This course material has been developed from the SimDataLab “Engineering in Energy and Mobility” (Project NHR@KIT) and the Engineering Competence Center (Project s5 of bwHPC) – both being parts of the Steinbuch Centre for Computing (SCC) at the Karlsruhe Institute of Technology

The course material should be used mainly for purposes of the course “Introduction to OpenFOAM” and may be shared between the users of the supercomputers of SCC as well as of the users of all bwHPC supercomputers

Tutorial: BwUniCluster 2.0/HoreKa
Hot Radiation Room

In this tutorial we will learn about the simulation of radiative heat transfer in OpenFOAM on multiple cores by submitting a job. We will do it using the example hotRadiationRoom from the series of built-in OpenFOAM tutorials.

1. Tutorial Case

First, we should copy the tutorial case from the FOAM_TUTORIALS directory and paste it into our workspace (denoted by a point):

```
$>  cd <workdir>
$>  module load cae/openfoam/v2106-impi
$>  source $FOAM_INIT
$>  cp -R $FOAM_TUTORIALS/heatTransfer/buoyantSimpleFoam/hotRadiationRoom/ .
$>  cp $FOAM_TUTORIALS/multiphase/compressibleInterFoam/laminar/depthCharge3D/system/decomposeParDict hotRadiationRoom/system
```

2. Creating the Mesh

The mesh in the hotRadiationRoom tutorial represents a 10m x 6m x 2m room equipped with a heat source in the corner of its floor.

In order to create the mesh using data from the blockMeshDict-file, we will use the following command:

```
$>  cd hotRadiationRoom
$>  blockMesh
```

Apart from describing the basic structure of the mesh, the blockMeshDict file also defines boundaries, also known as patches, for which special conditions will be set. In our case these areas are: floor, ceiling, fixedWalls and box. To view the file you can use the command:

```
$>  more blockMeshDict
```

The mesh is shown in Fig. 1. Figures 2, 3 and 4 show the different boundary patches.

