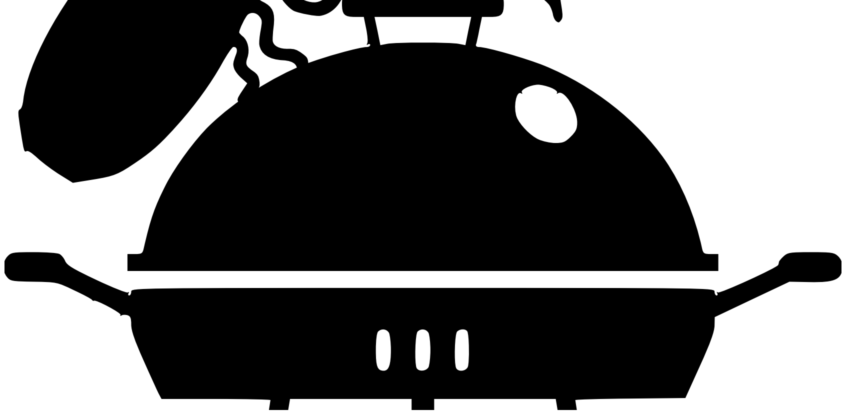
Plankton Barbec



Introduction

Natural Thermal Convection
Those plumes comming out from our BBQ grill are caused by differences on density consequence of temperature variations.

Governing Equations

- ($\approx$) **Momentum:**

$$\frac{\partial \omega}{\partial t} + \frac{\partial \psi}{\partial y}\frac{\partial \omega}{\partial x} - \frac{\partial \psi}{\partial x}\frac{\partial \omega}{\partial y} = \frac{1}{Re}\nabla^2\omega + \beta g\frac{\partial T}{\partial x}$$

- **Stream fnc - Vorticity - Velocity:**

$$\nabla^2\psi = -\omega, \quad u = \frac{\partial \psi}{\partial y}, \quad v = -\frac{\partial \psi}{\partial x}$$

- **Energy:**

$$\frac{\partial T}{\partial t} + (\overrightarrow{u} \cdot \nabla T) = \frac{1}{RePr}\nabla^2 T$$

- **(Bonus!!!) Mass Transfer:**

$$\frac{\partial c}{\partial t} + (\overrightarrow{u} \cdot \nabla c) = \frac{1}{Pe}\nabla^2 c$$

Where the last Eq. models a substance moving with the fluid.

Method

To solve numerically the equations ...

1. Set up the initial conditions for ψ, u and v.
2. Solve the vorticity equation. (Exp FTCS).
3. Solve the Poisson equation for ψ. (Std. discr. ∇^2).
4. Compute the new velocity from ψ.
5. Solve the energy equation for T. (Exp FTCS).
6. Solve the mass transfer equation. (Exp FTCS).
7. Go to step 2.

cue: Nutrient Flow due

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BBQ Grill: Air Thermal Convection

The

As benchmark parameters we chose:

$$Re = 4365.30,\ Pr = 0.72,\ Pe = 0.07$$

For a rectangular cavity width dimensions: 0.65m height, 2.6m wide, and normalized temperatures $Tc = 292.5°K$, $Th = 293.5°K$.

The Figure 2 shows the normalized velocities, temperature and concentration evolution for several times, some remarkable facts are:

- Buoyancy force makes rise the warmer water from the bottom.
- There are cell formations even for early times.
- Iso-thermal and Iso-concetration regions.

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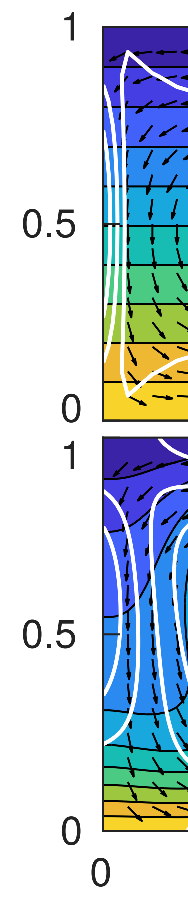

