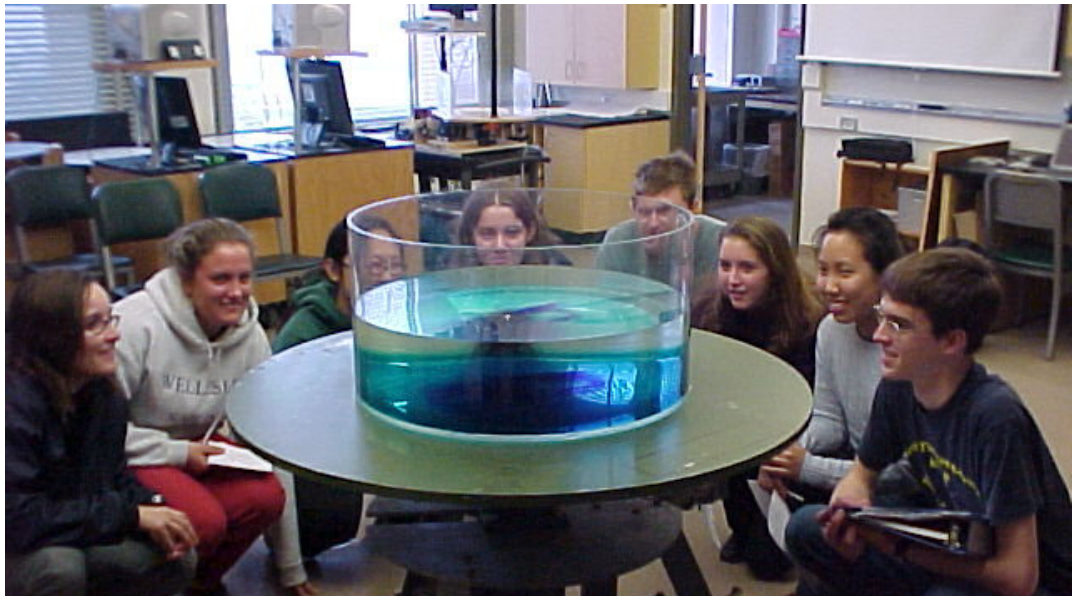
Weather in a Tank: Exploiting laboratory experiments in the teaching of meteorology, oceanography, and climate



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EAPS
Earth, Atmospheric and Planetary Sciences