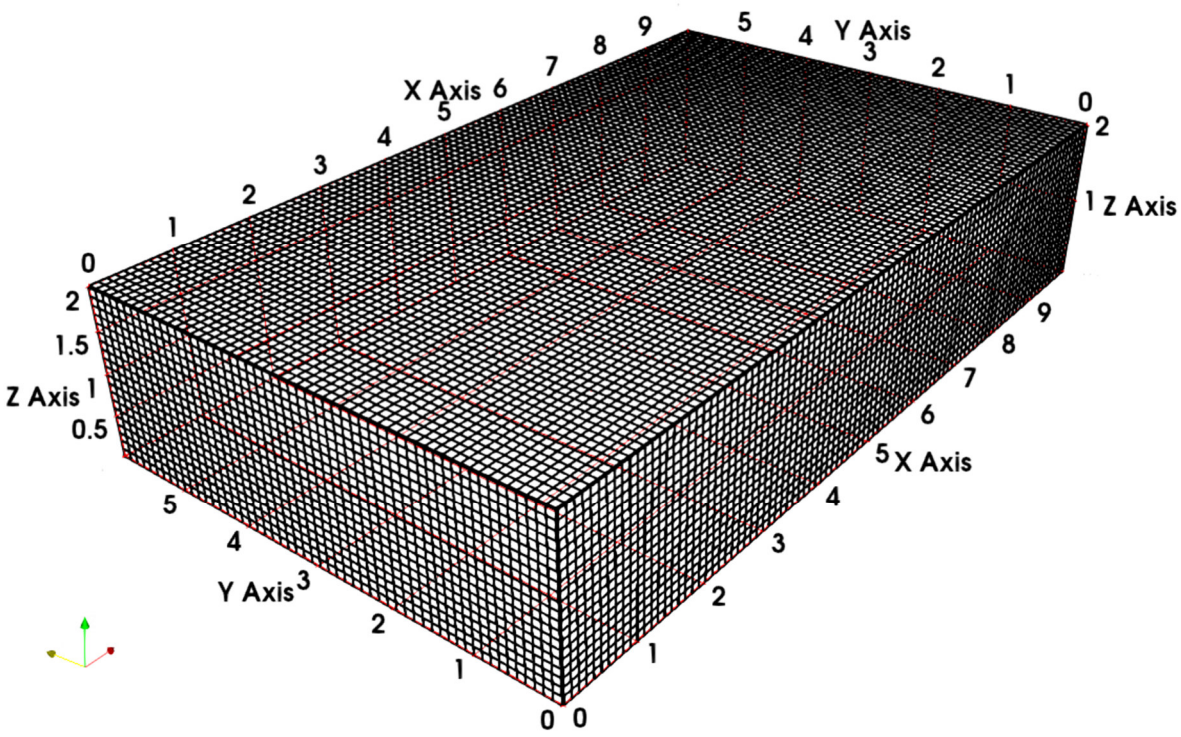


Fig.1 The hotRadiationRoom mesh created using blockMesh

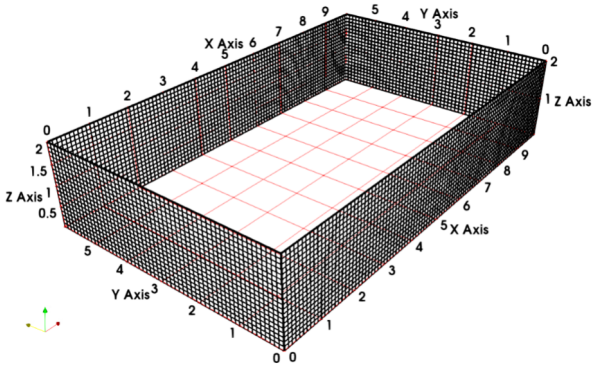


Fig.2 Boundary patch "fixedWalls"

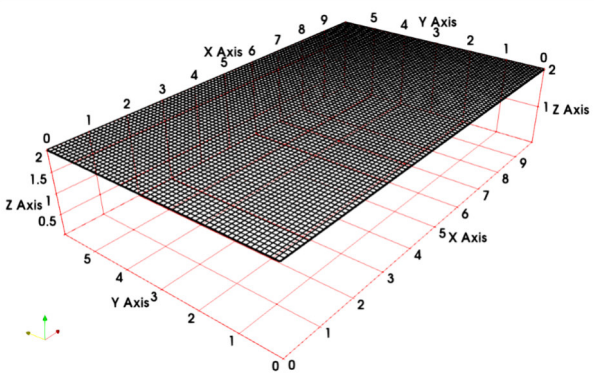


Fig.3 Boundary patch "ceiling"

Fig.4 Boundary patch "floor"

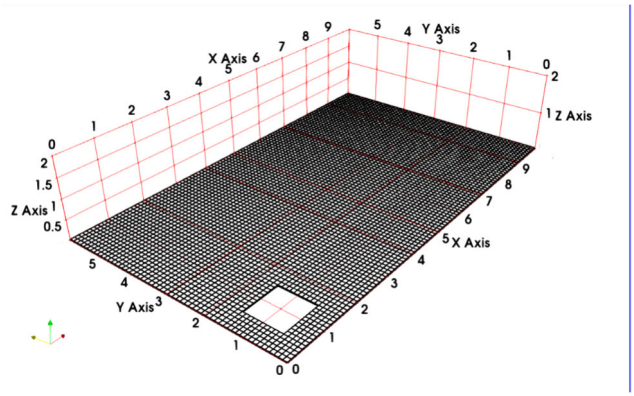
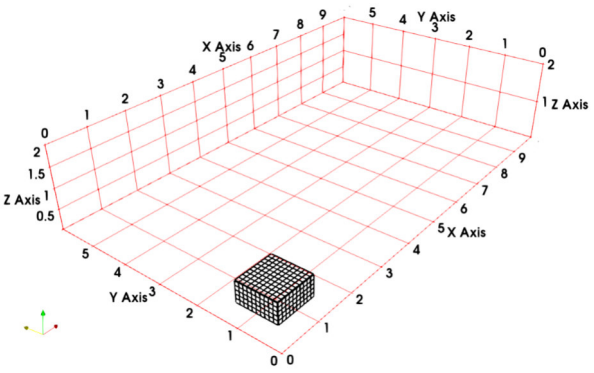


Fig.4 Boundary patch "box"



In this case there will be a heat source with the temperature of 500 K in the box patch:

