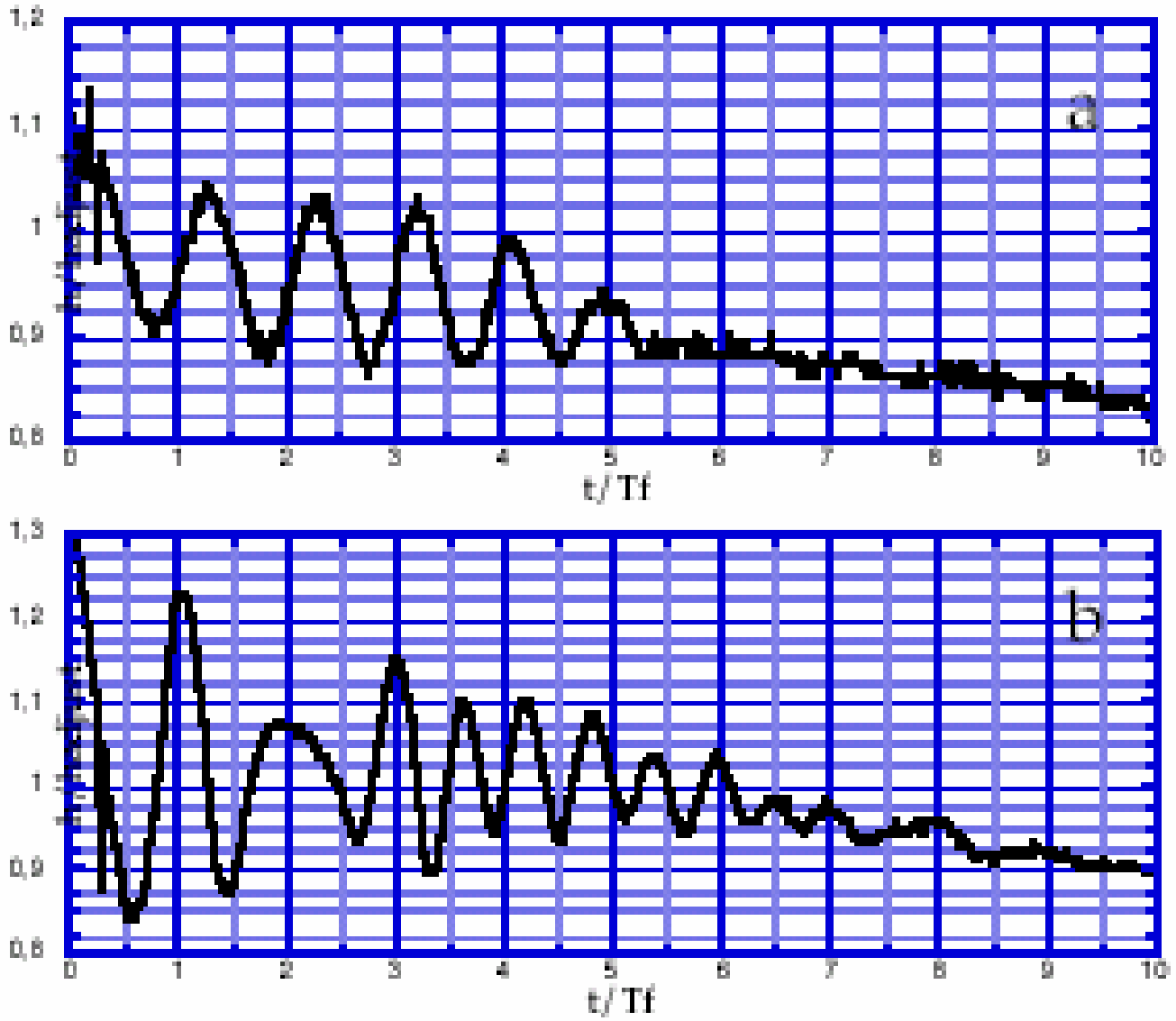
Comparison with inviscid adjustment theory



