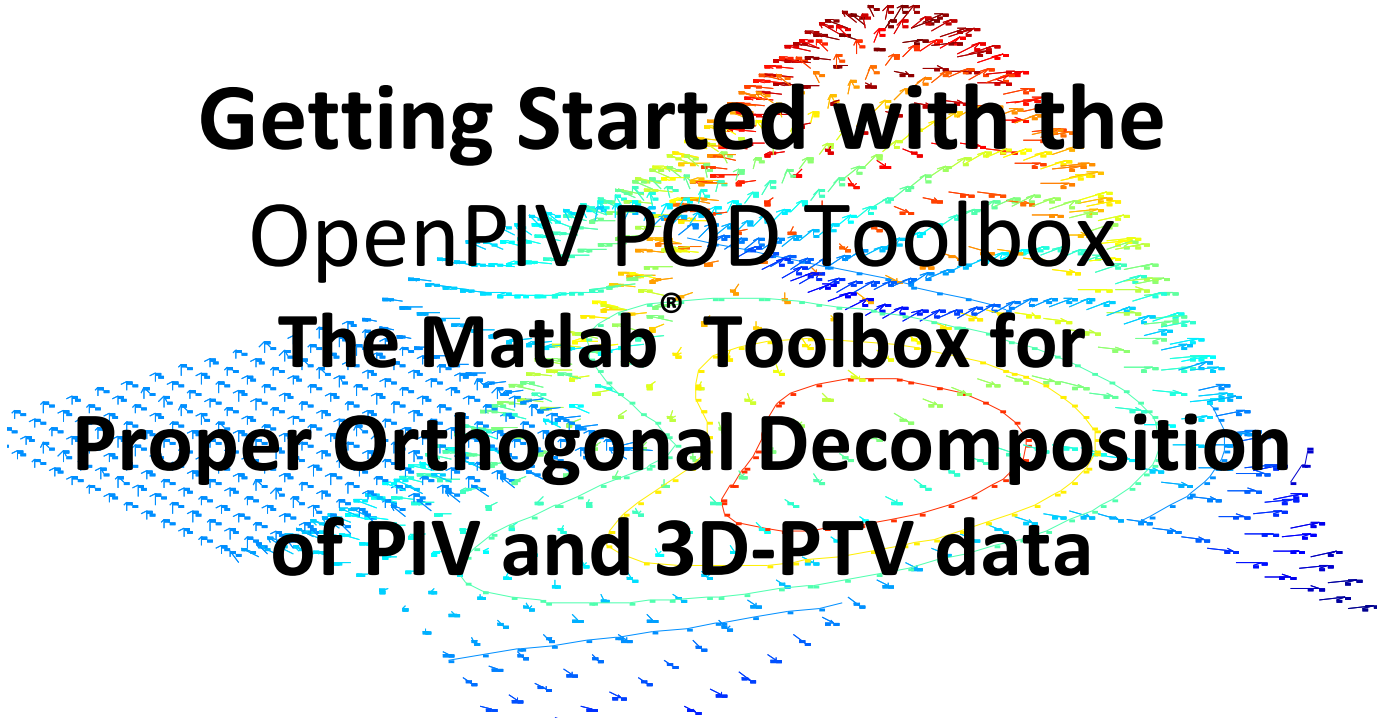
Getting Started with the OpenPIV POD Toolbox

The Matlab® Toolbox for Proper Orthogonal Decomposition of PIV and 3D-PTV data



OpenPIV is an open source particle image velocimetry software, http://www.openpiv.net

Getting started with**OPENPIV-POD Toolbox**

Introduction

OPENPIV-POD Toolbox (hereinafter will be denoted as "POD Toolbox") calculates **Proper Orthogonal Decomposition** of the velocity fields, measured with Particle Image Velocimetry (**PIV**) and it is devoted to the POD analysis, visualization and interpretation of the results.

Installation

Unpack the `podtoolbox.zip` into directory `$matlabroot$\work\podtoolbox` (recommended), where `$matlabroot$` is the path of the Matlab® installation, e.g. C:\Matlab704.

Run

1) On Windows run the RUNPOD.BAT file, e.g., Start - Run: `"runpod.bat"` + Enter.
2) a) Start Matlab

   Note: It is recommended to run the toolbox without loading Java Virtual Machine (JVM) environment of Matlab. The memory consumption of Matlab without JVM is much lower and it is recommended if the user encounters "Out of Memory" errors or slow performance. In order to run Matlab in the 'text mode' change the command line of the icon to "matlab –nojvm" or Start – Run: "matlab -nojvm" (without quotes)

   b) Change the path to the directory with the toolbox, or add the toolbox's directory to the Matlab path

   - Change working directory by typing:

   » `cd c:\matlab704\work\podtoolbox`

   or (recommended)

   - Add the directory to the path by typing:

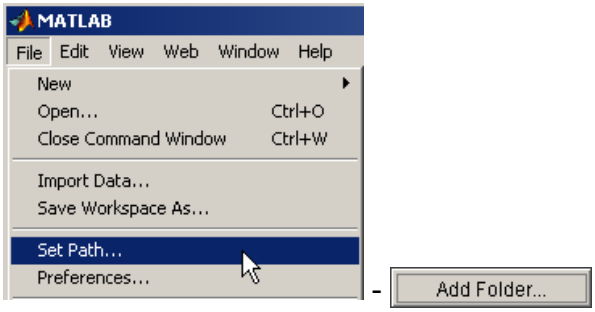
   » `addpath c:\matlab704\work\podtoolbox`

   c) Check that Matlab recognizes the toolbox by typing

   » `podbox`

   and pressing ENTER. If there is an error in command line that stays the PODBOX command is not recognized, check the path or repeat the above steps.

   It is also possible to add the POD Toolbox directory to the Matlab path with GUI (only under JVM environment):



