◄ Overview of the large density-stratified water flume

THE GEOPHYSICAL FLUID DYNAMICS LABORATORY OF CNRM-GAME

The fluid dynamics laboratory of the French meteorological service research center (CNRM-GAME, UMR3589 Météo-France and CNRS) provides unique facilities for fundamental and applied study of homogeneous, stratified and/or rotating flows, in particular to address geophysical and environmental issues.

Installation profile

The 30 m long, 3 m wide and 1.6 m deep water flume can operate with up to three layers of different densities (NaCl brines ranging from 1000 to 1200 kg/m^3), and velocities (ranging from 0.03 to 0.75 m/s), both computer-monitored. The temperature stability at 20 °C is better than 0.2 °C. A continuous density stratification is possible.
The flume can also be operated as a towing tank filled with water for homogeneous flows or with stable density-stratified brines of any profile. The towing speed ranges from 0.03 to 0.80 m.s^{-1}. Large and heavy obstacles are easily towed and the instrumentation can be transported on the carriage.
The laboratory includes two smaller water tanks (7 x 0.7 x 0.8 m^3 and 4 x 0.5 x 0.5 m^3) to study homogeous or stratified flows, as well as a rotating turntable (2.5 m diameter) to study the effect of rotation on stratified or non-stratified flows.
State-of-the-art flow measurement techniques are available, including Laser Doppler Anemometer (LDA), hot-wire anemometry, fast conductimeters, Particle Image Velocimetry (PIV) and Laser-Induced Fluorescence (LIF). New techniques are developed in the context of various collaborations.
The laboratory has expertise in numerical simulations ; we access to a cluster and to Météo-France supercomputer, and may provide support for complementary numerical simulations. The scientific, technical and logistical support required for using the facilities effectively is provided by one researcher and four technicians/engineers working in the laboratory.

Our activities

Our activities are divided into applied studies and more fundamental researches.

- High Reynolds number studies are conducted in the large water flume.
- Smaller tanks are used as testbeds or to run studies at lower Reynolds numbers.
- Effect of rotation on flows, in particular effect of the earth rotation on atmospheric and oceanic flows, can be studied on the rotating turntable.
- Last but not least, a version of the non-hydrostatic mesoscale atmospheric model of the French research community (Meso-NH) adapted to our water flume experiments is developed in the team, to be used as a complementary tool to our laboratory experiments.

Applied studies

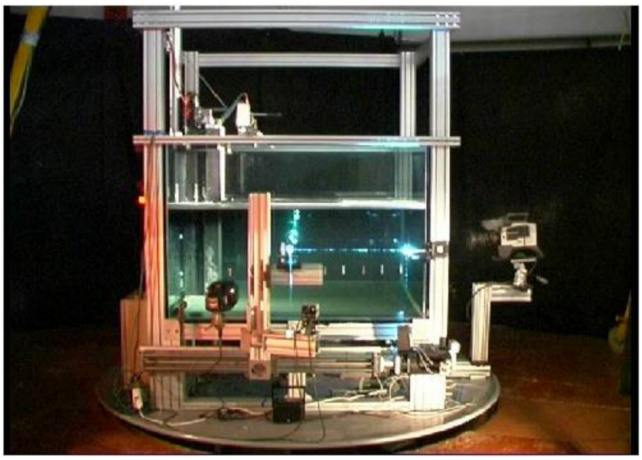
While numerical models are reliable for most 2D flows, this is not yet true for 3D flows, especially in the presence of small scale turbulence. A fully resolved numerical computation of a typical experiment would require a sub-millimeter scale grid mesh, resulting in several billions grid points, still beyond the state of the art in supercomputing. Hydraulic simulation permits in particular a better description of high Reynolds flows interacting with complex structures or topography. Our most recent applied studies include crosswind stability of a high-speed train, small-scale wind characterization on the Millau Viaduct, small-scale wind characterization for wild-fires fighting purposes, pollutant dispersion in the atmospheric boundary layer, selection of wind turbines location, as well as wind and turbulence characterization on an airport.

Fundamental research

Our research activities take place in the field of geophysical fluid mechanics, with a specialization in studies of stratified flows and boundary layers in the laboratory. Our aim is to improve our understanding of various atmospheric and oceanic phenomena, in particular in order to improve numerical weather prediction models.