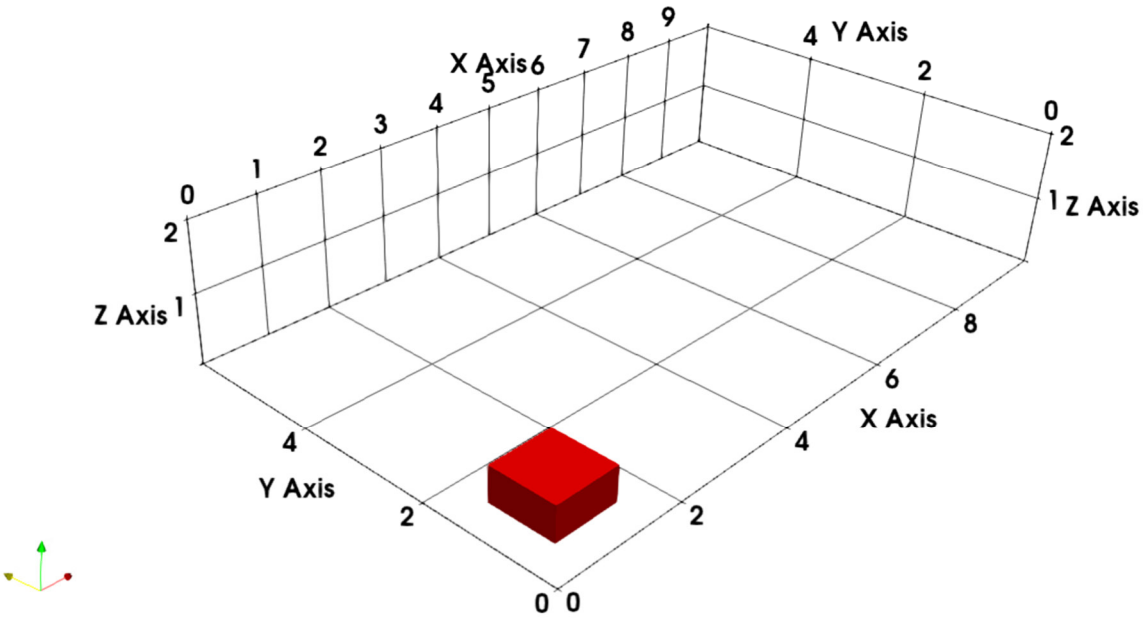


Fig.5 The heat source in the box patch

Since we will be conducting parallel computation, we also need to decompose our mesh into subdomains using the following commnad:

```
$>   decomposePar
```

This creates a directory for each of the eight processors (cores).

We want to conduct the simulation on 8 cores, therefore our decomposeParDict-file should look somewhat like this:

```
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //

numberOfSubdomains 8;

method          hierarchical;

coeffs
{
    n           (2 2 2);
}


// ************************************************************************* //
```

Now it is time to submit the job for calculation. Assuming we are conducting the simulation on a multiple cores the batch job file (name e.g. my_dev_multi_job.sh) should look something like this:

```
////////////////////////////////////////////////////////////////////////////////

#!/bin/bash                                  <-- header of the file

#SBATCH --partition dev_multiple             <-- job will be submitted to queue dev_multiple
#SBATCH --nodes=2                            <-- two nodes will be used
#SBATCH --ntasks=8                           <-- ntasks means „the number of cores”  to use
#SBATCH --time=00:30:00                      <-- the job will run for maximum 30 minutes
#SBATCH --mem=8000mb                         <-- the job may use max. 8 Gb
#SBATCH --job-name=hotRadiationRoom          <-- this name is given by the user

module purge                                 |
module load  cae/openfoam/v2106-impi         |-- loading OpenFOAM on the execute core
source $FOAM_INIT                            |
mpirun -n 8 buoyantSimpleFoam -parallel      <-- the name of the OpenFOAM-solver

////////////////////////////////////////////////////////////////////////////////
```

Note!: On HoreKa use dev_cpuonly instead of dev_multiple

We can then submit the job using the name of the job-file with the following command:

$> sbatch my_dev_multi_job.sh

After the simulation has been completed we can combine the results from different cores into one using the command:

$> reconstructPar

We can also continue without reconstructing. In that case we will be able to visualize results from different processors (decomposed case) as well as the reconstructed case in Paraview.