The toolbox is developed and tested under Matlab 7.0.4 version, also called R14SP2 version or Matlab 7 Service Pack 2. The user may check the installed version by typing

```
» ver
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Getting started

Once the user runs the toolbox as it is prescribed in the previous section, the first window, like the one shown in following Figure 1, will appear:

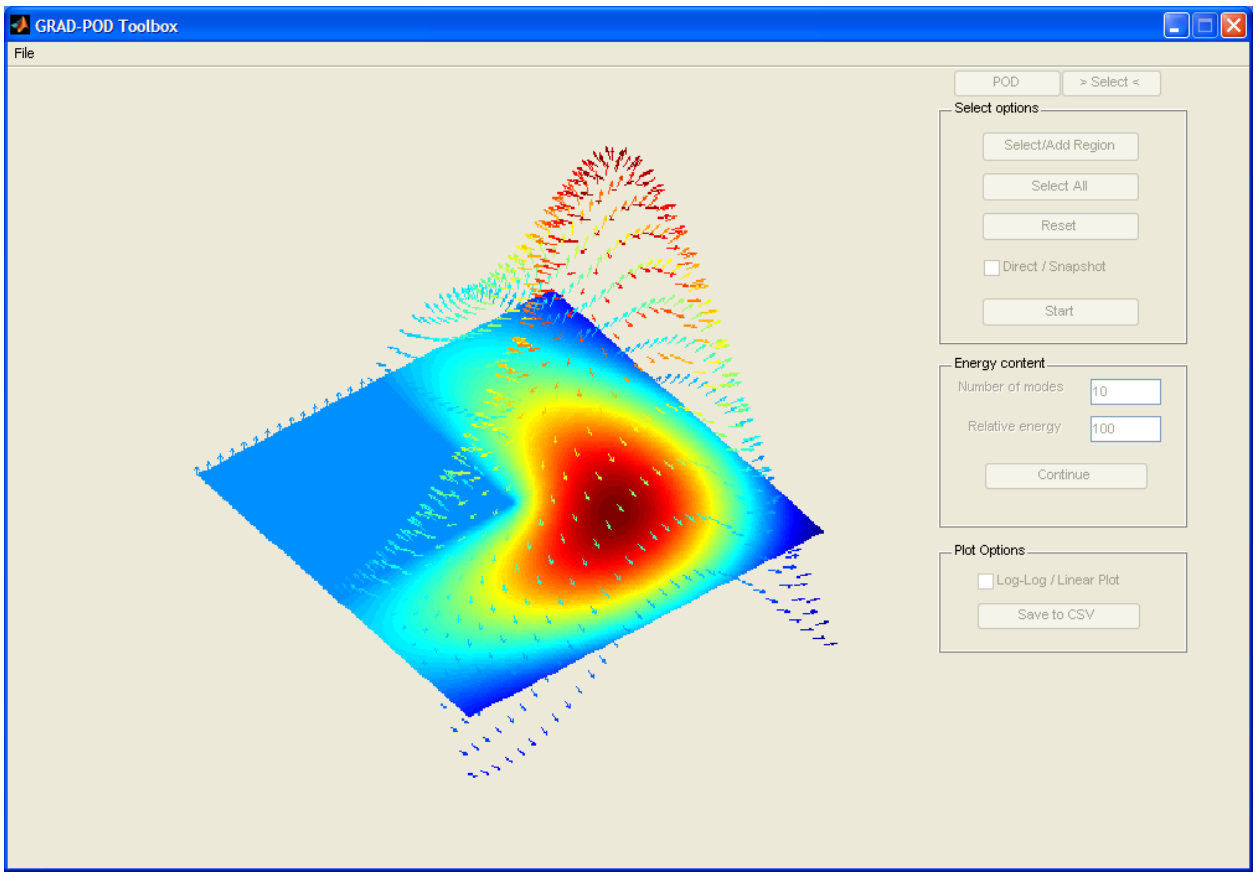


Figure 1: POD Toolbox GUI – the main window

At the top-left corner there is File menu, in the center there is a main axes and on the right-hand side there are GUI controls.

The POD Toolbox operation begins with loading the data. The data could be loaded as Insight® VEC files by using the menu: File - Load Vector Files.

The user can press the  button and then select the folder that includes the data files from the window, shown in Figure 2, or type the name of the folder instead of the default path. There is an option to double-click the '**..**' in the list of files box, or double click the name of the directory within the list in order to get the files in the subdirectory.

When the list of files is shown (see Figure 3), user might select more than one file with CTRL+Left-button mouse click, or by selecting the first file and the last file with holding the SHIFT button on the keyboard, thus extending the selection. The selected files could be loaded by pressing LOAD button. It is possible to cancel the operation by pressing CANCEL. It is impossible to select files from different subdirectories.

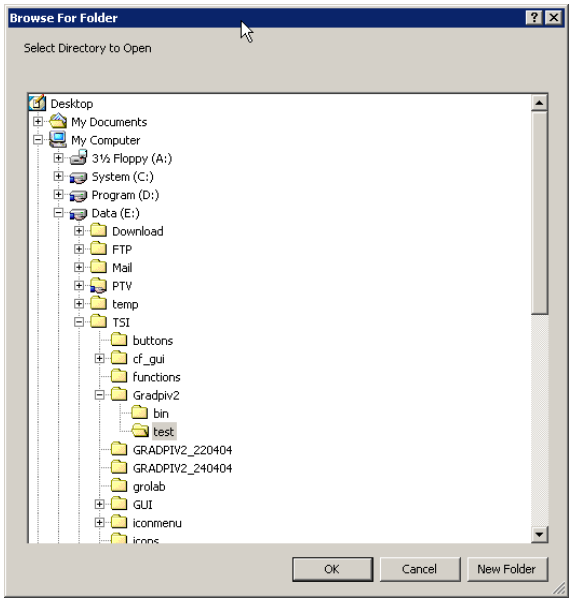


Figure 2: List of the directories to choose the path of the VEC files

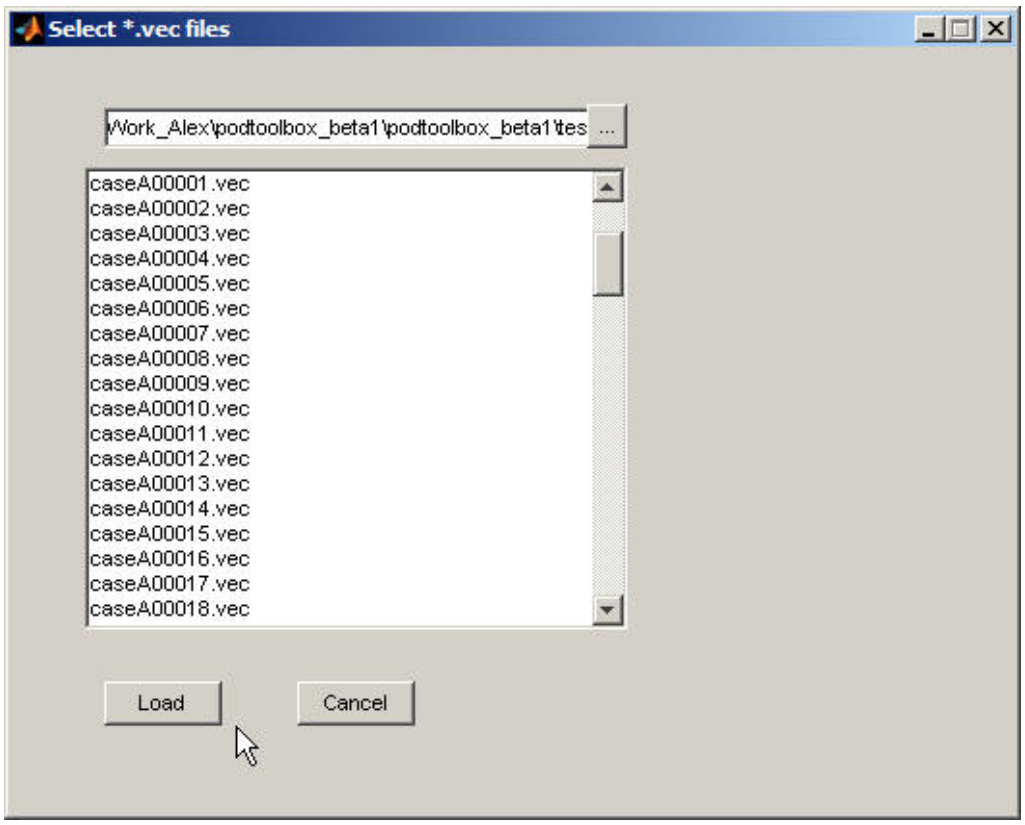


Figure 3: Selection of the files from the list. CTRL or SHIFT options are possible. Press LOAD button to finish the selection.

Press LOAD button to finish the selection. The POD Toolbox reads the vector files, and initializes the toolbox default variables. This part might take from several seconds to few minutes, depending on the length of the selected series and the size of each vector map.

