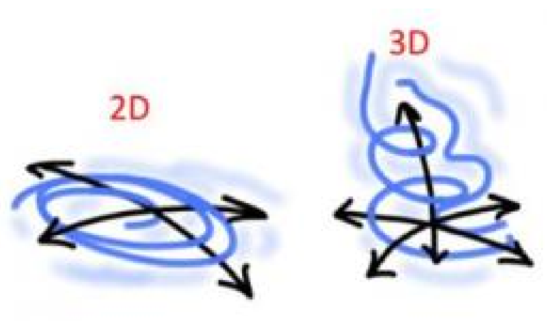
Turbulent flows in 2D can be calculated in new model

October 23 2012



Turbulent motion is chaotic, and even the largest computers can only reproduce this approximately. The motion of the atmosphere, the winds, is highly two-dimensional. The vertical motion of the air is about 1000 times smaller than the horizontal motion. Now scientists have developed a new statistical model of the behavior of turbulence in two-dimensions, which gives a better understanding of the process. Credit: Peter Ditlevsen, Niels Bohr Institute

Turbulent flows have challenged researchers for centuries. It is impossible to predict chaotic weather more than a week in advance. Wind resistance on a plane or a car cannot be calculated precisely, since it is determined by atmospheric turbulence. Now, however, researchers from the Niels Bohr Institute have succeeded in developing a statistical model that can replicate the chaotic flows and thereby provide a better understanding of the process. The research results are published in the scientific journal, *Physics of Fluids*.

"Without knowing the movements in detail, we know that they happen in such a way that the kinetic energy is conserved," explains Peter Ditlevsen, a research associate professor at the Niels Bohr Institute at the University of Copenhagen. He explains that when a liquid or air is set in motion, for example, if you create large eddies in a bathtub by stirring the water, it will transpire, that when you stop stirring, smaller and smaller eddies will continue to be created, while the large ones slowly die out. Finally, the movement in the smallest eddies are converted into heat. The entire process is called an energy cascade from large scales to small scales and is absolutely fundamental for understanding chaotic turbulent flow.

If the motion is limited to only being able to take place on a single plane, that is, two dimensions (2D), instead of in a volume, that is, three dimensions (3D), it will happen quite differently. The reason is that the flow cannot release its energy as small eddies cannot easily be formed in two dimensions. In two dimensions, both the energy and eddy density (which is called enstrophy) is retained in the flow, unlike in three dimensions, where only the energy is preserved.

Complicated calculations in 3D

A complex motion equation that has been known for almost 200 years, the so-called Navier-Stokes equation, is used to calculate the air's turbulent 3D movements. But even the world's most powerful computers, which have been dedicated to just this purpose, can only provide an approximate solution to the equation.

In order to describe the turbulent cascade processes, the researchers have therefore developed simplified mathematical models that are much easier to fully investigate in with computer calculations. The models have the same behaviour as the Navier-Stokes equation, but the models have not been able to reproduce the so-called inverse cascade in 2D.

Until now, the models have been too limited to show both the eddy density cascades down to small scales and the energy cascades up to large scales. They have been able to simulate the one cascade or the other, but not both simultaneously.

Simpler calculations in 2D

However, Peter Ditlevsen has now succeeded in developing such a cascade model that can reproduce the double cascade process in 2D turbulence.

"Turbulence can occur as a somewhat exotic phenomena. Though not in this case: Motion in the atmosphere, the wind and the weather is largely two-dimensional. The movements on the vertical axis are 100 to 1000 times less than those on the horizontal axis. The air has a much more difficult time moving vertically, so the movement of the weather systems movement is two-dimensional turbulence. This means that it is possible to predict the weather a ways ahead of time. If the movement had been three-dimensional, it would be dominated by small eddies, which are completely unpredictable, like when you see autumn leaves randomly floating around in a courtyard," explains Peter Ditlevsen.

The turbulent flows occur over a vast span of scales, so when researchers want to understand the processes, they have to study simplified models.

"With the new model of the two-dimensional turbulence we are one step closer to understanding which factors in the motion equations govern how energy is distributed in the flow," explains Peter Ditlevsen.

More information: *Phys. Fluids* 24, 105109 (2012); doi: 10.1063/1.4761834

Provided by University of Copenhagen