Figur

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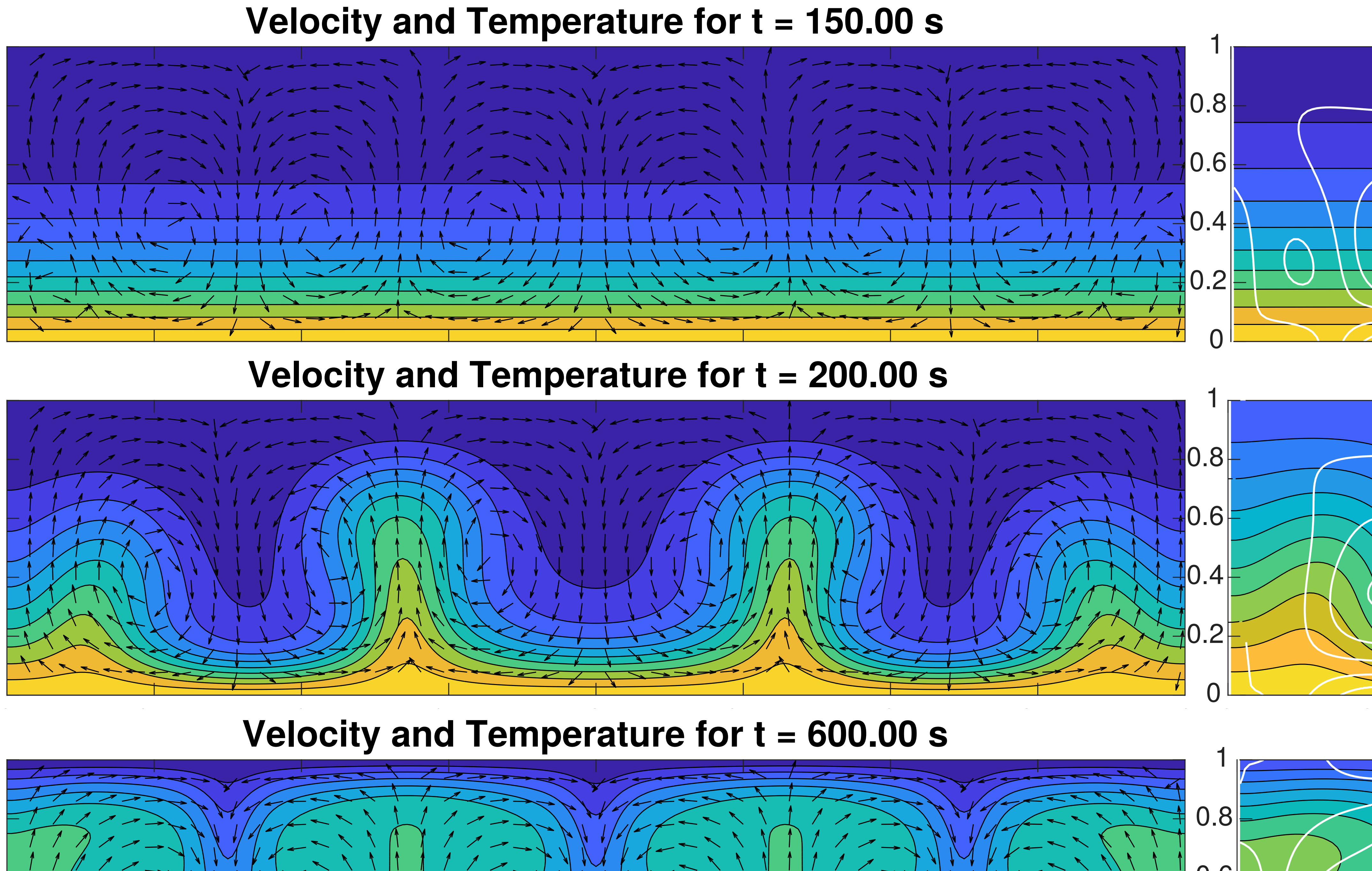
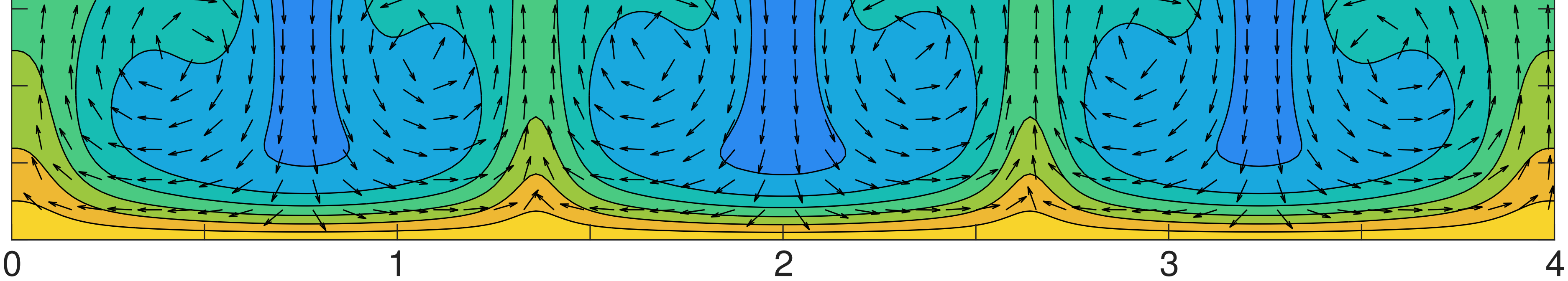