Note: for the POD Toolbox, the order of the selected files is not important, the user might pick the last file first and after that the first file. During the loading procedure, the files will be automatically sorted in the ascending order of their file names. This default sorting procedure has not influence on the following POD analysis, in which the order of the fluid velocity snapshots has no influence on the calculated result. It is defined in the theoretical background of the POD analysis that the snapshots must **not** be correlated with each other.

Operating Instructions

When at least one vector file is selected, the select window appears allowing user to select region of interest:

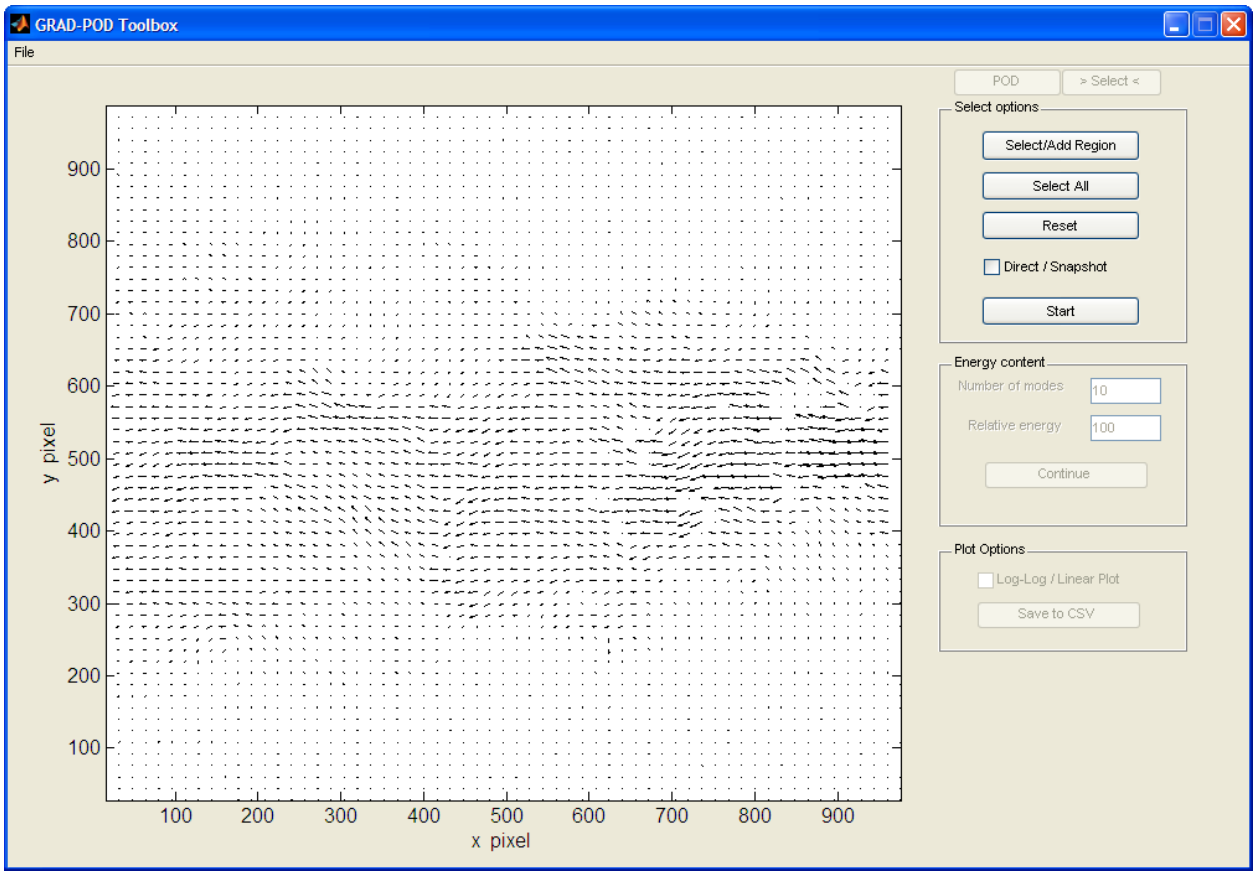


Figure 4: Default selection window.

Selection

Selection Tools – in selection tab, the following selection tools are present (see Figure 5)

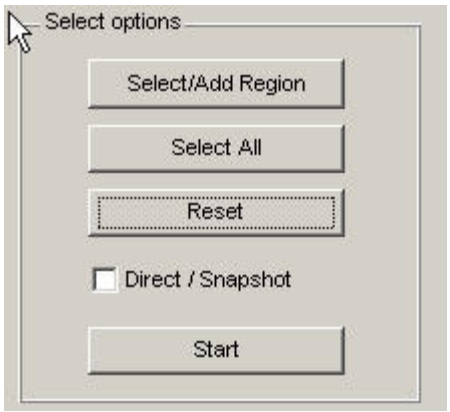


Figure 5: Selection tools

Select/Add Region – allows to select single region from the map (see Figure 6)

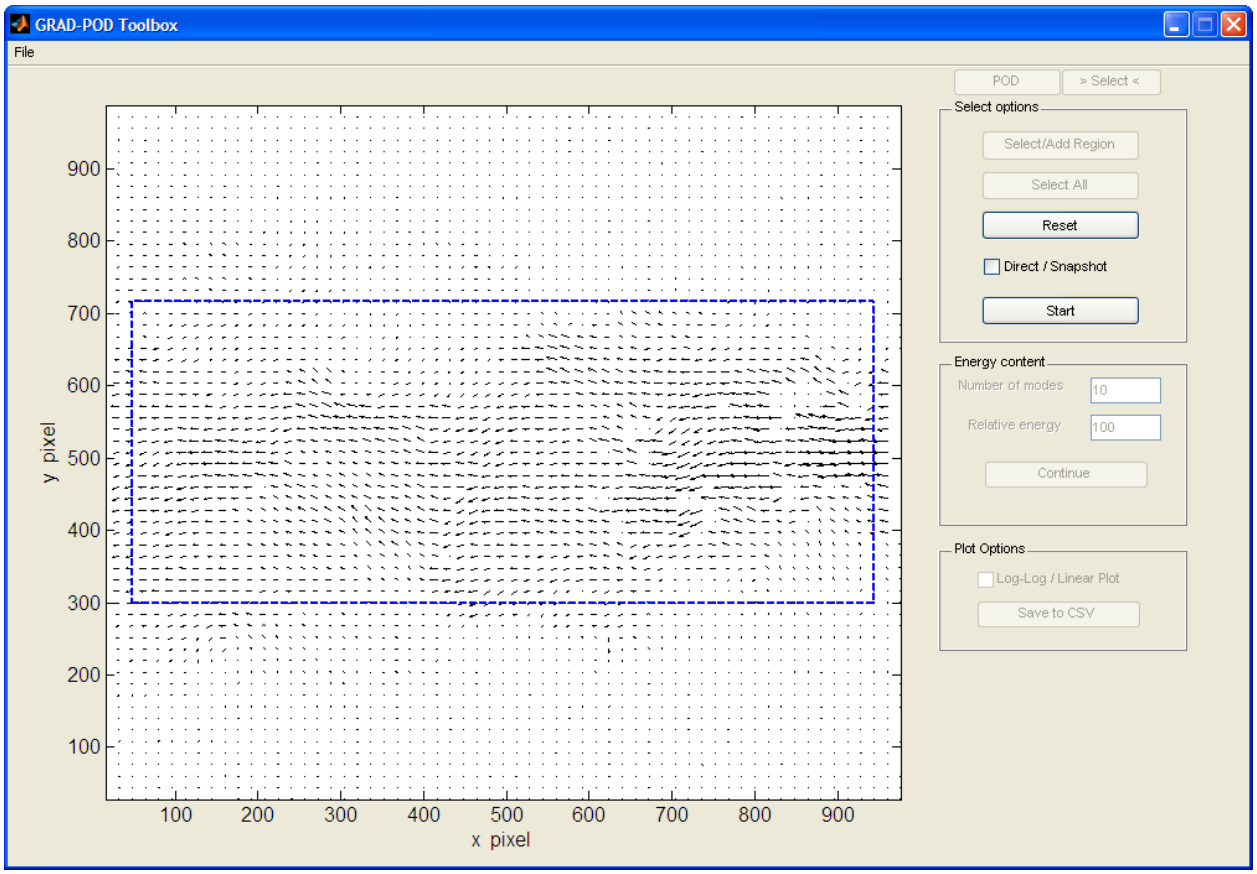


Figure 6: Selecting region

- Select All - Pressing 'Select All' will select the entire map (see Figure 7)

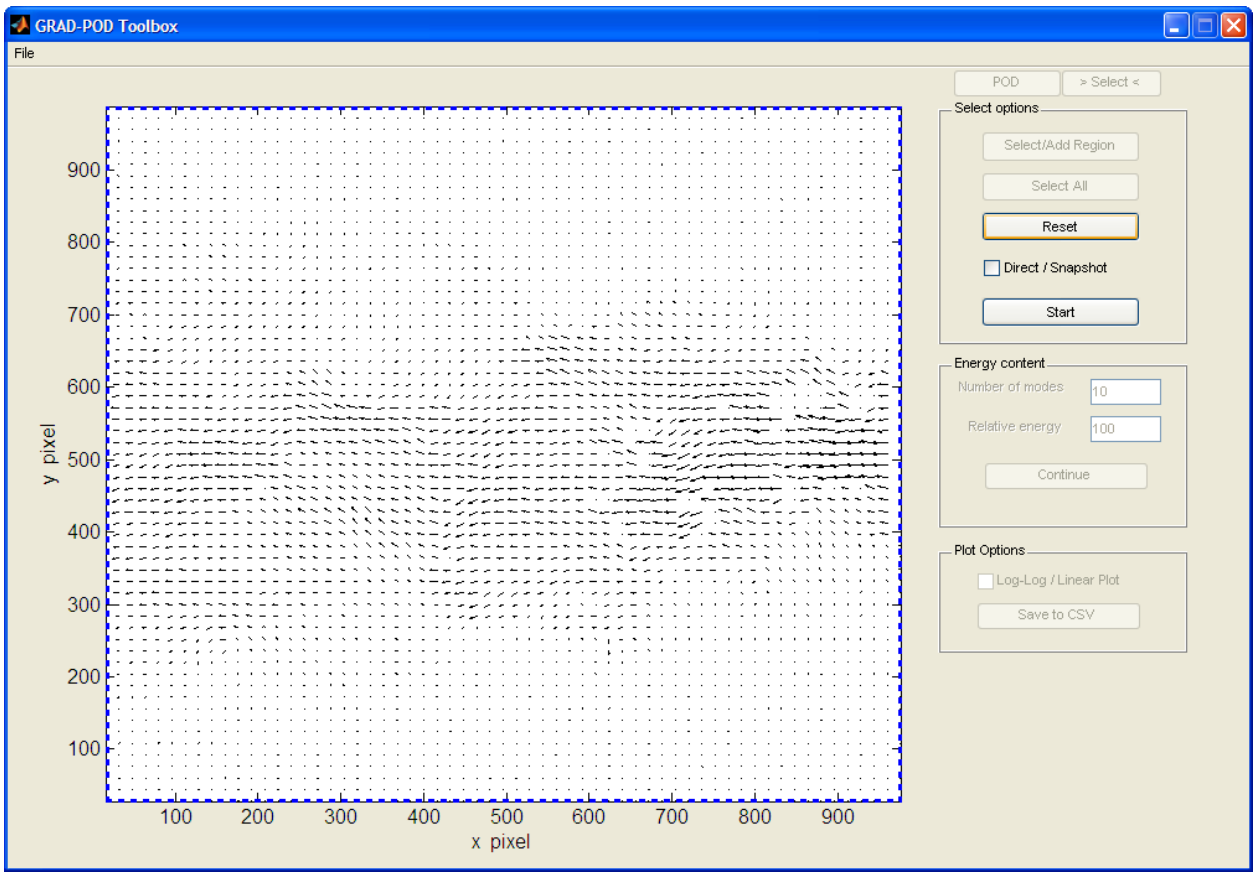
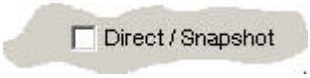


Figure 7: Selecting the entire map.

- When selection of region or selection of entire map is done, the only choice is to reset current selection and to do another selection, or to contiue with the current.
- Resetting of the current selection can be done with 'Reset' button

- Direct / Snapshot – this checkbox is checked and unchecked automatically by the software. There is still an option for the user to change the selection, however, the performance of the toolbox will be strongly altered. There are two methods to calculate the POD modes, as it is explained in details in theoretical and computational background: the direct method and the method of snapshots. The