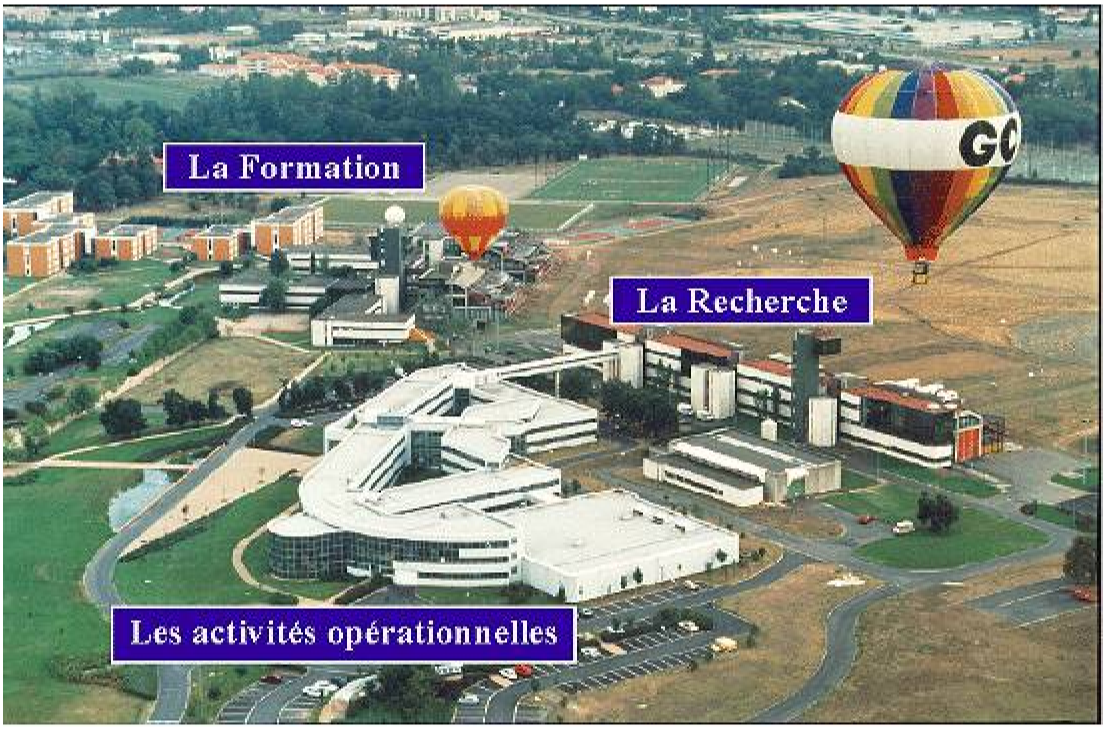
Our current research topics are :

- topographic internal gravity waves:
  - mountain waves in the atmosphere,
  - internal tides generated over a seamount in the ocean;
- (stable) atmospheric boundary layer.



The 2.5 m diameter rotating turn-table

The 7 m long tank



The French national weather service in Toulouse (« La Météopole »)

A stimulating environment

Our laboratory is located in Toulouse, the fourth largest city in France, in the heart of Southern France, between the Mediterranean and the Atlantic Ocean. Toulouse is well known for its pleasant lifestyle, it is also a very dynamic city in various domains. Our direct technical and scientific environment include: Groupe d'Etude de l'Atmosphère Météorologique/Centre National de Recherches Météorologiques (CNRM-GAME), Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique (CERFACS), supercomputer of Météo France… “La Météopole" includes also a restaurant, accommodations and offers nice sport and cultural activities.

Access being offered

The large water flume is a unique infrastructure in Europe. This is why it is opened to research team from eligible states in the frame of the Integrated Infrastructure Initiative HYDRALAB funded by the EC.

Access is offered to researchers and engineers who are interested in investigating problems in the field of geophysical fluid dynamics, in particular stratified flows and boundary layers. However more fundamental fluid dynamics studies are also very welcome. Access to the facility is coordinated with existing activities in the laboratory.

More generally, the laboratory is opened to new partnership. Students and scientists from all other the world are welcome to visit the laboratory, and there are possibilities for short or longer time stays in the frame of a scientific collaboration.

Partnerships

An active partnership has been developed for many years with OMP/LA (Laboratoire d'Aérologie) and IMFT (Institut de Mécanique des Fluides de Toulouse). A permanent collaboration is in place with other teams of CNRM-GAME (Météo France & CNRS), in particular for numerical simulations, but also for meteorological observations. Other partnerships involve LEGI in Grenoble, ENS in Lyon, Hannover University, Wageningen University, University College London...