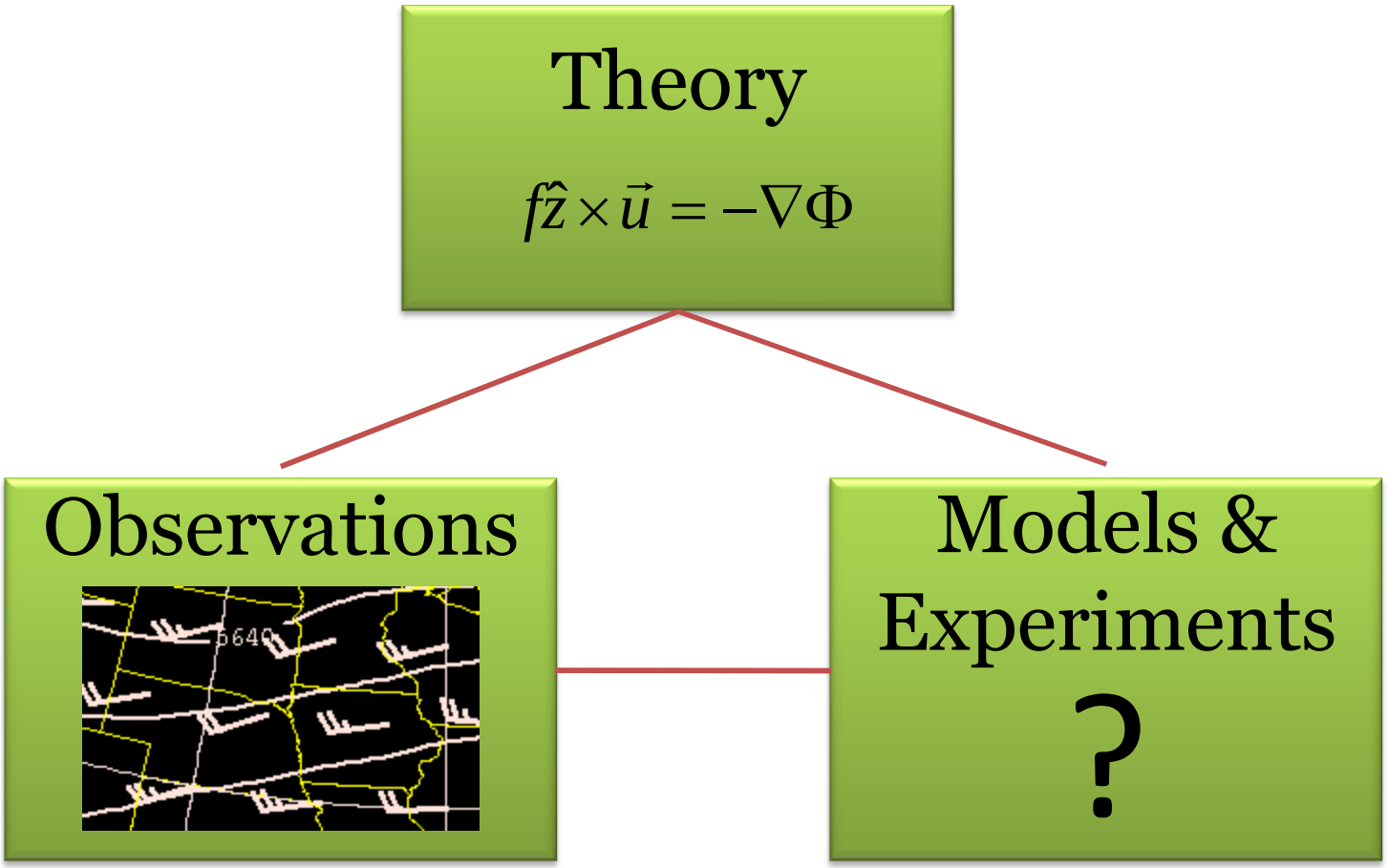
THE CHALLENGE

Teaching rotating fluid dynamics to a broad audience

Creating a learning environment where students are encouraged to learn through investigation and inquiry