selection is done according to the minimal size of the input matrix, i.e. if the number of vectors is less than the number of the velocity vector fields, then the computationally efficient method is the direct method. Otherwise, the most efficient method is the method of snapshots. The recommendation is **not** to change the default selection of the software. Both methods lead, obviously, to the identical result.



- After selection region of interest, user may proceed to choosing the energy content by pressing the Start button

or to adjust the selection by pressing 'Reset' button

Choosing Energy Content

- After pressing the start button, plot of relative energy versus number of modes is shown:

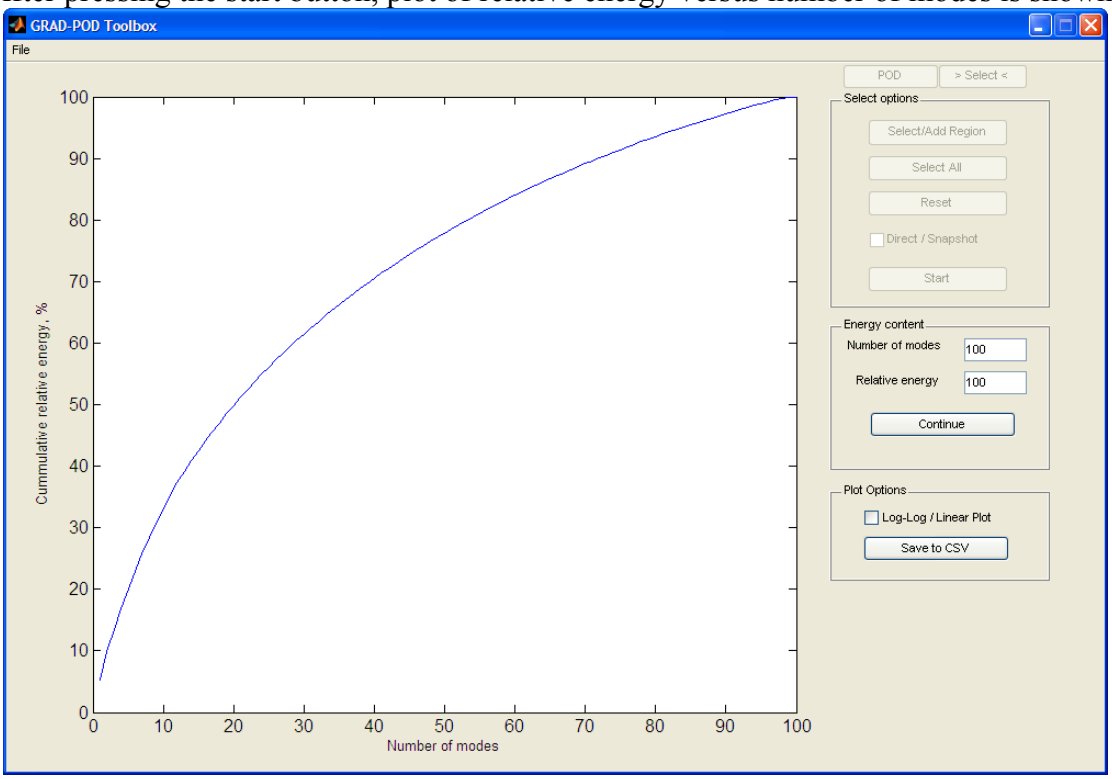


Figure 8: Plot of relative energy versus number of modes

and following controls are enabled (Figure 9) to let user choose number of modes or relative energy percent .User has 2 choices:

- To enter number of modes (minimum is 1, maximum is number of maps loaded), and press ‘Continue’ button. Related energy percent will be automatically calculated.
- To enter energy percent (1..100%), and press the ‘Continue’ button. Related number of modes will be automatically calculated.

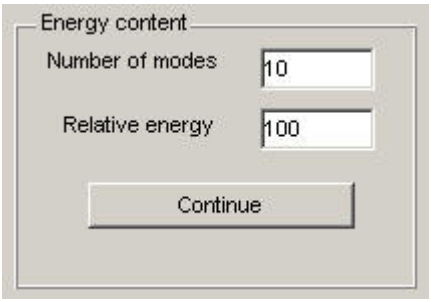


Figure 9: Energy content controls

- Energy plot can be switched to log-log (Figure 10) notation using the checkbox in plot options field (Figure 11).

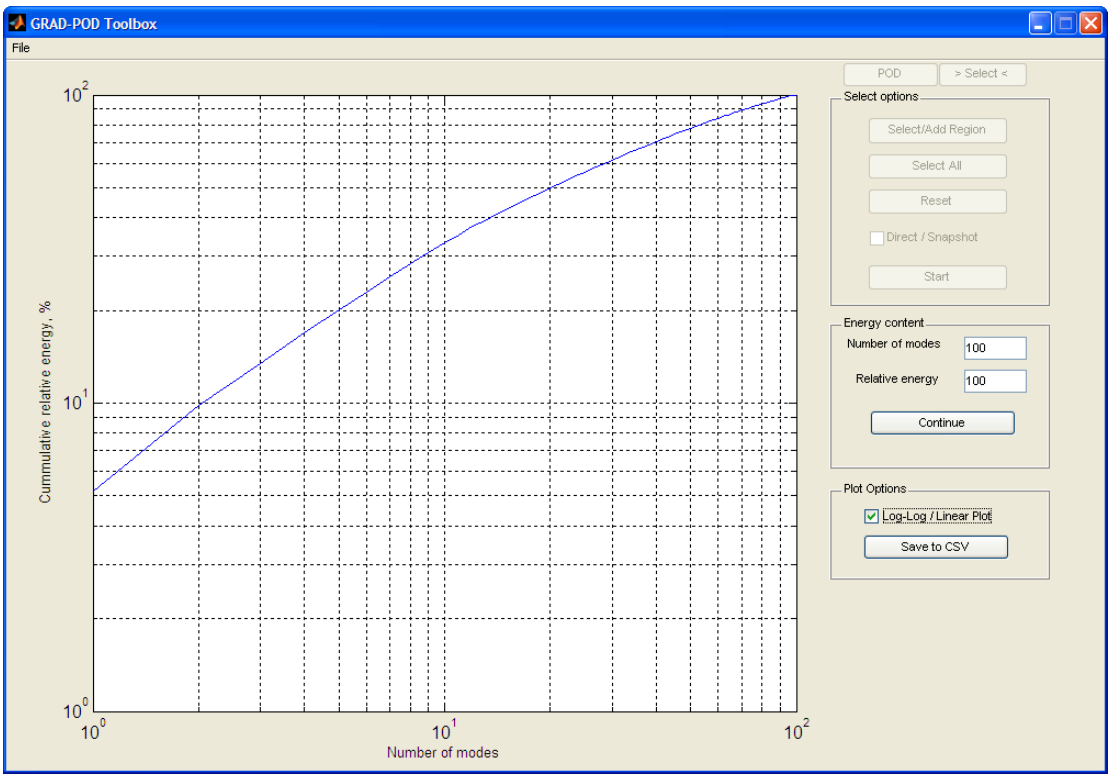


Figure 10: Energy plot using log-log notation

- Energy plot can be saved to CSV file using ‘Save to CSV’ button (Figure 11). When pressed, user will be asked for the filename to save:

Figure 11: Plot options field and file name dialog.

After pressing the 'Continue' button, default window looks like in the following illustration:

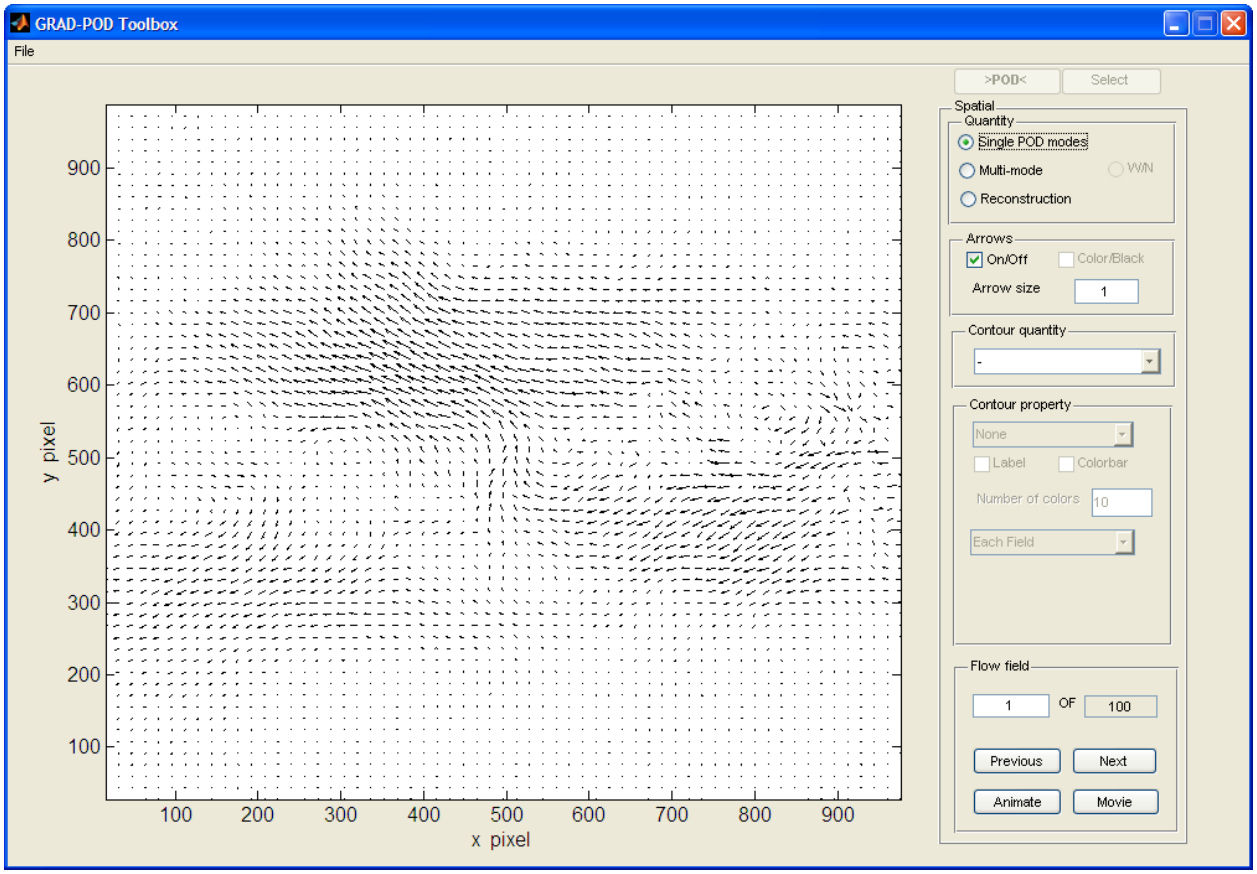
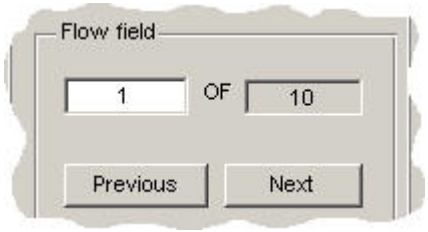


Figure 12: Default window, arrows, GUI controls, and main axes.

Navigation

- Navigation is done by the next/previous buttons, which displays next/previous maps accordingly