3. **Results**

After the simulation has been completed we can download the results onto our personal computer and visualize them in Paraview. This is the recommended way for visualizing results with small- or medium-sized grids which is the most common case.

We can now examine the steady state of the heat transfer in the room which has been achieved after 935 iterations. The following images depict the central plane of the control room from the top-down view with the box patch located in the bottom left corner:

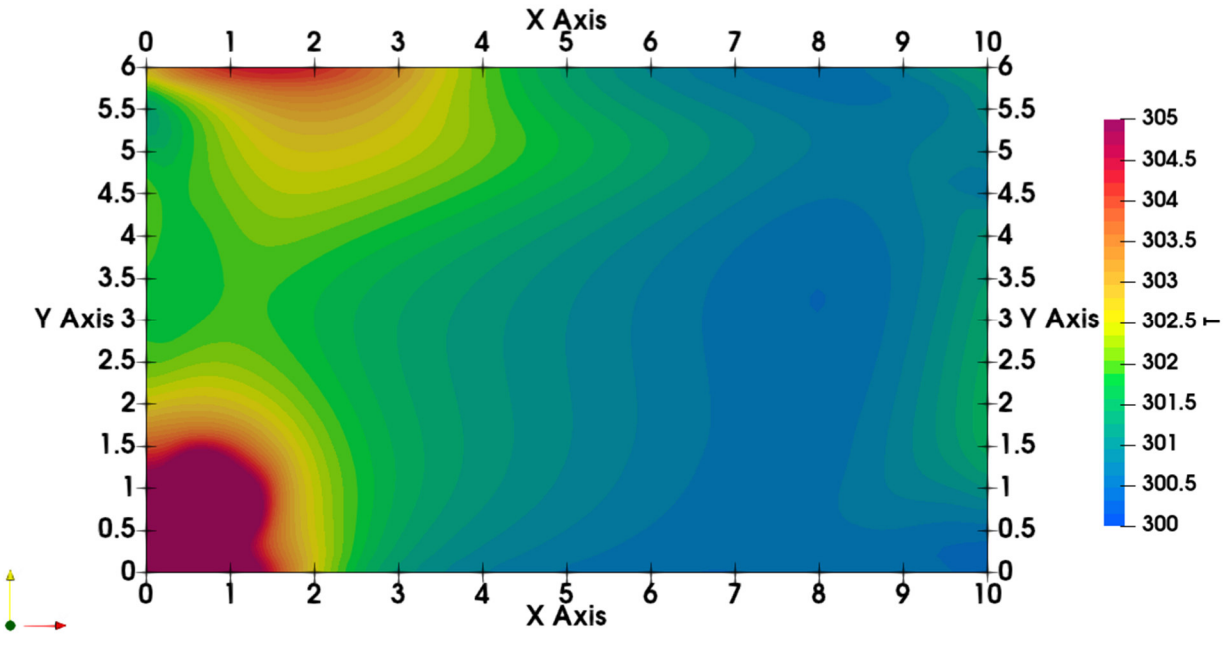


Fig.6 Temperature from the horizontal (top-down) view [K]