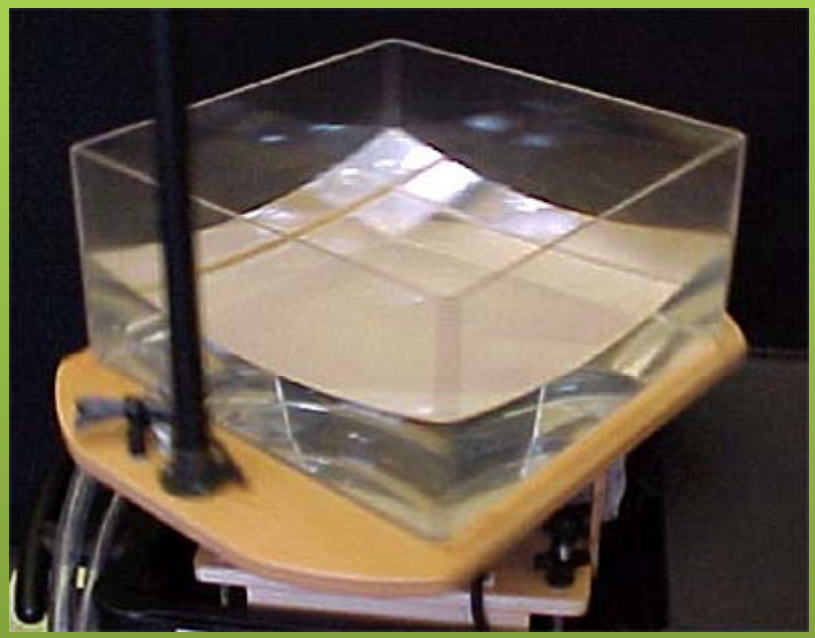
THE CHALLENGE

A combination of approaches is needed



THE CHALLENGE

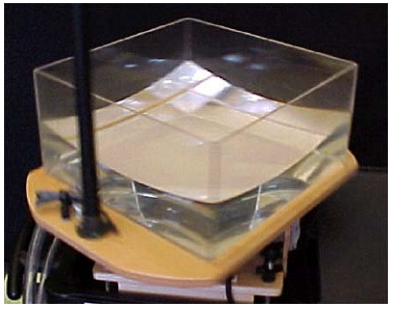
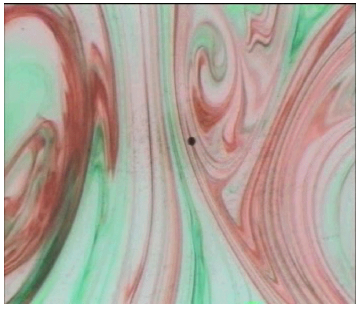
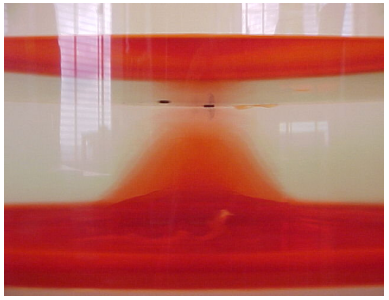
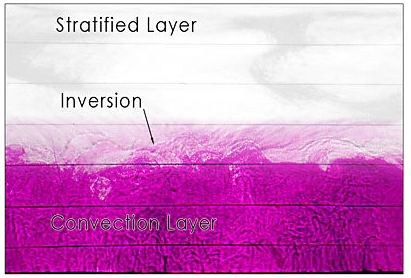
Models & Experiments



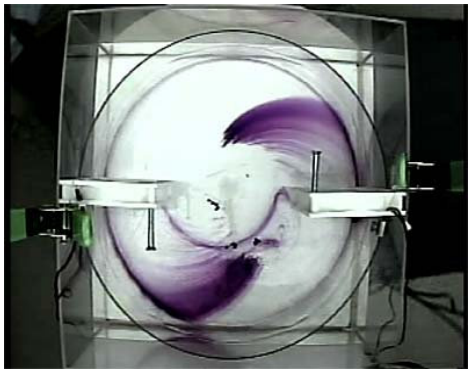
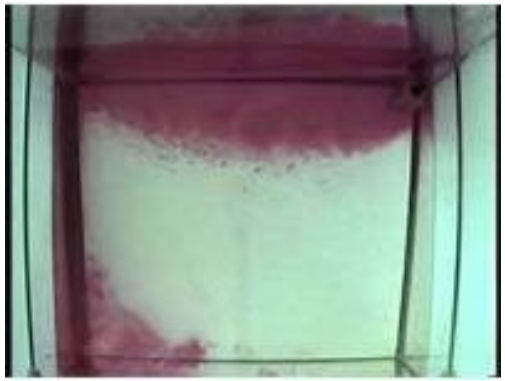
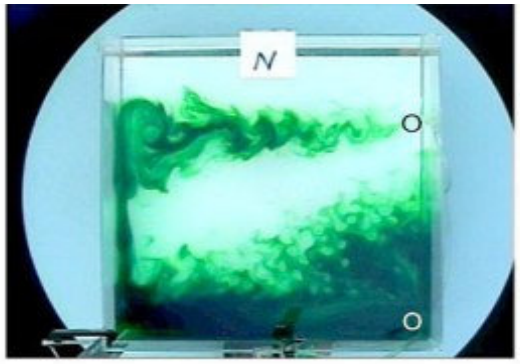
Propose using simple laboratory tank experiments as a key part of the education of students

METHODOLOGY: EQUIPMENT

PROJECTS

Solid Body Rotation 	**Dye Stir** 	**Balanced Motion** 	
Fronts 	**Ekman Layers** 	**General Circulation** 	**Convection** 