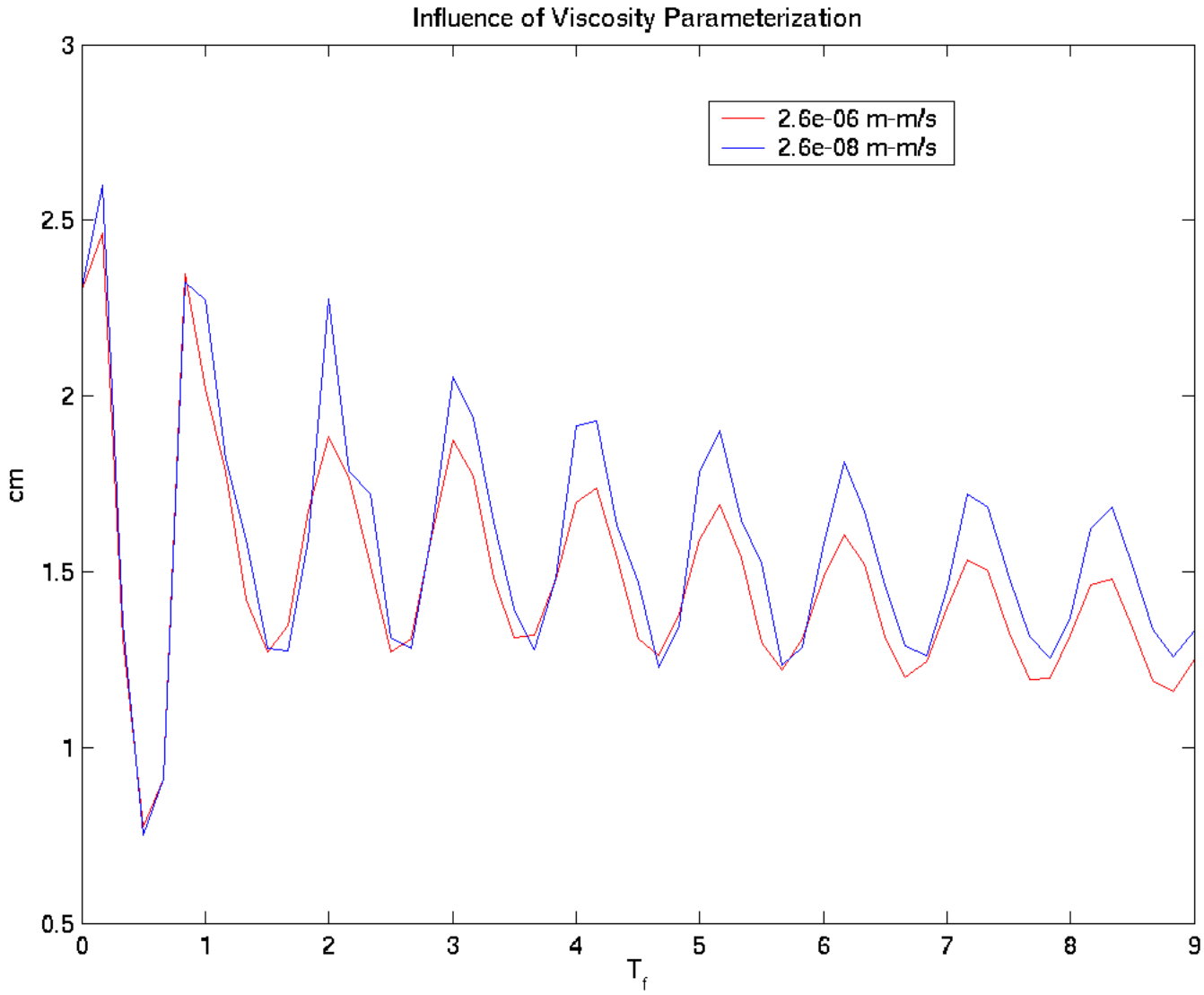

Time-averaged Azimuthal Velocity
T_f = 2 (central)
T_f = 7 (central)
T_f = 2 (Lab)
T_f = 7 (Lab)
cm /s
cm
-4
-3
-2
-1
0
1
2
3
-30
-20
-10
0
10
20
30

