



Rotating Tank Experiments in an Atmospheric and Oceanic Science Undergraduate Curriculum

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ABSTRACT:

We have implemented rotating tank experiments in undergraduate courses for Atmospheric and Oceanic Science majors at several points in the curriculum. Implementation was primarily as in-class demonstrations. Students first saw demonstrations in entry-level geophysical fluid dynamics courses and continued this experience through senior electives in climate processes and physical oceanography. Students' reactions to the tank demonstrations were overwhelmingly positive. Students found opportunities to "get their hands wet" even more beneficial to their learning.

MOTIVATION:

The Department of Atmospheric and Oceanic Sciences at University of Wisconsin – Madison has 25-30 undergraduate majors in each graduating class. Most students are interested in synoptic meteorology and severe weather, having their interest in the subject initiated through a fascination with phenomena observed in the upper Mid-West.

Our curriculum includes a rigorous treatment of geophysical fluid dynamics (GFD). This subject matter is generally quite challenging for students, pushing both their mathematical skills and their intuition about fluid behavior. We believe that rotating tank experiments will assist our students in developing a deeper physical intuition regarding geophysical fluids and improve their learning of GFD. We are implementing the tank in the undergraduate curriculum, and participating in assessment through the Weather in a Tank project, in order to test this hypothesis.

IMPLEMENTATION:

The tank has been used primarily for in-class demonstrations. Hands-on opportunities were offered in two of the courses, in each case consisting of one hands-on experience for each student during the semester. Student reactions, see below, suggest these hands-on experiences were particularly rewarding.

Title	Course #	Level	# students	Demo	Hands-on
Dynamics II, Spring 2007	AOS 311	Undergrad	28	✓	✓
Physical Oceanography, Fall 2007	AOS 660	Under/Grad	17	✓	✓
Climate Processes, Spring 2008	AOS 425	Undergrad	11	✓	
Dynamics II, Spring 2008	AOS 311	Undergrad	20	✓	

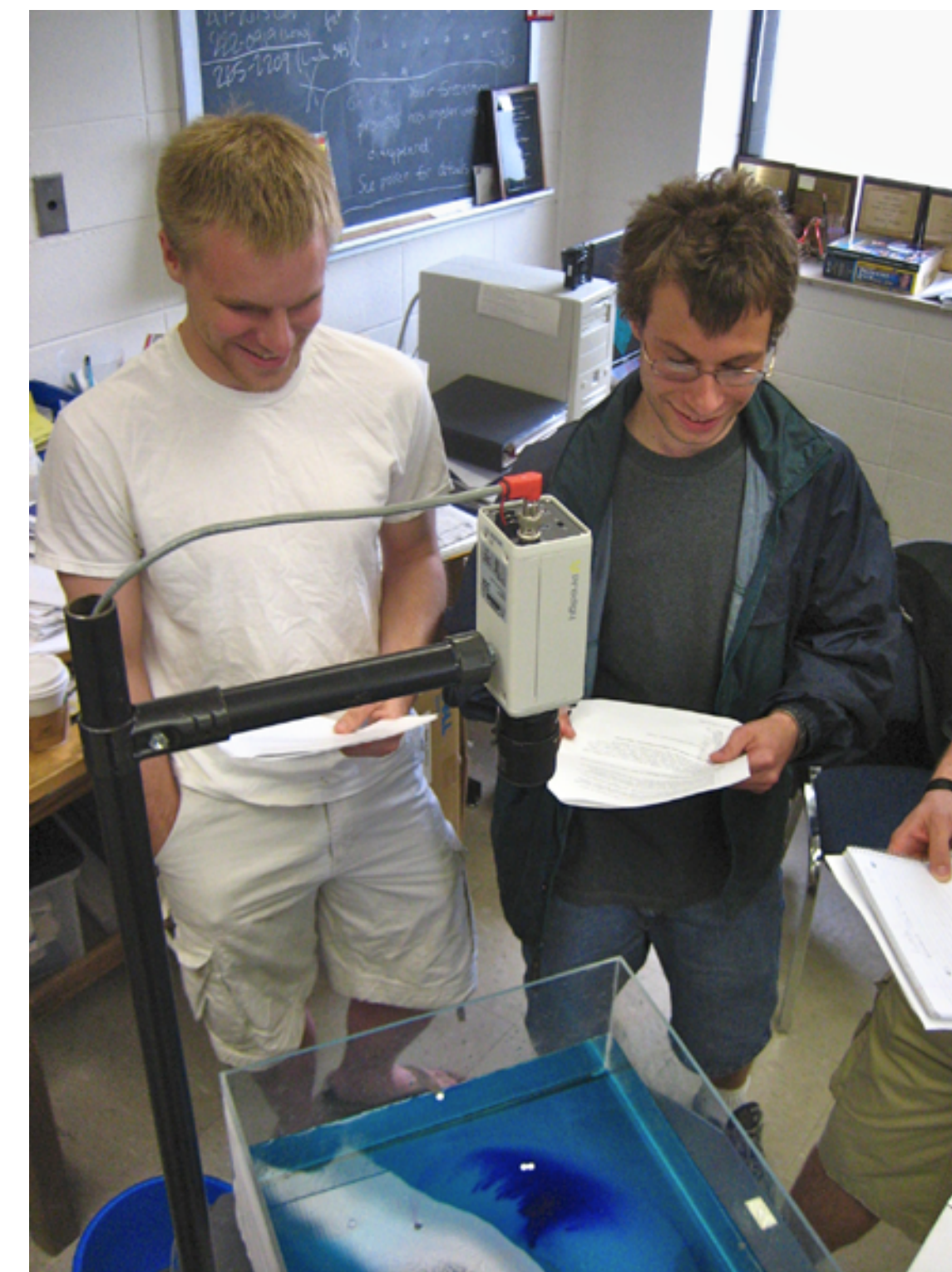
The equipment and experimental designs were provided through the Weather in a Tank project, funded by NSF.