PROJECTS

Taylor Columns	**Density Currents**	**Ekman Pumping/Suction**
		
Ocean Gyres	**Thermohaline Circulation**	**Source/Sink Flow**
		

PROJECTS

Potent Potables

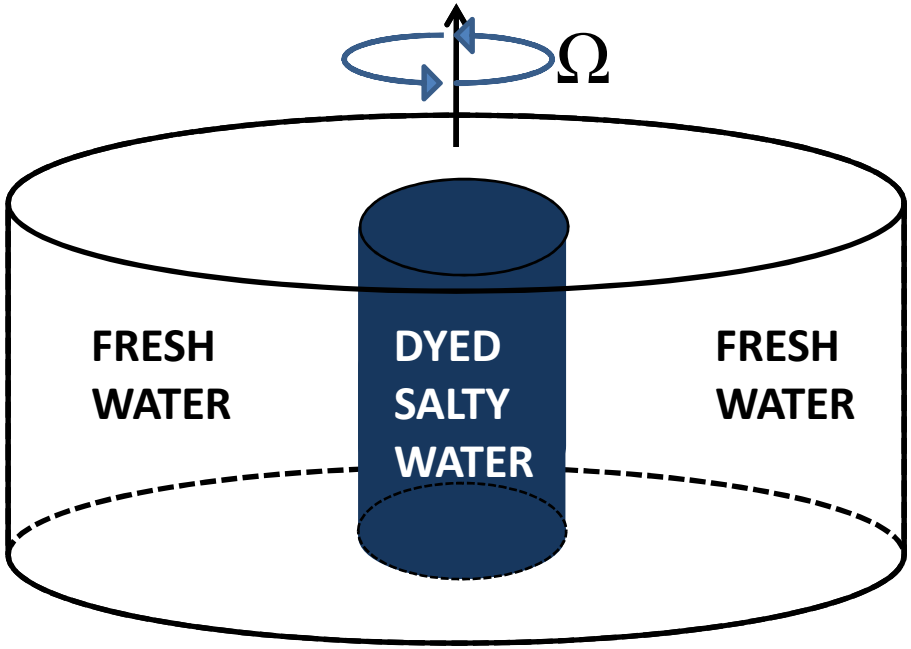
METHODOLOGY: IMPLEMENTATION

INSTRUCTOR	STUDENTS
Describe premise of experiment	
	Make prediction of experiment
Demo experiment	
Highlight relevant theory	
	Perform experiment
	Analyze real world observations
	Reports and presentations
Connect the dots	

EXAMPLE: FRONTS

1. Describe premise of experiment

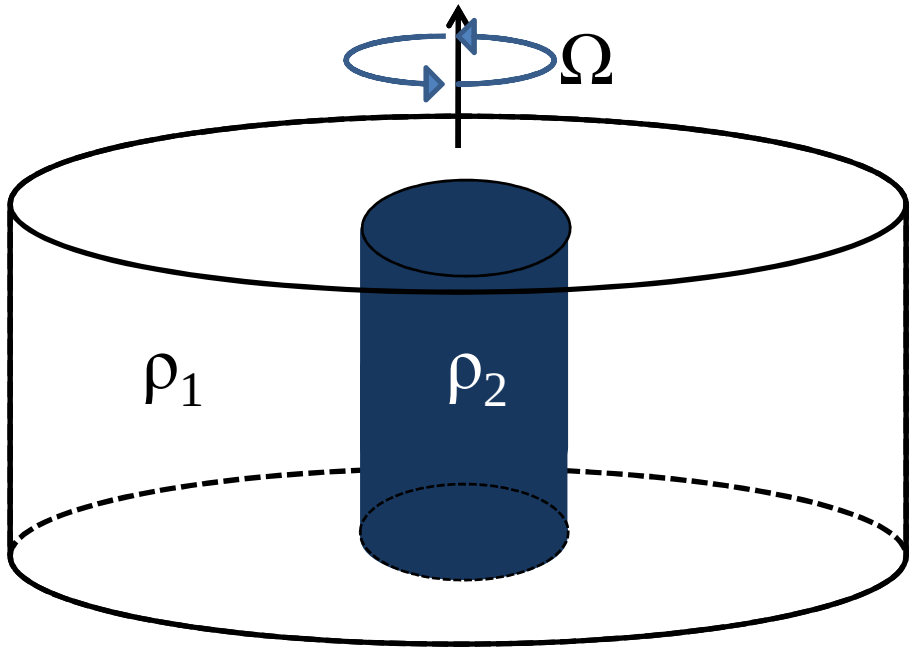
   - What is the polar front?
   - What is the cause of the jet stream?



2. Make prediction of experiment

What they think they will observe in the rotating frame of reference for combinations of Ω and Δρ.