Velocity and Temperature for t = 150.00 s
Velocity and Temperature for t = 200.00 s
Velocity and Temperature for t = 600.00 s
1
0.8
0.6
0.4
0.2
0



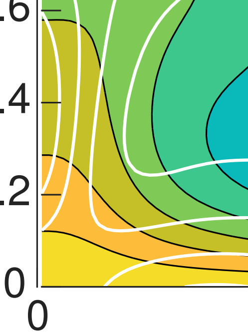


Figure 2:Air thermal convection and mass transfer normalized velocity, te

Numerical Conve

Due to the high Reynolds number the experimental study for the convergence rates presents some challenges:

- Changes in the grid size lead to variations in the direction of rotation in the cells.

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e to Natural Thermal

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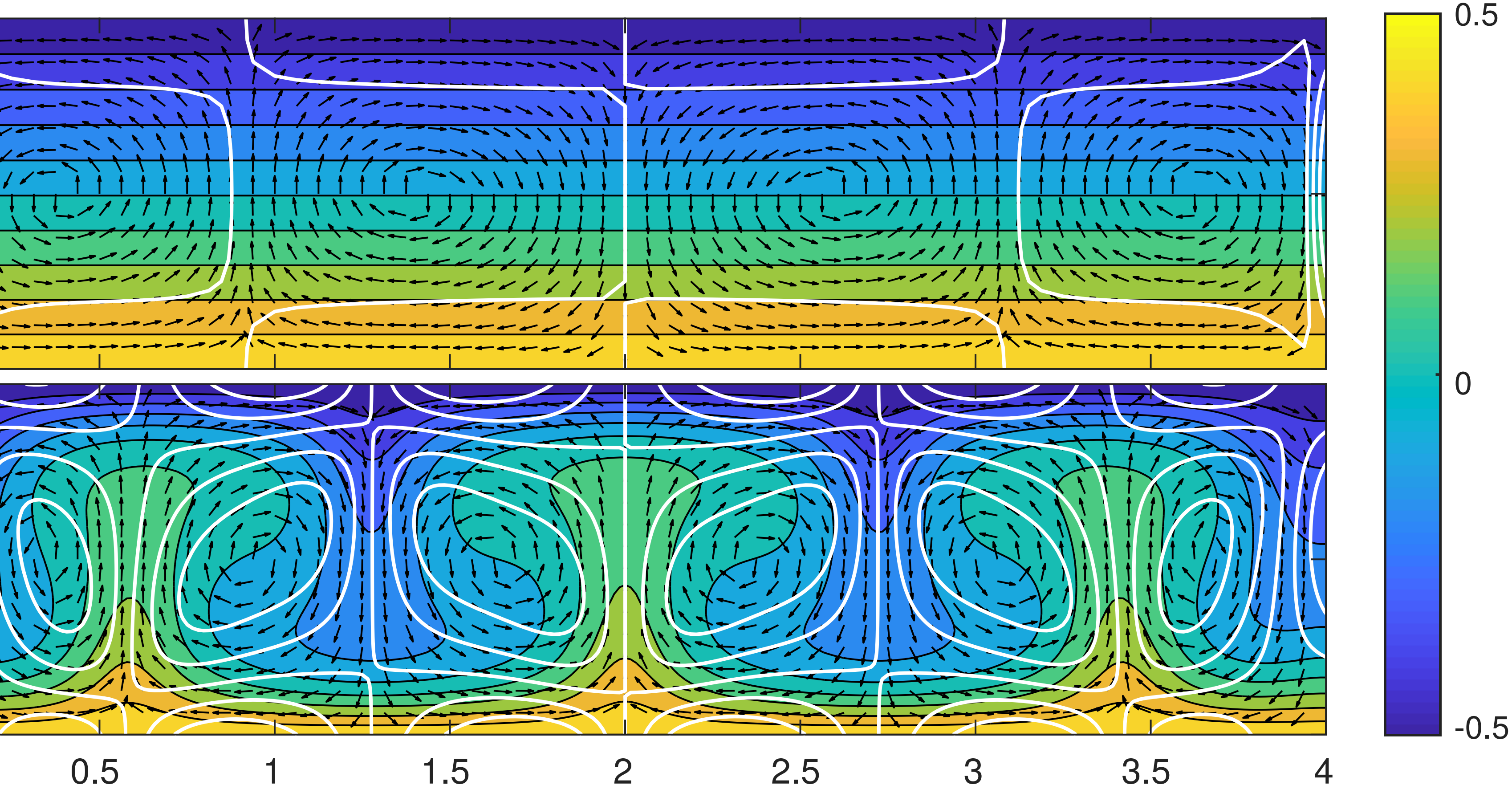
Spring 2019