Selected publications

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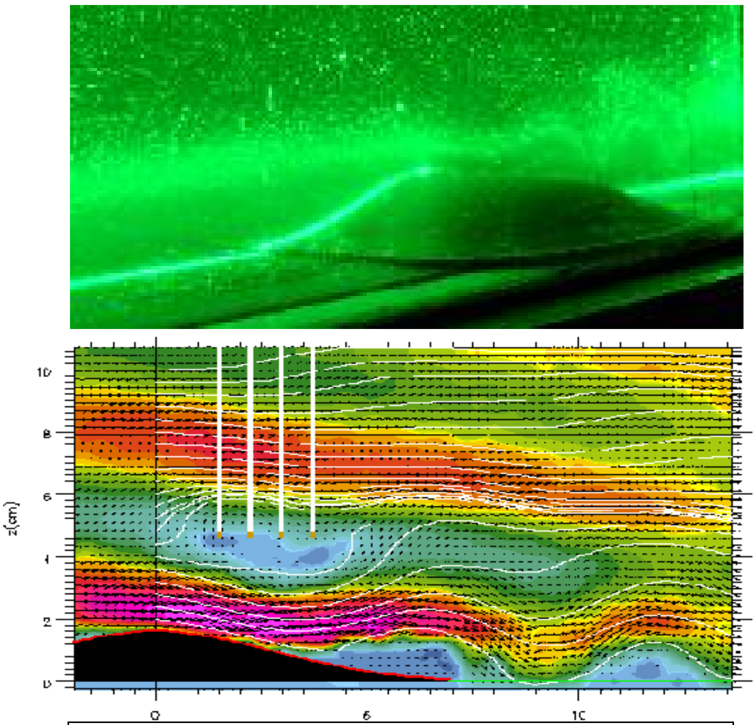
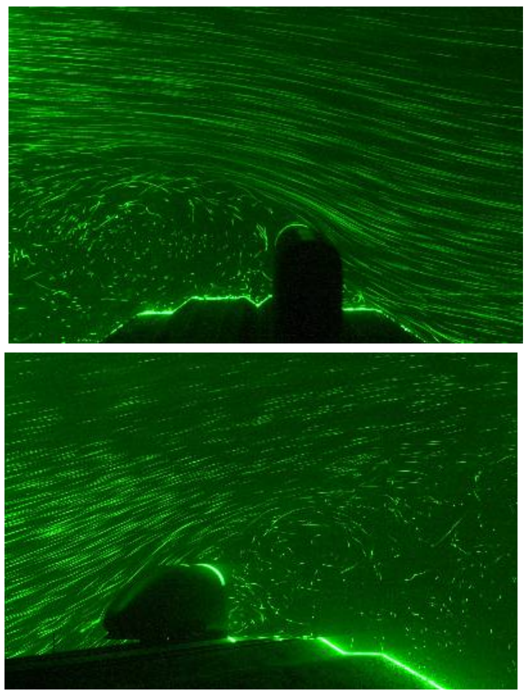
- Billant P. and J. M. Chomaz (2000): Three-dimensional stability of a vertical columnar vortex pair in a stratified fluid, *Journal of Fluid Mechanics*, 419: 65-91.
- Bonnier M. and O. Eiff (2002): Experimental investigation of the collapse of a turbulent wake in a stratified fluid, *Physics of Fluids*, 14: 791-801.
- Paci A., G. Caniaux, H. Giordani, M. Lévy, L. Prieur, and G. Reverdin (2007): A high resolution simulation of the ocean during the POMME experiment : Mesoscale variability and near surface processes, *J. Geophys. Res.,*112 (C04007), doi:10.1029/2005JC003389.
- Knigge C., D. Etling, A. Paci and O. Eiff (2010): Laboratory experiments on mountain-induced rotors. *Q. J. R. Meteorol. Soc.* 136: 442–450. DOI:10.1002/qj.564
- Steeneveld G.-J., D. Dobrovolschi, A. Paci, O. Eiff, L. Lacaze and A.A.M. Holtslag (2010): Sensing the stable boundary layer in a towing tank, 19th Symposium on BL and Turbulence, Keystone (USA).
- Tomas S., O. Eiff and V. Masson (2011): Experimental Investigation of Turbulent Momentum Transfer in a Neutral Boundary Layer over a Rough Surface, Boundary-Layer Meteorology, 138 : 385-411.
- Dossmann Y., A. Paci, F. Auclair and J. W. Floor (2011): Simultaneous velocity and density measurements for an energy-based approach to internal waves generated over a ridge, *Experiments in Fluid*, 51 (4) : 1013-1028, doi :10.1007/s00348-011-1121-3.
- Dossmann Y., F. Auclair and A. Paci : Topographically induced internal solitary waves in a pycnocline : primary generation and topographic control, accepted for publication in *Physics of Fluids*.
- Lacaze L., A. Paci, E. Cid, S. Cazin, O. Eiff, J.G. Esler and E.R. Johnson : Wave patterns generated by an axisymmetric obstacle in a two-layer flow, submitted to *Experiments in Fluids*.
- Dossmann Y., A. Paci, F. Auclair, M. Lepilliez and E. Cid : Topographically induced internal solitary waves in a pycnocline : coupled ultrasonic and stereo-correlation measurements, submitted to *Physics of Fluids*.



Mountain waves :
laboratory experiment (top),
and results from PIV measurements (bottom).



Applied study on the crosswind stability of the French high-speed train (TGV) on a high embankment