Activity 1 – 2d turbulence

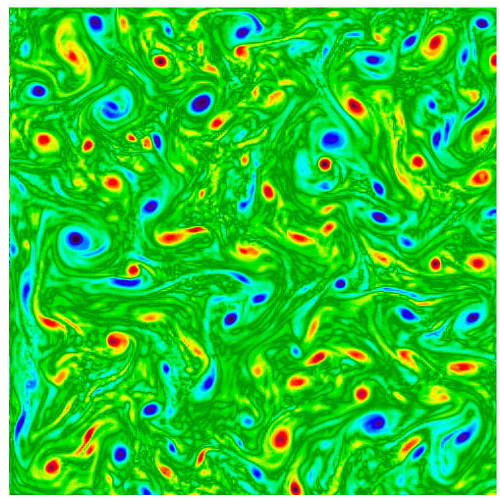
Introduction

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

The documentation can be found here: http://mespages.univ-brest.fr/~roullet/fluid2d/ (see in particular the equations of the model)

Get and run the script

Download and unzip Fluid2d from: https://github.com/pvthinker/Fluid2d



Download experiments energy_cascade.py and enstrophy_cascade.py from here: jgula.fr/Turb

Install:
- Fluid2d-master.zip
- cd Fluid2d-master
- make
- (in bash) source activate.sh
- (in csh) source activate.csh

Run the experiment:
- cd experiments/TwoDimTurb
- python inverse_cascade.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

1. Free decay (without forcing)

a) Run a first experiment in free decay (inverse_cascade.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: 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 95 in the user script). Monitor how it diverges from the first experiment.
f) Monitor the time evolution of the energy spectrum (with the notebook). 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) 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. Because of the initial distribution of tracer (tiles of value 0, 1 and 2), when the tracer is fully mixed the value is 1. Of course, you may design a different tracer distribution.
h) Monitor the evolution of the probability density function (P.D.F.) of the tracer concentration. Without any mixing, it should be invariant in time. The mixing causes the P.D.F. to shrink around the mean value of c, thereby reducing its variance.