- To jump to specific map, enter number of the map in edit box, followed by Enter:



Available options:

The user might choose between one of the large set of various combinations to present its data: arrows in black or in color. The color of arrows could represent any one of the available quantities for that particular mode. The arrows could be on top of the contour map of the selected quantity, and contour could be as color patterns, bounded, or unbounded (smooth view), color or black contour lines. Below, in the working example, we show some of the combinations.

Controls:

Arrows

- On /Off – shows / hides arrows
- Color /Black – if turned on, arrows will be colored according to the current quantity

Contour Quantities

The user can choose the quantity that will be displayed in the list (see Figure 13).

The list of quantities is:

$u, v, \sqrt{u^2 + v^2}, w = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}, s_{xx} = \frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}, \frac{\partial v}{\partial x}, s_{yy} = \frac{\partial v}{\partial y}, \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}, s_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$ and in the same order they appear in the toolbox:

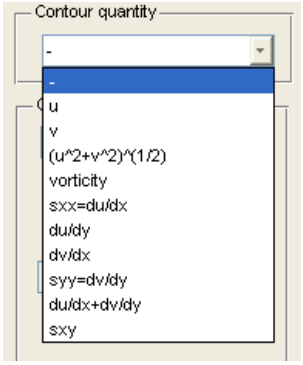


Figure 13: List of available quantities to use for a contour- or color-coding of an output.

Output options

The results could be presented in one of the following ways:

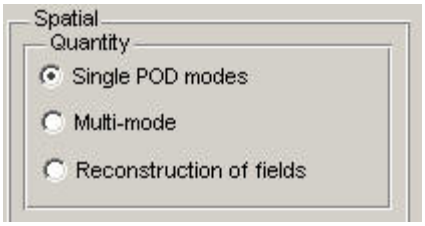


Figure 14: List of available ways to show the output.

Description of various ways to represent the output:

- Single POD modes – Every POD mode of velocity vector fields could be shown as a vector field, by arrows and with derived quantities as the background contours. The derived quantities are calculated instantaneously from each POD mode, as it has been a regular flow snapshot. Navigation and animation/movie options are: Next/Previous (from one to the number of modes, selected before) and Animation/Movie from the current mode towards the last.