We have frequently used the Dye Stirring / Taylor Column experiment as part of an introduction to the effects of rotation on fluids; the Fronts / Cylinder Collapse experiment to illustrate how rotation allows for the existence of observed fronts and to demonstrate the thermal wind relationship; and experiments illustrating Ekman flow in a boundary layer.

We have also used the tank to illustrate the atmosphere's General Circulation. In the presence of a thermal gradient, a slower rotation allows for a Hadley Cell-like flow. A faster rotation leads to baroclinic eddies as found in mid-latitudes.

For Physical Oceanography, Ekman pumping, the wind-driven ocean gyres, and the thermohaline circulation have been simulated. All experimental setups can be found at <http://paoc.mit.edu/labguide>.

STUDENT REACTIONS:



"The tank was very useful in getting a sense of how the atmosphere and ocean work. It is interesting to see how what happens on the global scale may be seen in a small tank. The use of the tank helped reinforce theory."

"The demonstrations were good at actually illustrating what schematic diagrams / sketches simply can't do!"

"Very useful to visually comprehend rotaton effects."

"Very useful. Allowed us to see the physical processes at work in the atmosphere and oceans. I would have liked to have done it more."

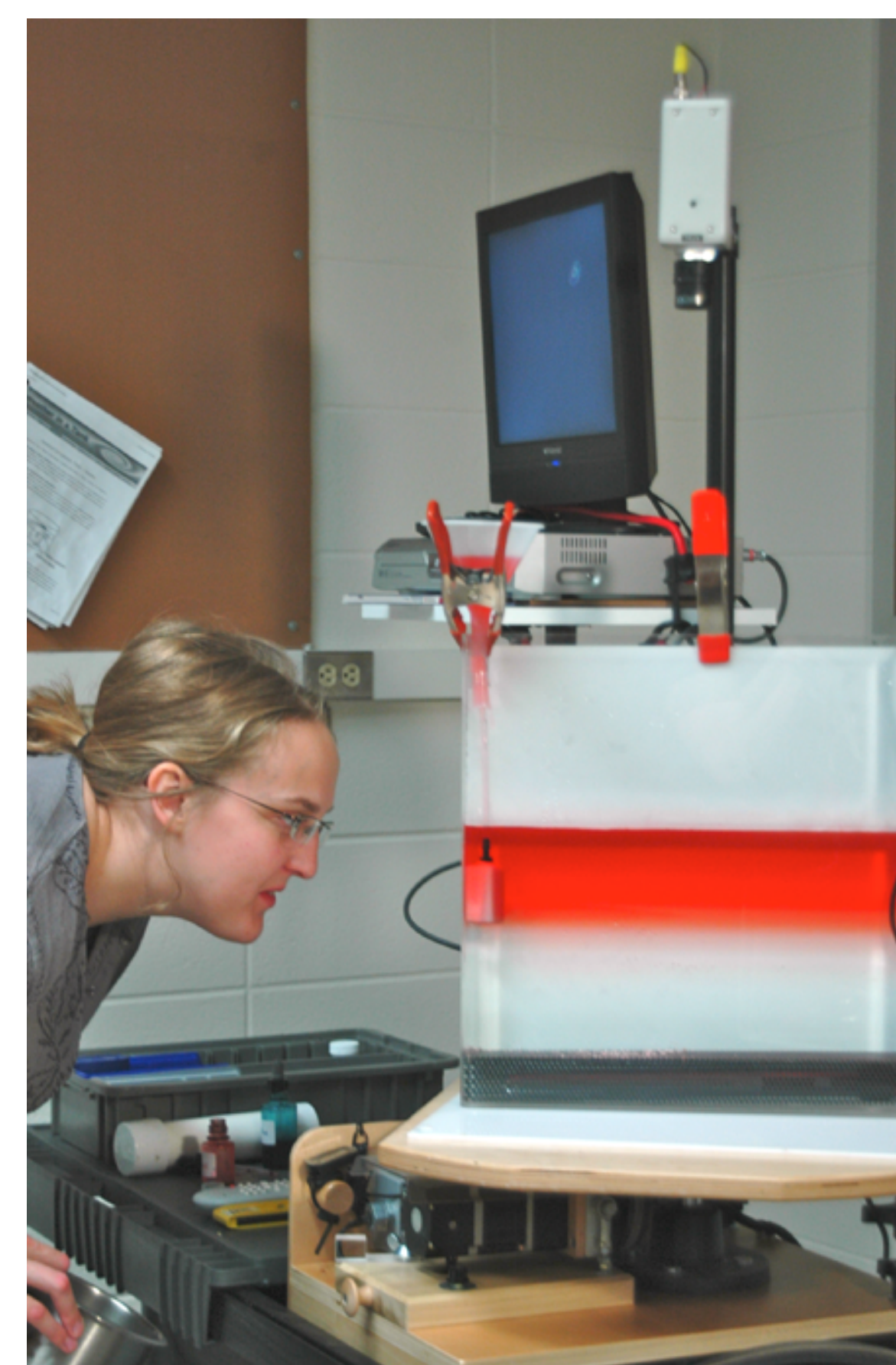


"Helped give a visual interpretation to the dynamics/equations we were learning about in lecture."

"Excellent! Gave great hands-on experience and understanding."

"The actual [hands-on] experiment was a good way to be creative and test our knowledge of the material."

"This was one of the best parts of the class, especially for visual learners."



PRE / POST TEST RESULTS:

