Activity/**Homework 1** – 2d turbulence

Introduction

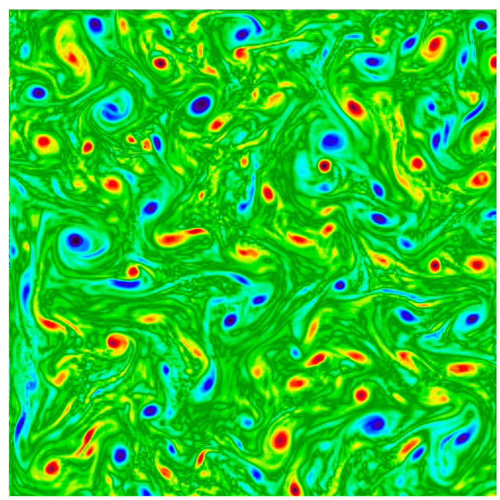
You need to provide a written report for this homework, which will be used for the evaluation of the Turbulence course. Due date is: **March 22, 2024**

During this activity, we will use the **fluid2d** code to run two dimensional turbulence.

The documentation can be found here: https://github.com/pvthinker/Fluid2d/tree/master/docs (see in particular the equations of the model)

Get and run the script

Download Fluid2d: **git clone https://github.com/pvthinker/Fluid2d.git Fluid2d**



You will need a python env. with the following modules:

- mpi4py >= 2.0.0
- netCDF4
- matplotlib
- numpy
- scipy

On LOPS/IUEM computer you just need to do:

module load phyocean/2023.05

Then install the code:

- **cd Fluid2d**
- **./install.sh**

Then each time you open a new terminal you need to do:

- ***source ~/.fluid2d/activate.sh*** if you're under bash
- *source ~/.fluid2d/activate.csh* if you're under csh/tcsh
- *source ~/.fluid2d/activate.fish* if you're under fish

Run an experiment:

- **cd myexp/Twodim_turbulence/freedecay**
- **python freedecay.py**

The code displays an animation of the vorticity while it is being computed. The results are saved in two NetCDF files (saved in $HOME/data/fluid2d/) for snapshots of the model and diagnostics (energy, enstrophy, etc.)

2d Turbulence

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1. Free decay (without forcing)

a) Run a first experiment in free decay (free_decay.py)
b) Look at the evolution of vorticity and tracer and see how vortices get bigger and fewer with time. This is the inverse cascade of K in action.
c) Look at the evolution of bulk quantities (in the diagnostics file): energy (K), enstrophy (V), and circulation (Γ). Observe the dissipation of K and V and the conservation of C.
d) Redo the experiment with the same initial vorticity field but multiplied by a factor 10. What is changed?
e) Redo the experiment with the slightly perturbed initial conditions *(uncomment line 97 in the user script)*. Monitor how it diverges from the first experiment.
f) Plot a power spectrum at different times of the simulation and monitor its evolution *(You can find power spectra examples in the script "myexp/Twodim_turbulence/spectrum_analysis.py")*. You should see that large scales (small k) get progressively energized. This is a more accurate evidence of the inverse cascade of energy in action.

2. Forced-dissipative cases

a) Go to myexp/Twodim_turbulence/turb2d_forced and Run two other experiments with:
    a) forcing at small scale (energy_cascade.py)
    b) forcing at large scale (enstrophy_cascade.py)
b) Plot the evolution of kinetic energy and enstrophy in the system for the two experiments
c) Plot energy density spectra at different times, and check if it is converging to a $k^{-5/3}$ or a k^{-3} spectrum.
d) Challenge: try to excite both cascade by setting forcing at an intermediate scale. You may need to increase the model resolution, but . . . if you do so, the simulation time will be multiplied by a factor 8.

3. Mixing and stirring

e) Look at the 'tracer' field in the experiments you have done so far. The tracer is passive, meaning it is simply transported by the velocity, without retroacting on the flow – contrary to vorticity, which is an active tracer.
f) Look how eddies are able to trap tracer over long periods of time and long distances. Trapping is an important properties of coherent structures.
g) Look how eddies induce stirring and how stirring enhance mixing. The initial distribution of tracer correspond to tiles with values 0, 1 and 2. What are the tracer values when it is fully mixed?

h) Plot the probability density function (P.D.F.) of the tracer concentration at different times. Without any mixing, it should be invariant in time. How does it evolve here? What does it mean for the tracer variance?