- Multi-mode – the result is a linear combination of POD modes, defined by the user in the vector of indices of modes. The combination could be of consequent or randomly selected modes (i.e. from 1 to 5 or 1,2,5, for example). In addition, the toolbox allows calculating the sum of the selected modes or their linear combination by using their respective eigenvalues. The latter option is called weighted version and realized by checking the radio-button 

(the short version of Weighted/Non-Weighted). The default is a regular sum (Non-weighted version) and checking the radio-button will show the weighted version. When working in 'Multi-mode', following controls are becoming available (Figure 15)

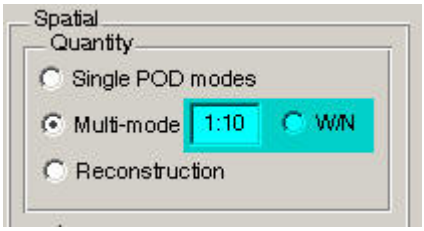


Figure 15: Multi-mode controls.

1. The 

edit-box allows user to choose modes that will be used to calculate quantities in multi-mode.

The software allows to use any index notation of a vector in Matlab and gives lot of flexibility, allowing to choose single modes, group of modes, group of modes with given step, etc. For example:
1:10 – Choose all modes from 1 to 10.
1:2:10 - Choose all modes with step of 2 – i.e. 1,3,5,7,9 will be chosen.
1, 3, 5 or 1 3 5 – modes 1,3 and 5 will be chosen and any other combination, like 1:2:5,10 will also work

Note: minimum allowed value to enter is 1, and maximum allowed value is maximum number of modes.

- Reconstruction of fields – every one of the selected vector fields could be reconstructed by using all the modes, or some of the modes. The reconstruction with all the modes gives the exact original vector field, while the reconstruction with lower number of modes will provide user with the low-order reconstructed model of the vector field. The user is advised to understand more about the low-order representation from additional document providing a theoretical and computational background.

When working in 'Reconstruction' mode, following controls are becoming available:

Figure 16: Reconstruction mode.

The user can make custom selection of modes to use in reconstruction, similarly to the way explained in the multi-mode section.
Note: A default selection for reconstruction and multi-mode is a vector of [1:maximum number of modes].

Contour types
Available contour types are:

- Flood - smooth color patches, no sharp boundaries
- Color Line - only color boundaries, according to the color map of the selected quantity.
- Flood + Line – color patches, with sharp boundaries
- Black Line – only boundaries of the contours

There are several examples given below to show some of the available arrow and contour combinations:

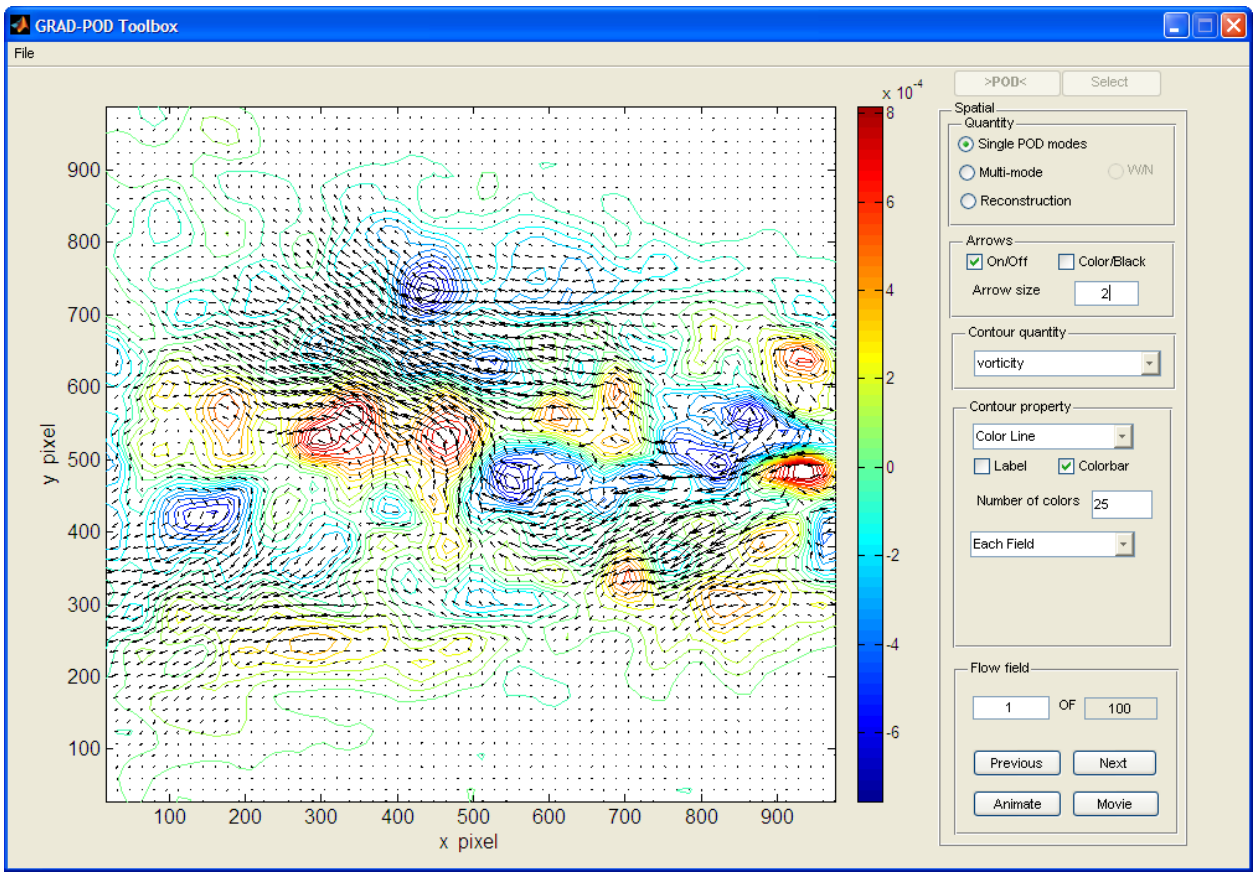


Figure 17: Single modes velocity field (arrows) and the instantaneous vorticity field in color-line contour mode. Note that a number of contour levels is set to 25.

Control of contour levels and colors

The user can manually enter number of contour levels (or number of colors), by entering the desired number in the edit box: 

and pressing Enter.

The number of colors (default or manually set) defines the number of contour levels of the selected quantity, but in one of four modes (contour modes):

- Each Field – the contour is automatically updated to each presented map limits (min and max) and distributed evenly into number of contour levels (i.e. number of colors)
- All to Display – the currently presented map defines the contour levels for all forthcoming maps, unless other option is selected. If the user changes the quantity, the limits are updated, but still will be constant for all forthcoming views.
- All Fields – the contour levels are defined by the maximum and minimum values of the selected quantity from the whole selected dataset. This is very powerful option, that allows one to compare the values visually, when not even one value will be out of the defined color set (which is possible to happen in manual or All to Display modes). However, one should realize that in order to determine the absolute maximum and minimum values, the whole dataset has to be calculated at least once. For example, All Fields of the vorticity demands the calculation of gradients in both directions of the selected dataset