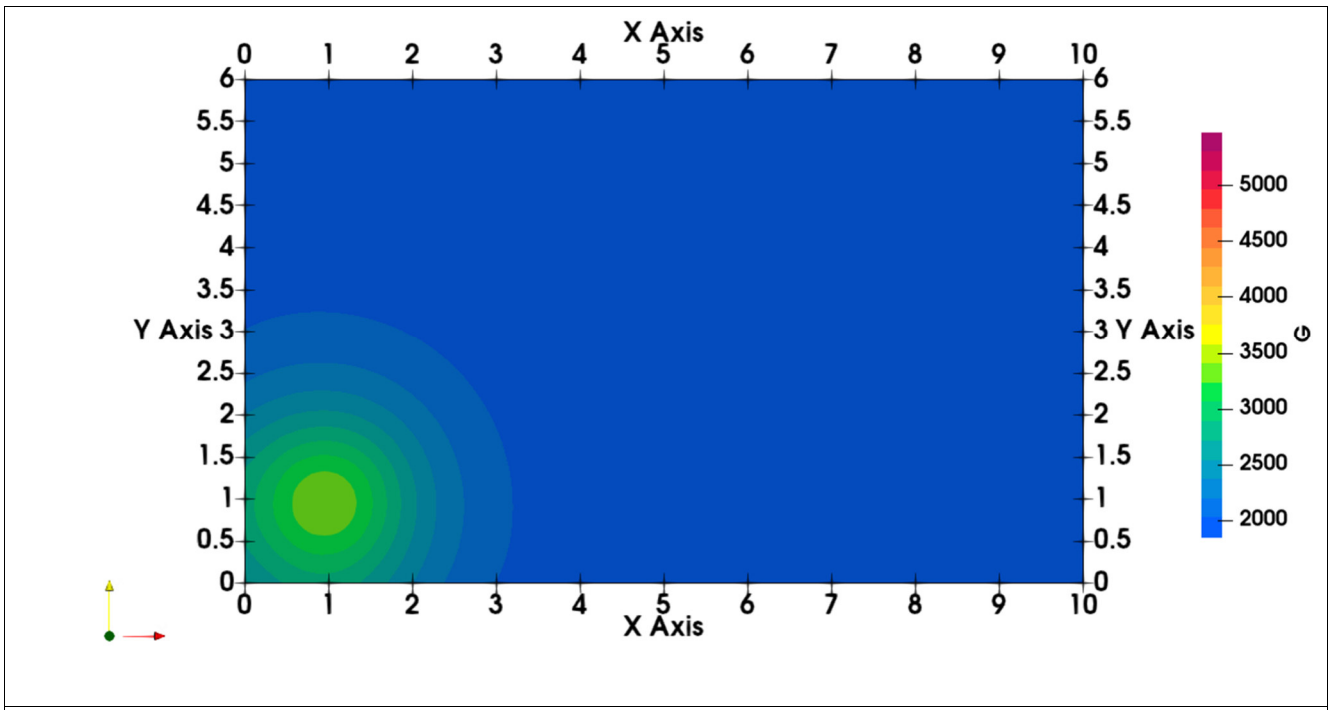


Fig.7 Radiation Intensity „G" from the horizontal (top-down) view [W/m^2]

