Faculty Profile

Nicolas Grisouard

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Professor Grisouard joined the Department in January 2015. He is a geophysical fluid dynamicist whose research focuses on the theory of internal waves in the oceans. He is primarily interested in modelling non-linear processes associated with internal inertia-gravity waves.

He became interested in this topic in 2004 when he was a physics undergraduate student looking for a summer internship. He was actually interested in Astronomy and Astrophysics and applied to the OHP (an astronomical observatory in southern France). The group that got back to him was an atmospheric physics group and the proposed internship consisted of processing data from an automated LIDAR (Light Detection and Ranging) and he went for it. Professor Grisouard says "In practice, the work was very simple: design an algorithm, that would automatically extract how often cirrus (thin, high-altitude clouds) would show up in the data. Nothing from my intensive physics training was required but I had found a project which had meaning for me: every day when going to and from work, I would look up and wonder if I could see any cirrus that day."

The following year, he decided to keep studying the Earth, but wanted to find an undergraduate project which would put his physics training to better use. Something more mathematical with "an active feedback loop from nature," he says. He also wanted to combine this with his favorite class as an undergraduate student, fluid dynamics. He found an internship at Scripps Institution of Oceanography in San Diego, studying internal gravity waves. He really enjoyed this topic and says "I could use my knowledge about wave physics and my training in scientific programming. Moreover, when compared to other sub-fields of physics like quantum physics or non-linear optics, this field had been left relatively untouched and it felt like large advances, with concrete impacts for society, were within reach" .

Professor Grisouard got his PhD from the University of Grenoble, followed by post-doctoral work at the Courant Institute and at Stanford.

How did the ocean inspire you and impact your research?

Fluid dynamics had been my favorite topic as an undergraduate, but this class probably was simply the trigger of something which was simmering deeper down. I would often be mesmerized by fluid dynamics phenomena, like smoke or river flows. Nothing conscious, it would just happen, and I would snap out of it and resume my activities of the time. Only when I took my first fluid dynamics class did I realize that this was actually a thing, like supernovae or electricity.

But teaching of fluid dynamics was, and still is, often geared towards engineering applications, and somehow that did not resonate with me. Only when I did the internship at Scripps and started reading books on oceanic flows did I realize that this could actually be a job. The rotation of the Earth and the variation of densities across the ocean would introduce physics unlike anything I had ever heard of and the diversity of oceanic fluid dynamics phenomena was just a bottomless well where I could find inspiration.

Later on, I would realize how important the ocean is for the climate system, which also resonated with concerns I had as an ordinary citizen. As my career progressed, observing the ocean (to this day, it is still an immense pool of dark water as far as our knowledge of it is concerned), and properly integrating my research with the larger oceanographic and geophysics community have become new and exciting challenges for me.

Can you give me an example of a non-linear process that you have worked on and its significance?

My most recent work involves a very peculiar phenomenon happening when internal waves reflect against the surface of the ocean from below. The sub-surface of the ocean is peppered with "fronts", which are physically the same type of flow that you hear about in weather forecasts ("a cold front will sweep through Toronto", things like that), except that they are much smaller in the ocean. These fronts can capture internal waves, which are then squeezed towards the surface and reflect against it. When they do, and this is where the internal wave physics is unlike any other, they do not reflect against it in a specular manner, like light against a mirror or sound against a wall. Instead, the angle of propagation of their energy is modified after reflection, and if the conditions are right, this angle can even be parallel to the ocean surface, effectively trapping the waves in a thin and very energetic layer just below the surface. As it turns out, and this is one of the many small miracles happening in this problem, the "right conditions" are often met in the ocean: the waves simply have to oscillate at the same frequency as the rotation rate of the Earth, and the ocean finds many ways to create such waves.

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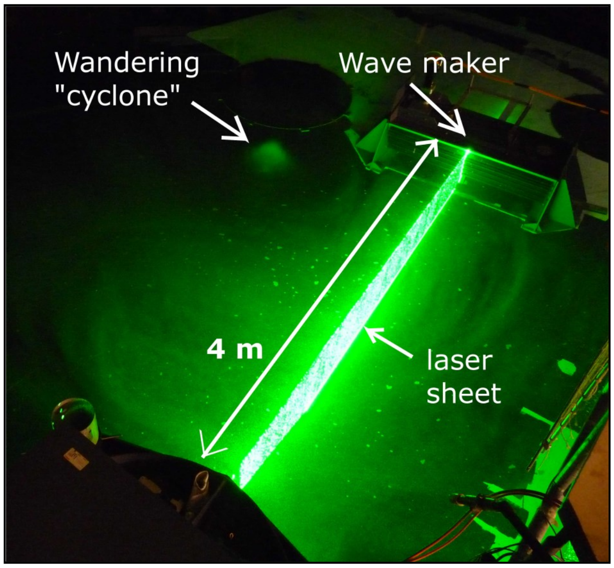
When focused in this thin, energized layer, the waves become very non-linear, break and dissipate. They don't do it with a whimper but a bang: some of the energy associated with the front dissipates with it, one of the other small miracles associated with this seemingly abstract problem.

Why is it important? Fronts occupy a special place in oceanography; for example, they host intense ecosystems. In our case, we were interested in the fact that they are where the ocean's kinetic energy, which is mainly stored in vortices that are much larger than fronts, dissipates, although in ways that are still mysterious.

Our study provides the oceanographic community with a new process, which could partially explain how internal waves make this dissipation happen.

You use numerical simulations, laboratory experiments and analytical modelling to model non-linear processes, can you give our readers an example of one of your experiments? What was the outcome?



This is an annotated picture of the set-up in action, taken from the observation platform above the fluid. The laser sheet illuminates Styrofoam particles that "tag" the fluid. A movie of the particle motion allows retrieval at the motion of the water.

In 2009, we performed a tank experiment in Grenoble, France on the largest rotating tank in the world: 13m diameter, the whole facility being able to rotate with the tank in order to reproduce the Earth's motion. We wanted to understand the processes by which internal waves break down into ever-smaller waves, eventually breaking down into turbulence, which mixes waters of different densities vertically.

Instead, we were surprised to observe the contrary: rather than creating smaller and smaller scales, the flow was creating larger and larger vortices. It was as if a fast, messy process was giving rise to a smooth and coherent type of motion, seemingly lowering the entropy in the tank (the readers may rest assured that no fundamental law of physics was broken in the end).

Although we ended up only re-discovering a process that was known in other areas of fluid dynamics, we were surprised by the strength of it, and started to think that this process was underestimated in the ocean, which would keep me busy in the years to come, and still to this day!

What are your plans for research at the University of Toronto? What is exciting?

The University of Toronto offers a fantastic environment for research and a stronger integration inside the climate science community than I am used to. I find it very exciting, a source of inspiration as well as a natural evolution of my career.

For example, my arrival in the department also coincides with the future launch of the SWOT (Surface Water and Ocean Topography) satellite, to which the Canadian Space Agency is a contributor. This satellite will revolutionize how scientists observe the ocean's currents, but the correct interpretation of the future data will require making important advances in how we understand the fluid dynamics. This is a new and exciting challenge to me, because it requires work not only at the laboratory scale, which I am used to, but also to integrate such basic research within a community consisting of government agencies, large engineering teams, and hundreds of scientists. I have to say that even though I have only been here for a few weeks, I have already been able to tap into the atmospheric physics group's expertise in operating in such a complex research environment. What would have been an overwhelming endeavor had I been elsewhere already feels like a success within reach here.