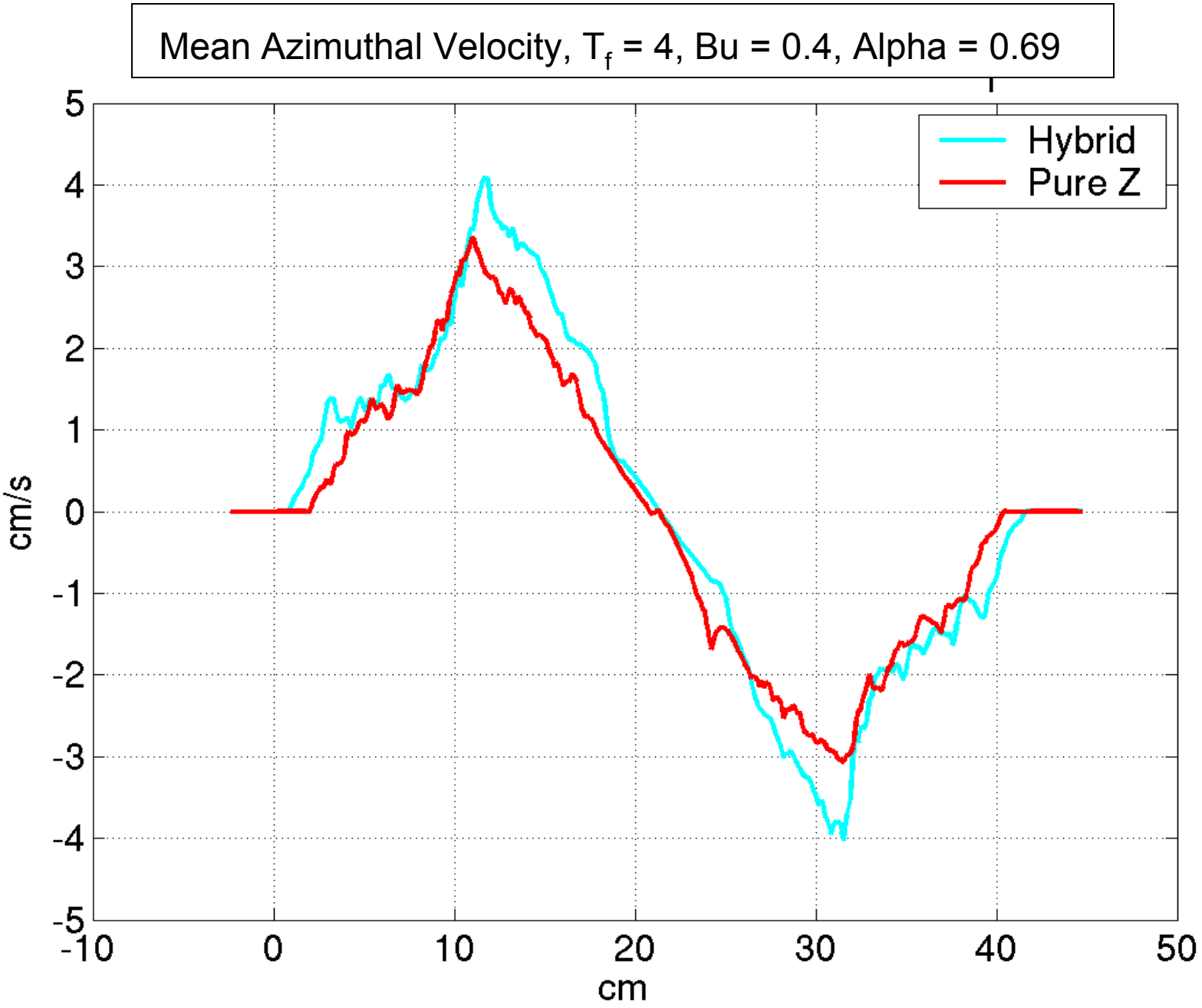
Oscillations of the density interface in the center – from Stegner et al. (2003)