Cells and Spatial Resolution

Figure 1 shows that the simulation results de-

- Pythopl

l on the discretization size. In the coarser dis-
zation only 4 cells Rayleigh-Benard cells form,
pared to 6 in the finer one. This indicates that
e discretizations cannot completely resolve the
cture of the flow.



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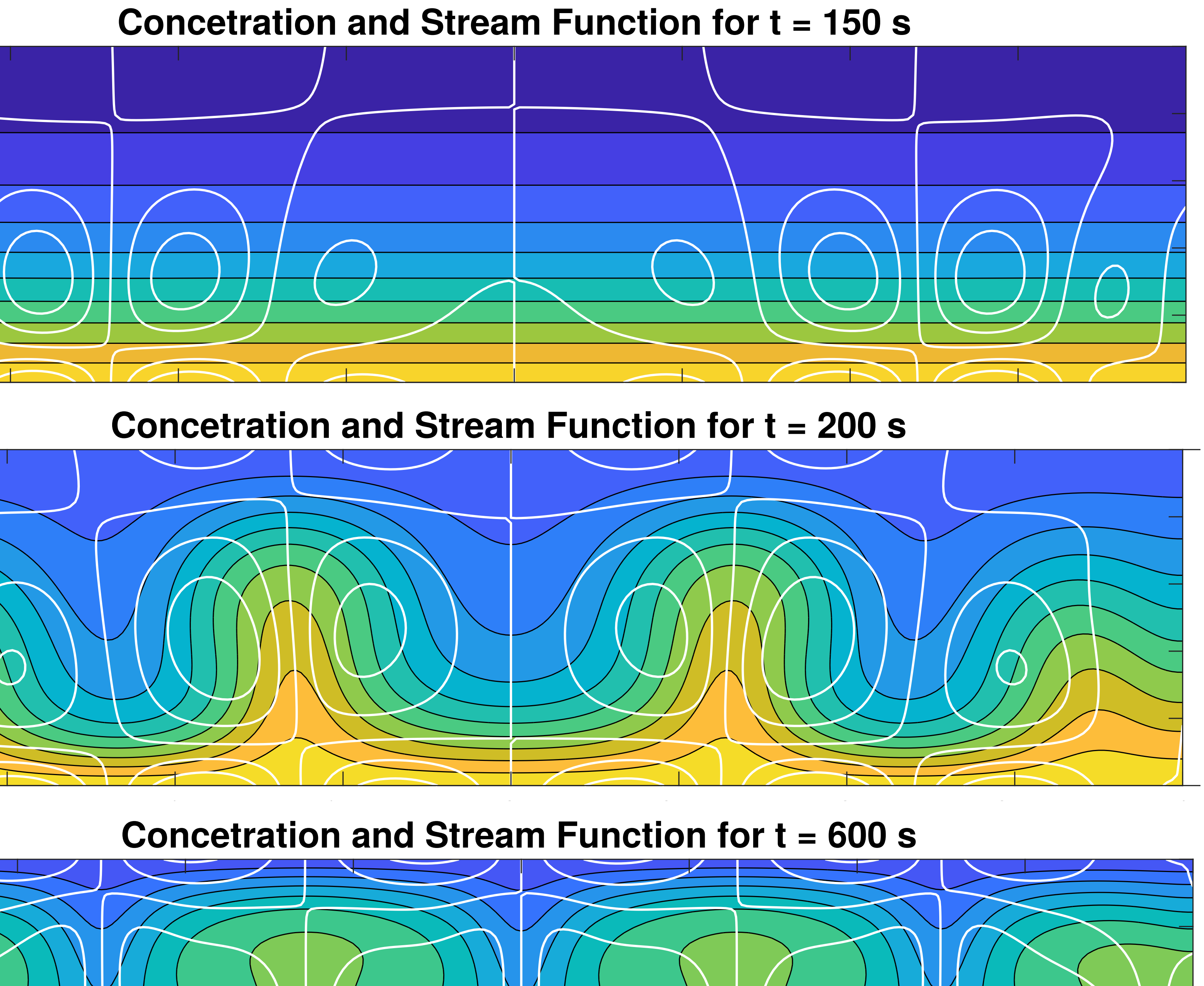
- The tem
  $10°K$ pe
- The buo
  of ocean