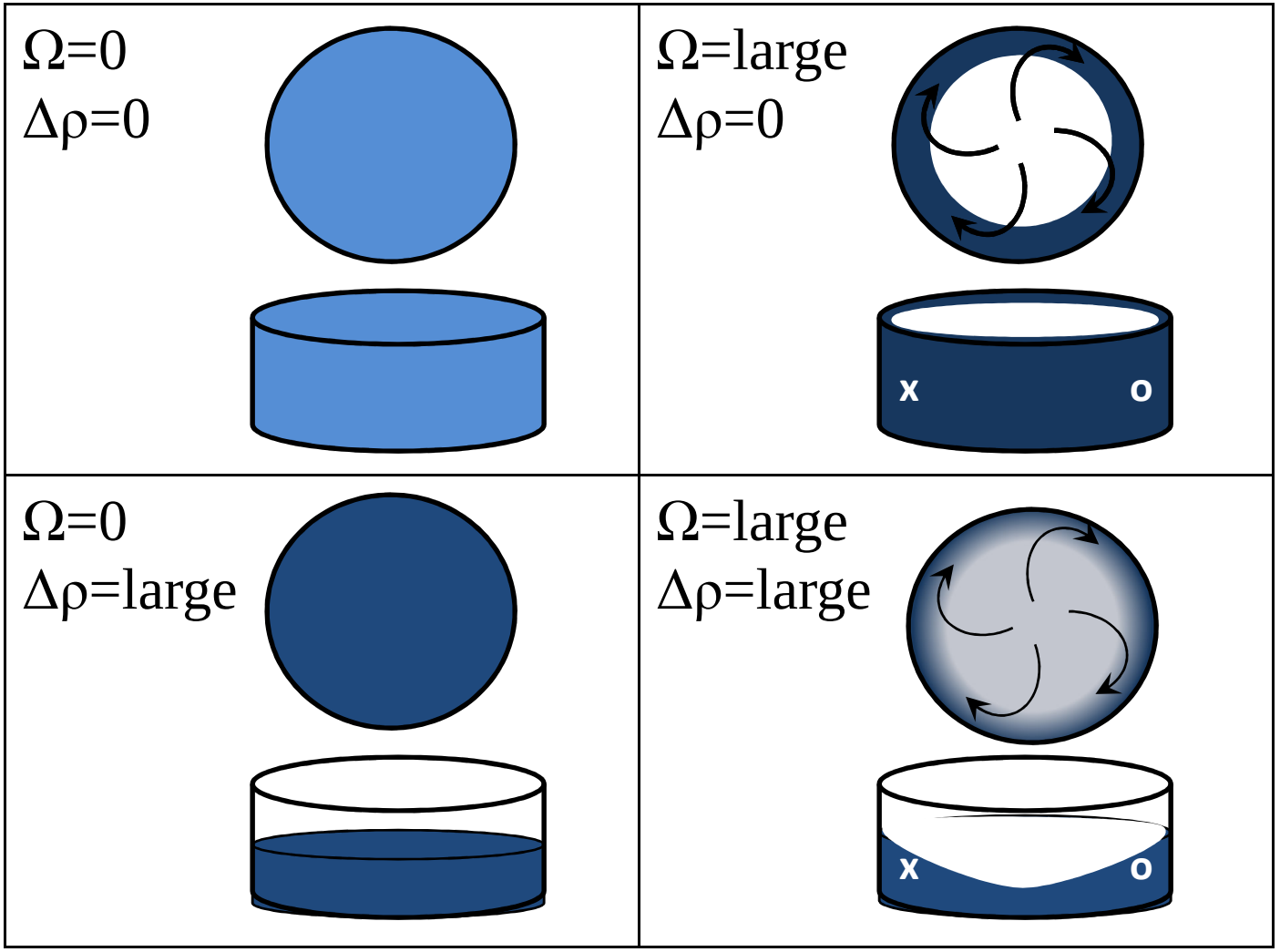
Δρ \ Ω	Ω=0	Ω=large
	Δρ=0	Δρ=0
Δρ	Ω=0 Δρ=large	Ω=large Δρ=large



