Geophysical Fluid Flow Cell Experiment

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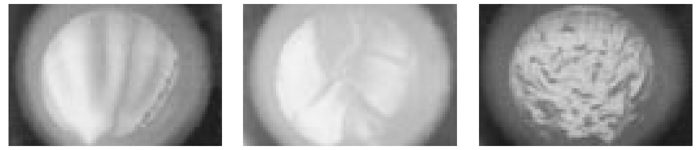
Purpose: To study how fluids move in microgravity as a means of understanding fluid flow in oceans, atmospheres, planets, and stars
Significance: Large-scale motions of the atmospheres of planets, such as Earth, and in the convection zones of rotating stars are strongly constrained by rotation and gravity, which creates the buoyancy forces that cause thermal circulations. The structures of these large-scale flows are often surprising and continue to baffle scientists seeking fundamental understanding of such phenomena as the zonal bands of Jupiter, the origin of extremely high winds in the tropics and subtropics of Jupiter, Saturn, and Neptune, the persistent differential rotation of the Sun, the complex patterns of convection in the slowly-rotating mantle of Earth, and the rapidly rotating flows in Earth's core that are thought to generate Earth's magnetic field.

Studying this type of fluid mechanics in the laboratory can be done only in microgravity, which offers unique opportunities to study how fluids behave in the absence of gravitational forces that dominate their behavior on Earth. The thermally-driven motion of a fluid in a spherical experiment is similar to that in a thermally driven, rotating shallow atmosphere or in a deep ocean on a spherical planet. Controlled experiments on rotating, spherical models cannot be done on Earth because gravity distorts the flow patterns. Normal gravity causes bubbles to rise to the surface of a liquid — *buoyancy* — and forces lighter substances to rise. These effects will be greatly reduced on orbit, and useful information on the transfer of heat by the circulation of fluid — *thermal convection* — in atmospheres and oceans is expected.

Laboratory studies have been limited to rotating layers between parallel plates oriented perpendicularly to gravity. This is because when rotating shells are used, terrestrial gravity is no longer perpendicular to all the spherical surfaces, creating anomalous motions in the fluid. Even so, laboratory experiments have yielded some data on geophysical fluid dynamics. Experiments using a cylindrical ring-like structure (*annulus*), which contained a fluid heated by making one side of the ring hotter than the other, produced waves similar to those observed in Earth's atmosphere. However, because gravity and rotation are parallel in these experiments, the results are only relevant to the polar regions of the atmosphere.

The Geophysical Fluid Flow Cell offers the opportunity to study rotating fluid shells in an environment unhindered by gravity, making it possible to perform experiments and obtain data that cannot be gathered on Earth. Photographs of the experiment will contain data that can be used to deduce temperature and velocity fields, revealing the fundamental fluid mechanics processes that govern Earth's atmospheres and oceans, atmospheres of other planets, and the Sun and other stars. The atmosphere of Jupiter, composed mostly of hydrogen and helium, is of particular interest since it radiates more heat than it receives from the Sun, indicating that there may be an internal heat source. Scientists hope that by experimenting with temperature differences in the Geophysical Fluid Flow Cell they can better understand what causes the distinctive cloud patterns on Jupiter.

This facility previously flew on Spacelab 3 in 1985, and more than 100 hours of experimentation were performed. Some 50,000 frames of photographic data were generated, containing images of convection structures, instabilities, and turbulence under varying conditions of differential heating and rotation. During the course of the experiment, several new types of convection were observed. However, some of these interesting phenomena were not investigated in sufficient detail because of time limitations and a lack of real-time data. Increased interaction between scientists, the crew, and experiment operations on the Second United States Microgravity Laboratory will allow investigation of a variety of phenomena. This experiment will concentrate on convectional stability and stratified atmospheric flows that are more like the layers of Earth's atmosphere and will investigate climatic evolution and examine temperature distributions not studied on Spacelab 3.



These data images from Spacelab 3 show patterns of fluid convection cells and wavy disturbances.

Method: On this mission, one experiment (with four distinct parts) is planned, and scientists hope to obtain more than 100 hours of observations. The instrument is located in the Spacelab module and consists of a stainless-steel hemisphere the size of a baseball surrounded by a sapphire hemisphere, with silicone oil in between. Sapphire is used because it is a unique material that conducts heat well and also is transparent. This allows precise temperature control and observations of the silicone oil as it flows between the hemispheres.

An electric charge will be applied to the fluid to create a buoyancy force identical to buoyant forces on Earth and in other atmospheres being modelled. The silicone oil contains a chemical that forms blue dye lines when subjected to ultraviolet light. Studying the movement of the lines allows investigators to measure the fluid movement and velocity. Temperature measurements are made by studying the variations in the density of the fluid. Varying the rotation rate, temperature, and voltage in the facility creates flows that are relevant to the study of oceans, planetary atmospheres, and stars.

The Geophysical Fluid Flow Cell