Top: Bu = 0.18, Bottom: Bu = 0.38; **Alpha = 0.8**

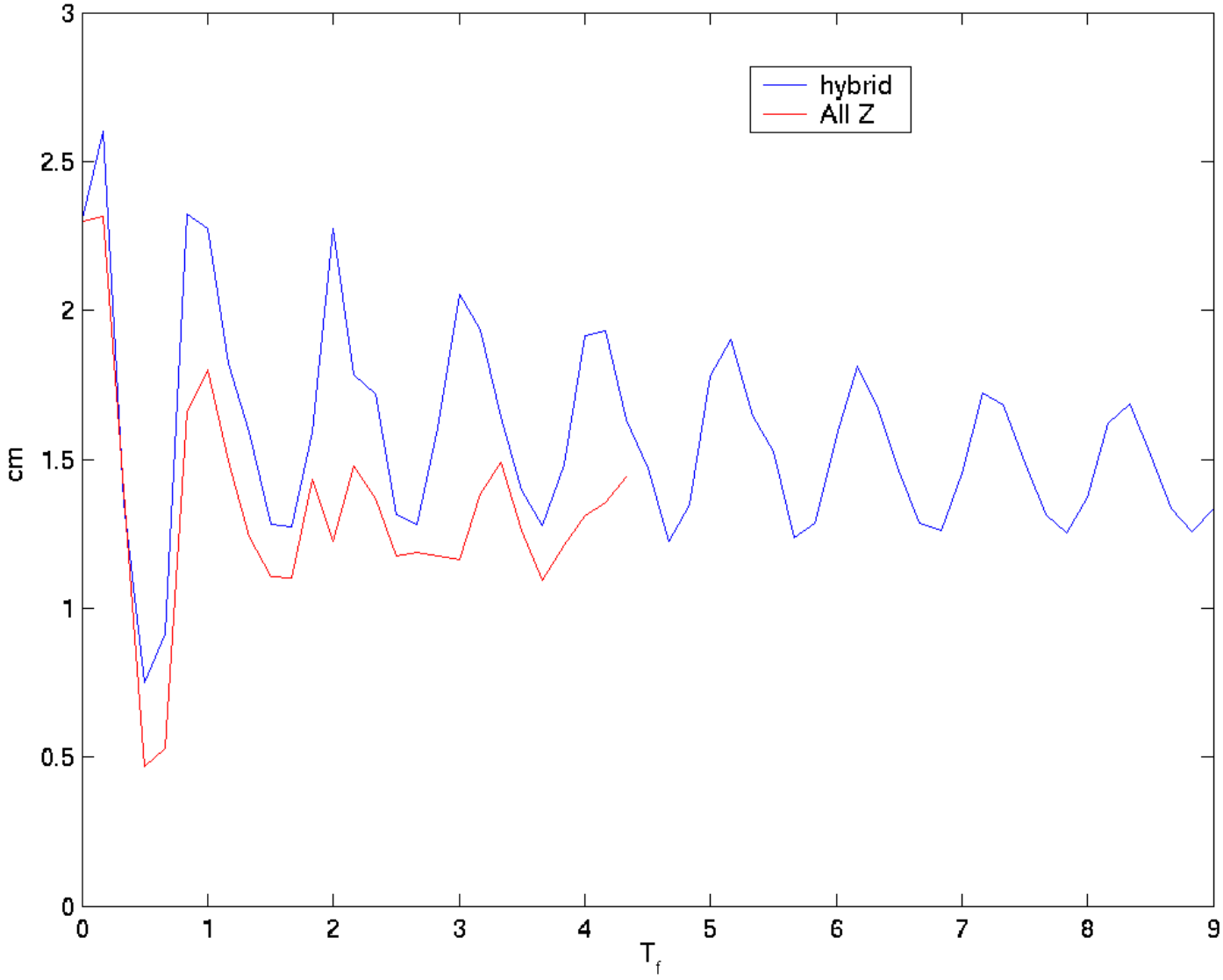


Oscillations of the density interface in the center




Mean Azimuthal Velocity, T_f = 4, Bu = 0.4, Alpha = 0.69
Hybrid
Pure Z
cm/s
cm
5
4
3
2
1
0
-1
-2
-3
-4
-5
-10
0
10
20
30
40
50

All Z Vs. Hybrid: oscillations of the density interface in the center



Today's conclusions

- **HYCOM simulations compare well with Lab measurements of geostrophic adjusted states**

- **Hybrid better than Z**

Future Work

- **Other vertical coordinates (isopycnal)**
- **Analyze transient processes (Stegner et al. Part II)**
- **Practical criterion to select hybrid coordinates near the surface**