As part of the Weather in a Tank project, a Pre / Post test was developed to evaluate the impact of the rotating tank on student learning (see presentation Thursday morning by Dr. Kathie Mackin). We have participated in this study. Analysis of first year results suggest that use of tank experiments in meteorology and climatology courses has a statistically significant effect on student learning. Since the sample size at Wisconsin is not sufficient to achieve statistical significance, results from all participating Colleges and Universities were used. For more information, please see the full report posted at <http://paoc.mit.edu/labguide>.

CHALLENGES TO DISCUSS:

Hands-on experiences seem to be the most beneficial to students, yet time and space are limited.

- What are efficient and effective strategies for optimizing student exposure in hands-on mode?
- Can we bring some of the hands-on benefit to in-class demonstrations?

Though we have found the rotating tank supportive to student learning and relatively easy to incorporate into lectures, we have had little success with expanding implementation to classes by other professors.

- What strategies might we pursue?
- Have you had success with this?

Student reactions are overwhelmingly positive, and the Pre / Post tests indicate positive impacts on student learning. Still it seems there are many "nodding heads" who may not really "get it".

- How do we engage students more actively?

FUTURE PLANS:

In spring 2009, McKinley and Morgan will teach a laboratory course in which the rotating tank is a central element. Data analysis and theory associated with tank experiments will also be pursued. This course will be aimed at upper-level undergraduate AOS majors and first-year AOS graduate students.

We also plan to continue using the tank in courses where it has already been implemented.



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