$$\Delta\rho = \rho_2 - \rho_1$$

EXAMPLE: FRONTS

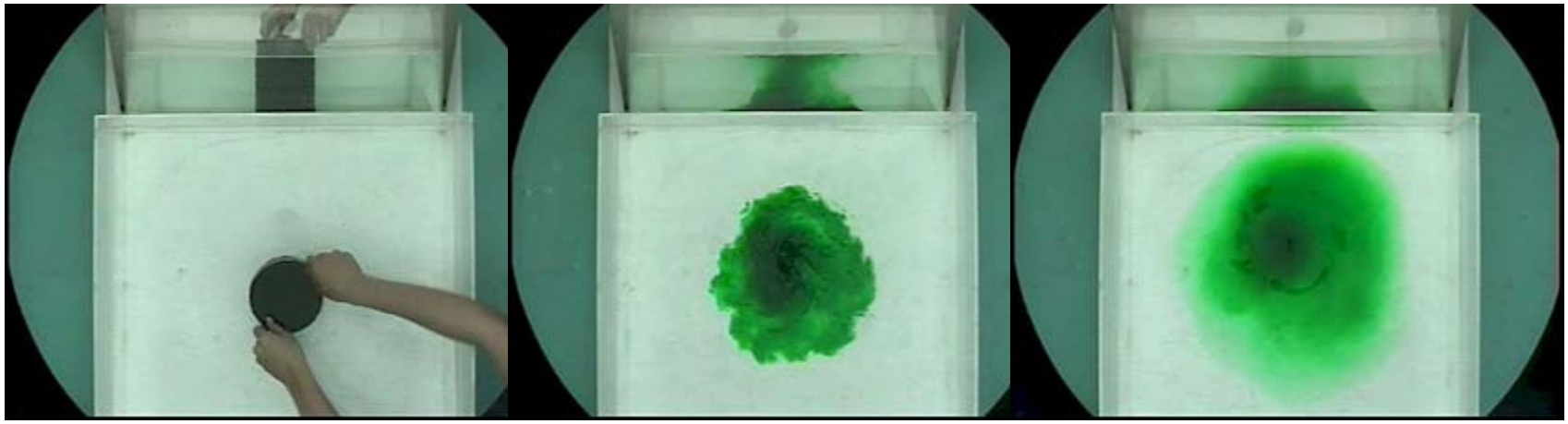
No rotation is fairly intuitive. Once rotation enters the mix, get some interesting responses.

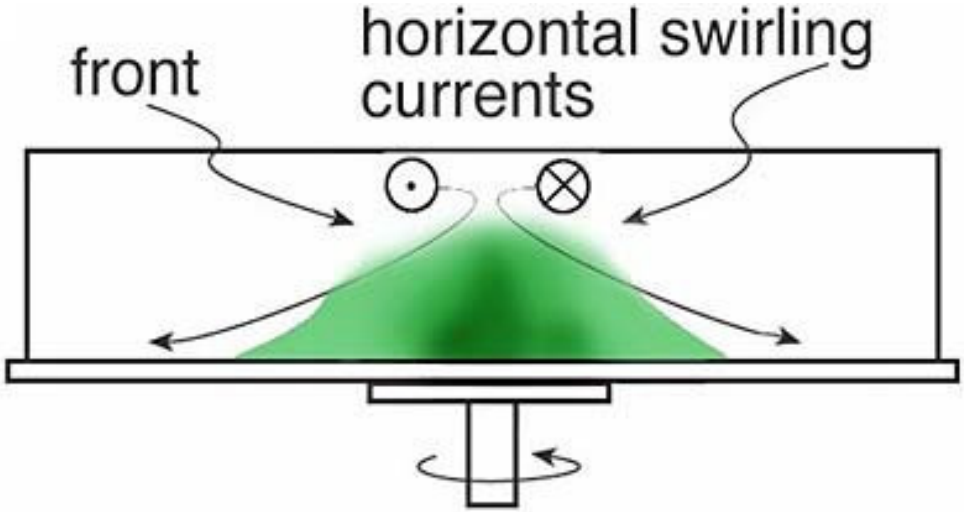


EXAMPLE: FRONTS

3. Demo experiment

Dome of salty water. Cyclonic motion at surface.