- Manual - the user can select the maximum and minimum level of the color to be shown, the selection could be symmetric by entering the same positive and negative values or anti-symmetric, if different values are used.

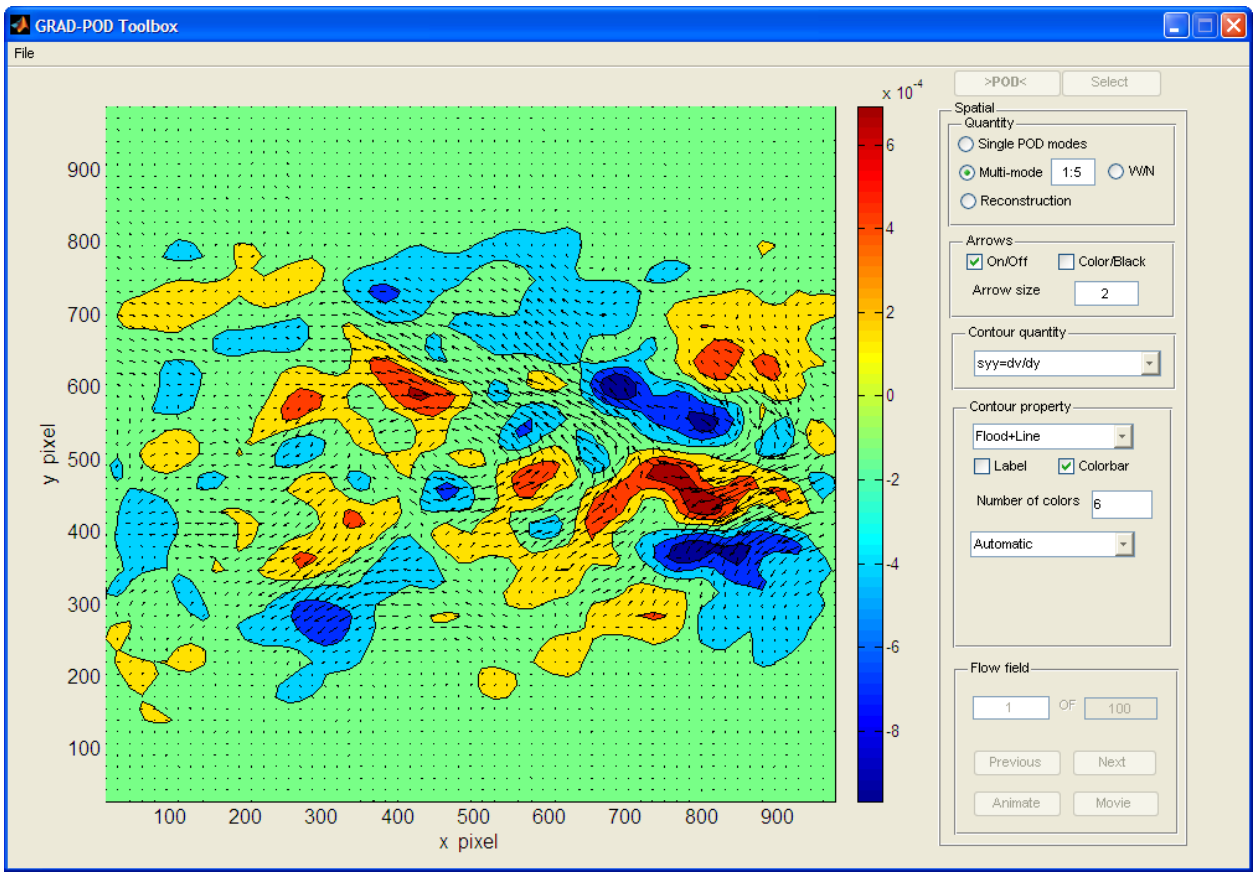


Figure 18: Multi-mode output, non-weighted sum of the first 5 POD modes. Contour is set to flood+line type of the rate-of-strain component s_{yy}, number of contour levels set to 6 to emphasize strong positive and negative regions.

Animation and movie options

The user can run the animation of the successive maps, with all the visualization properties that were selected before, by pressing Animation button. The first map is the current map (that could be manually entered in the edit box) and pressing again the Animation button stops the animation at any map. Otherwise the animation will continue up to the last map.

During the animation, the movie is NOT stored in the memory. The user should operate Movie button in the same way as Animation button, but in addition, the user will be prompted to type in the file name of the AVI file. The Windows AVI video file (uncompressed, default rate is 15 frames-per-second) is saved, when the last map is reached, or the Movie button is pressed again (i.e. released).

Note: The POD Toolbox window must be in the front while the movie is recorded. The movie is recorded by using Matlab standard function `getframe()` that captures the screen. Therefore, if another window pops-up in the front of POD Toolbox, it might be captured and it may corrupt the movie.

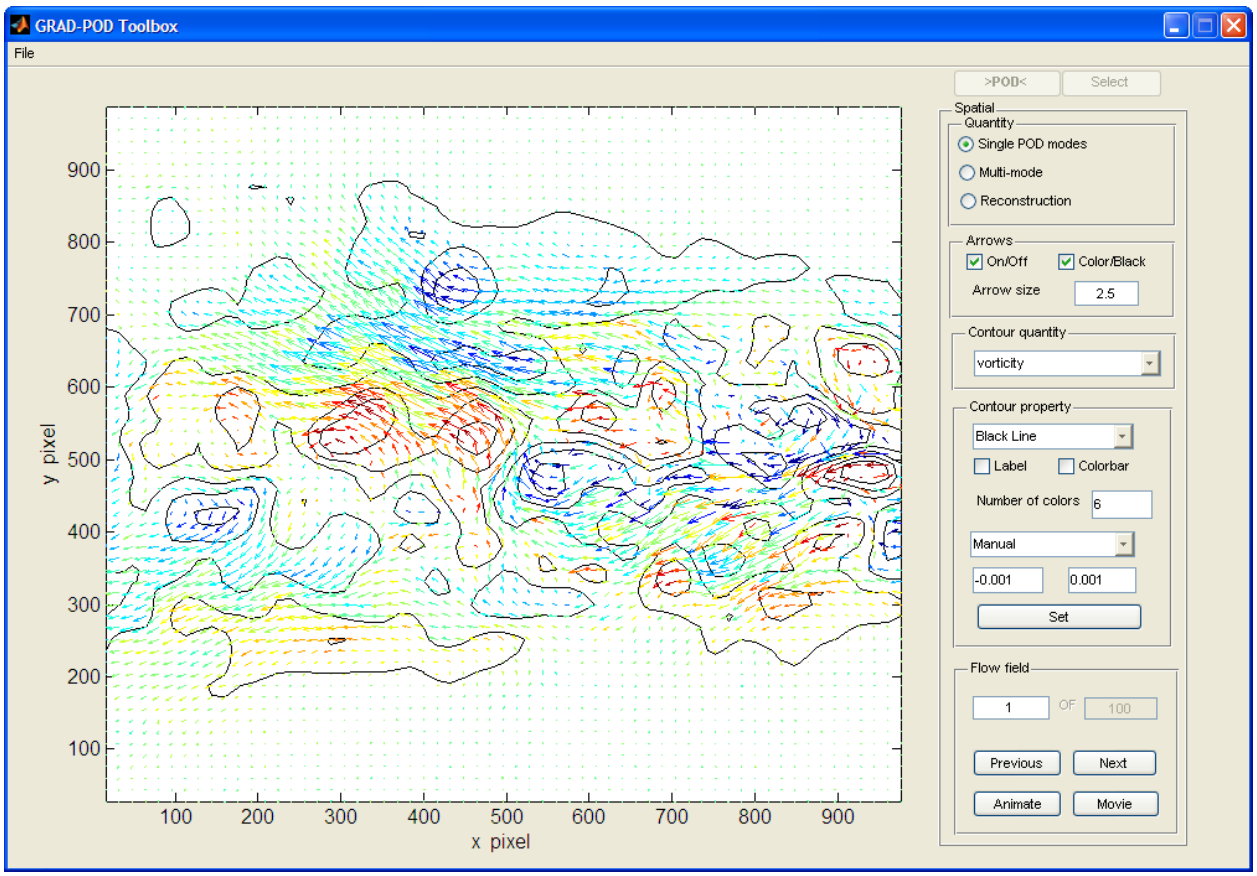


Figure 19: The color of the arrows and the contour lines correspond to vorticity, the number of contour levels is set to 6, and the colour is distributed symmetrically by manual set of contour levels between –0.001 and 0.001.