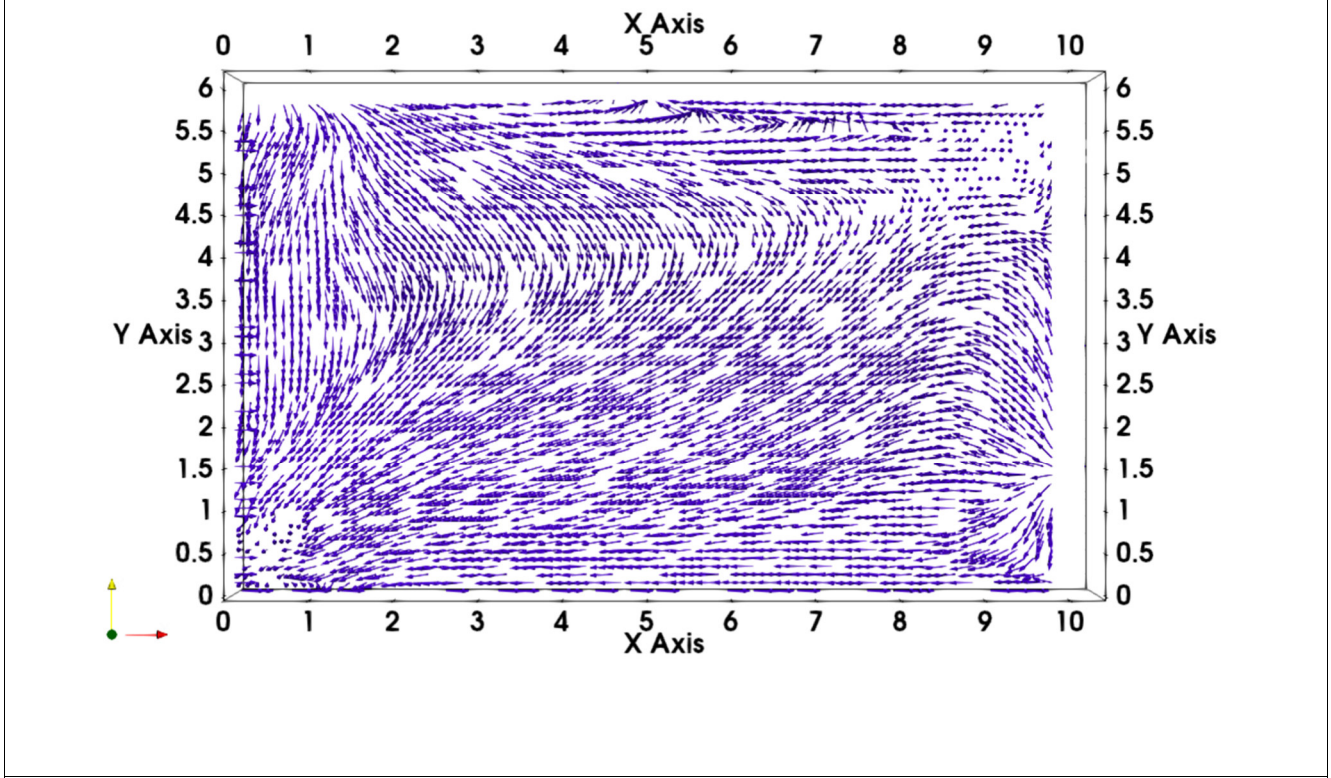


Fig.8 Velocity from the top-down view [m/s]

As one could have expected, the heat transfer caused by radiation is prominent exclusively in and above the box patch due to absorption of the medium. The remaining heat transfer as well as the mass transfer take place due to convection.

Another place worth looking at is the Y-normal plane going through the box patch:

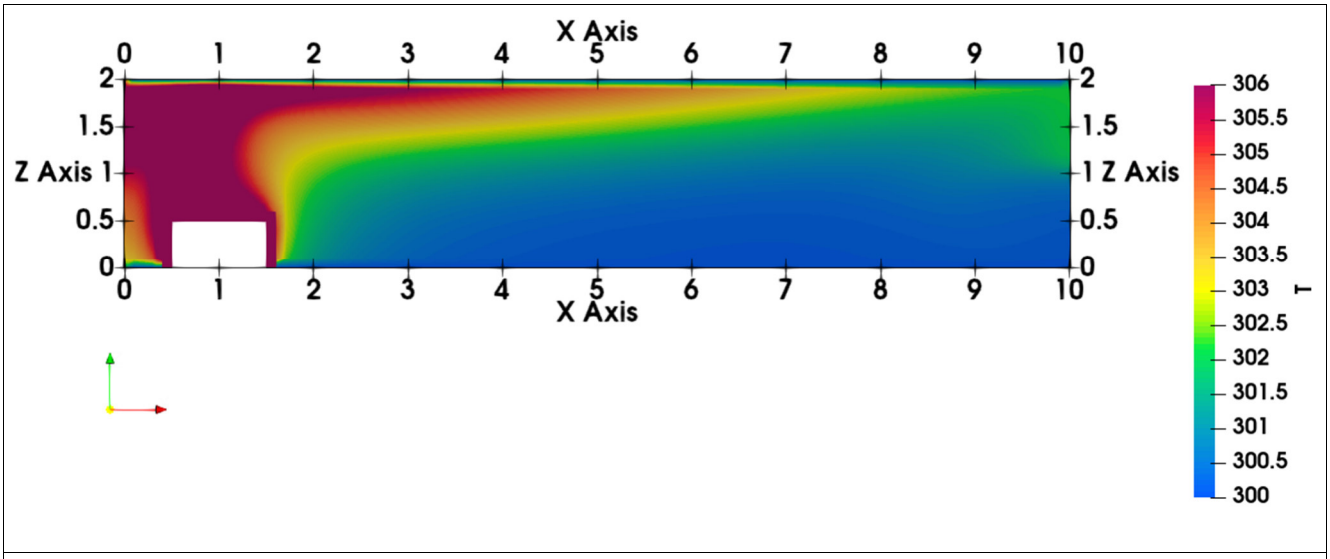


Fig.9 Temperature as viewed from the side [K]