We wante
perature
the sea (
organisms

Re =

Although
general st

e 1: Cells on grids: (top) $\Delta x = 156 \times 10^{-}$, $\Delta y = 62.5 \times$
(bottom) $\Delta x = 39 \times 10^{-3}$, $\Delta y = 15.4 \times 10^{-3}$.



served, e.g
centration

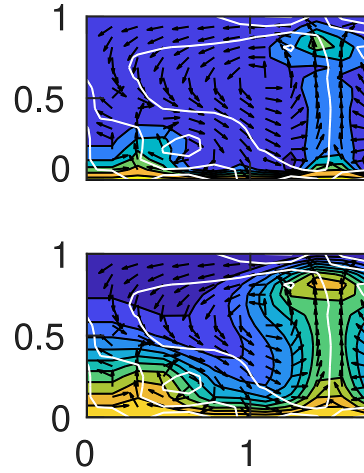


Figure 3:Th
the sea.

Conclu

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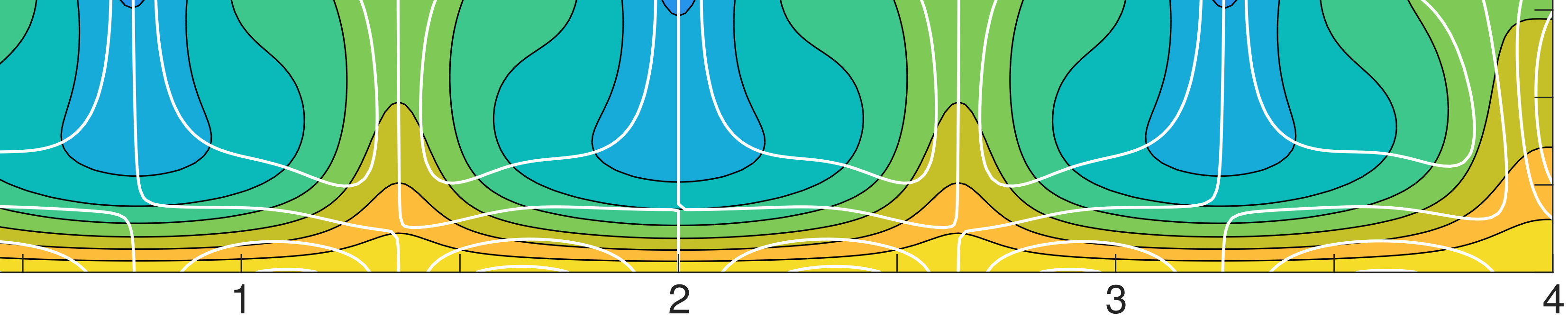


emperature and mass concentration for different times.

ergence

get a reliable reference it is necessary both y fine grid and pretty small time step.