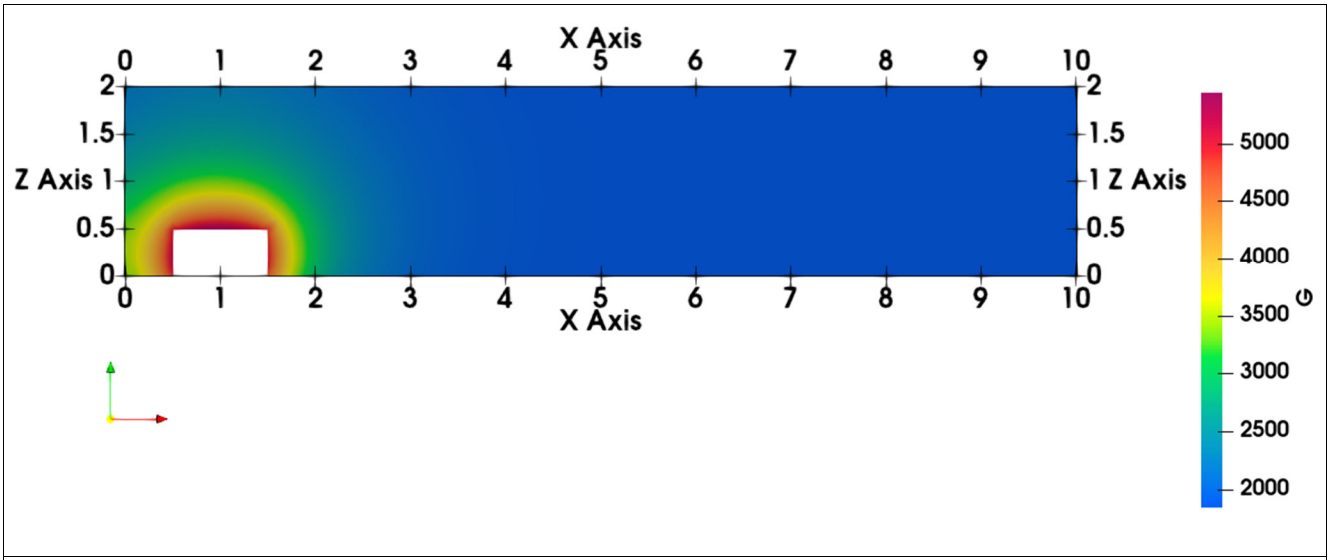


Fig.10 Radiation Intensity „G" as viewed from the side [W/m^2]

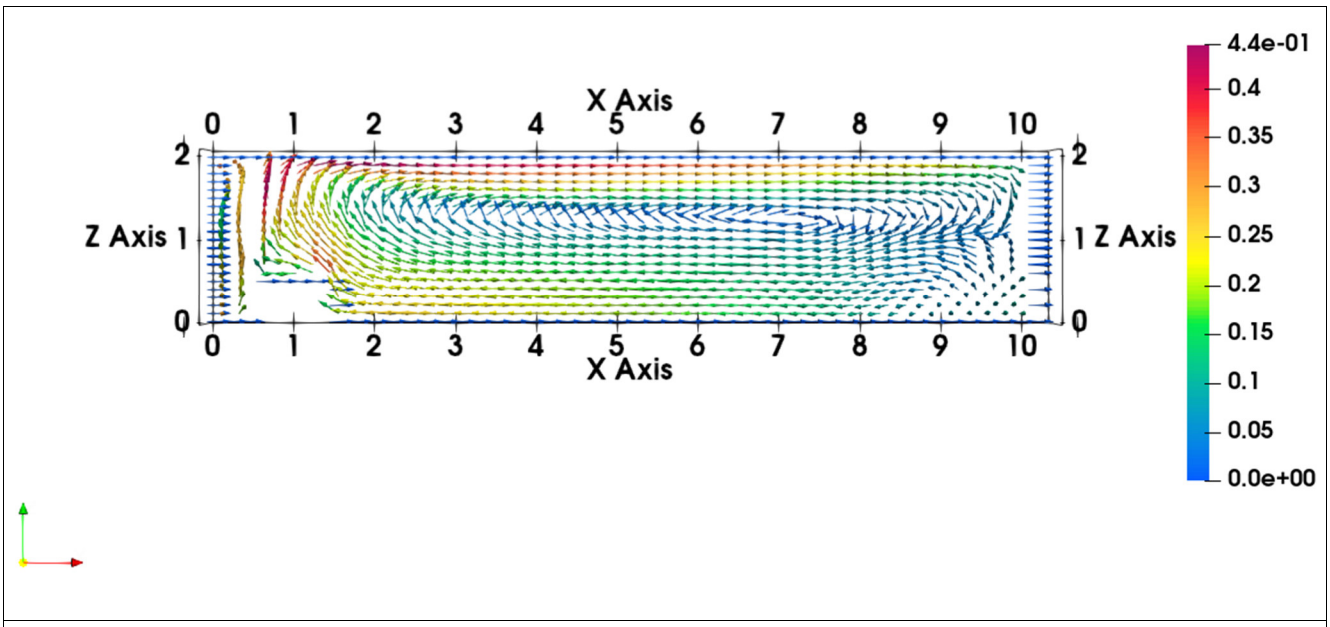


Fig.11 Velocity as viewed from the side [m/s]

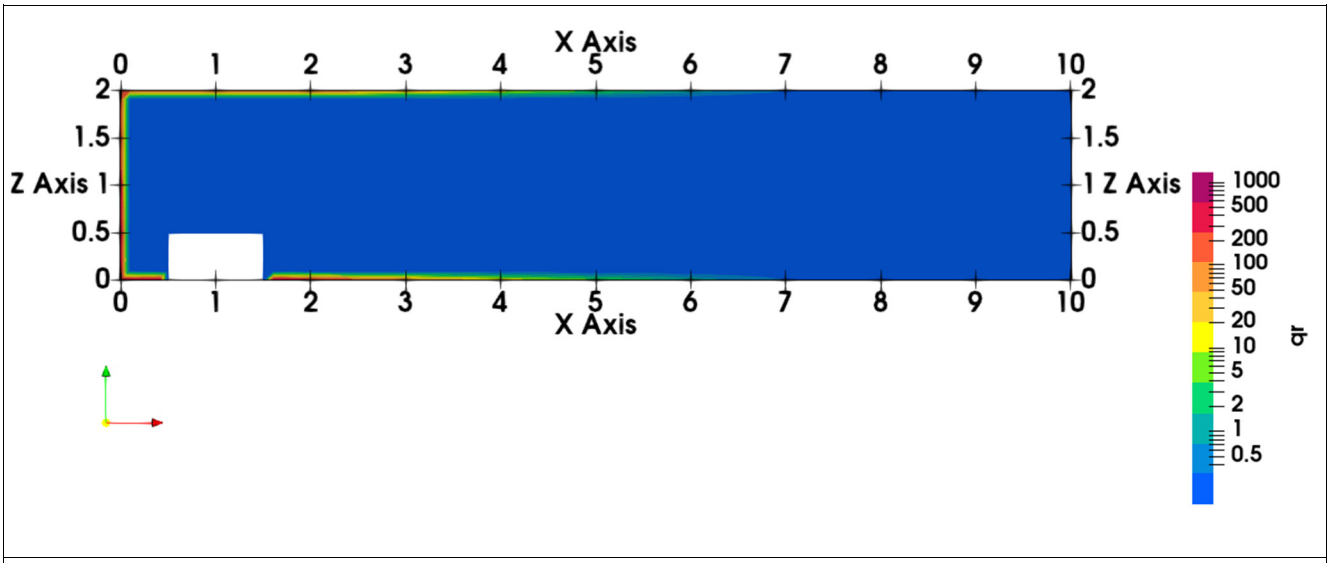


Fig.11 Radiative heat flux „qr" as viewed from the side [W/m^2]

As expected, the radiation coming from the box causes the air arround it to heat up. Then, due to convection, the hot air moves towards the ceiling where it cools down which drives the circulation in the room.

Legend

a	Absorption coefficient	[1/m]
alphat	Turbulent thermal diffusivity	[m^2/s]
epsilon	Turbulent kinetic energy dissipation rate	[J/kg/s]
G	Incident radiation intensity	[W/m^2]
qr	Radiative heat flux	[W/m^2]
phi	Mass flow	[kg/s]
k	Turbulent kinetic energy	[J/kg]
nut	Turbulent viscosity	[m^2/s]

The names in the leftmost column are the variables in the 0 directory.