Spatial Convergence order					
u	1.5339	v	1.3119	T	0.3145

the size

- Even w implem the gen

Pendin

- A solve conside not wo
- An imp FTBS Reynol

Convection

And the plankton?

ackton is the base of the oceanic food

sinks in the oceans upto 160m per year
swimmers).

perature in the ocean may vary up to
er year.

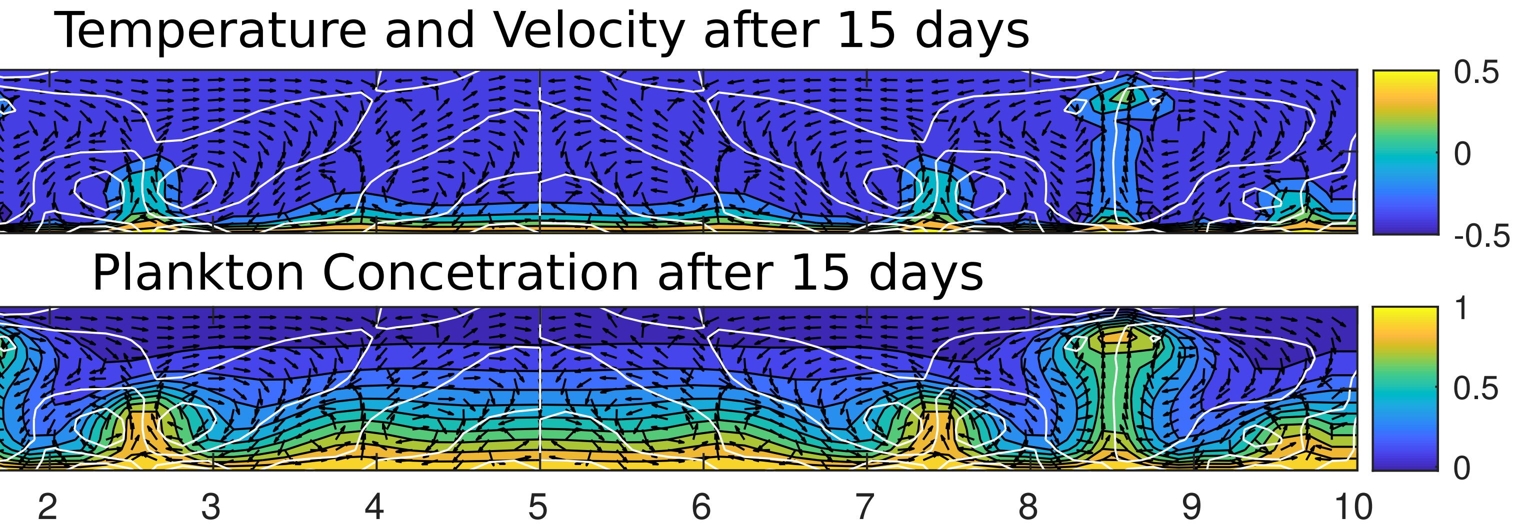
yancy forces keep them in specific regions
.

d to study the effects of variations on tem-
around $2°K$ in a big rectangular area in
160m deep, 1.6km wide) with planktonic
s in the bottom, getting as parameters:

$$= 184269,\ Pr = 7.56,\ Pe = 6965.39$$

the Reynolds number in enormous, some
tructure of this phenomena may be pre-

g. the number of cells or the average con-
n in specific areas.



ermal convection with planktonic mass transfer in

Final Thoughts!

sions

ehavior of the thermal cells depends on

e of the spatial discretization.

vith high Reynolds numbers the
nented method seems to show properly
neral structure of the fluid.

ngs

er using the projection method was
ered, however, the staggered grid was
rk as expected for the energy equation.

plementation using the second order
scheme will help to deal with higher
lds numbers.