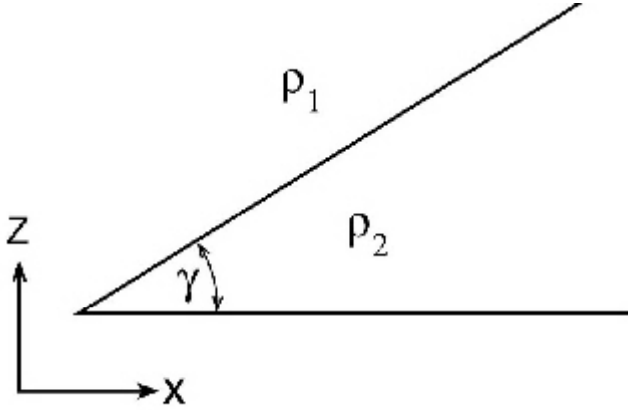




4. Highlight relevant theory

- Margules' Equation

$$v_2 - v_1 = g\frac{\rho_2 - \rho_1}{\rho_2}\frac{\tan\gamma}{f}$$

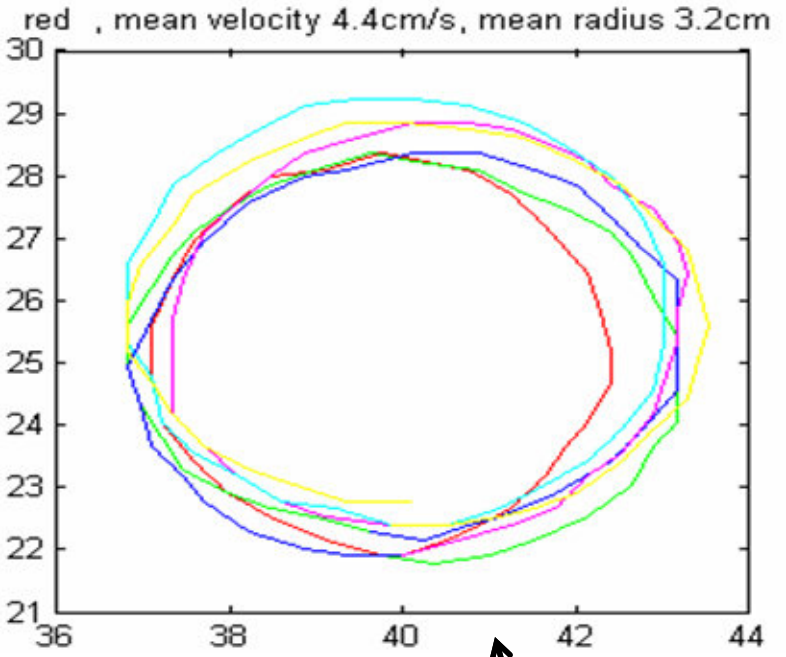


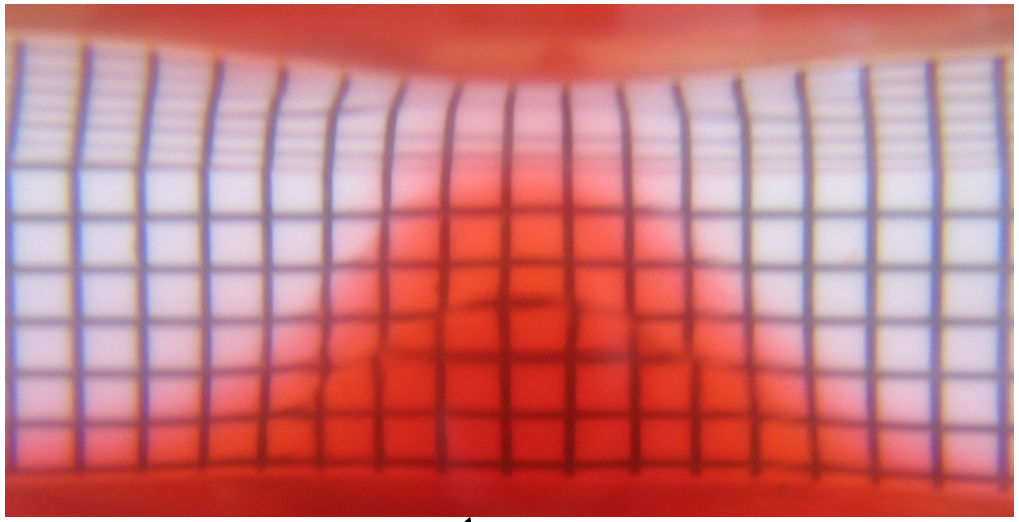
- Thermal Wind Equation

$$\frac{\partial \vec{u}_g}{\partial z} = -\frac{R}{fp}\hat{z}\times\nabla T$$

5. Perform experiment

Collect data to validate Margules' Equation

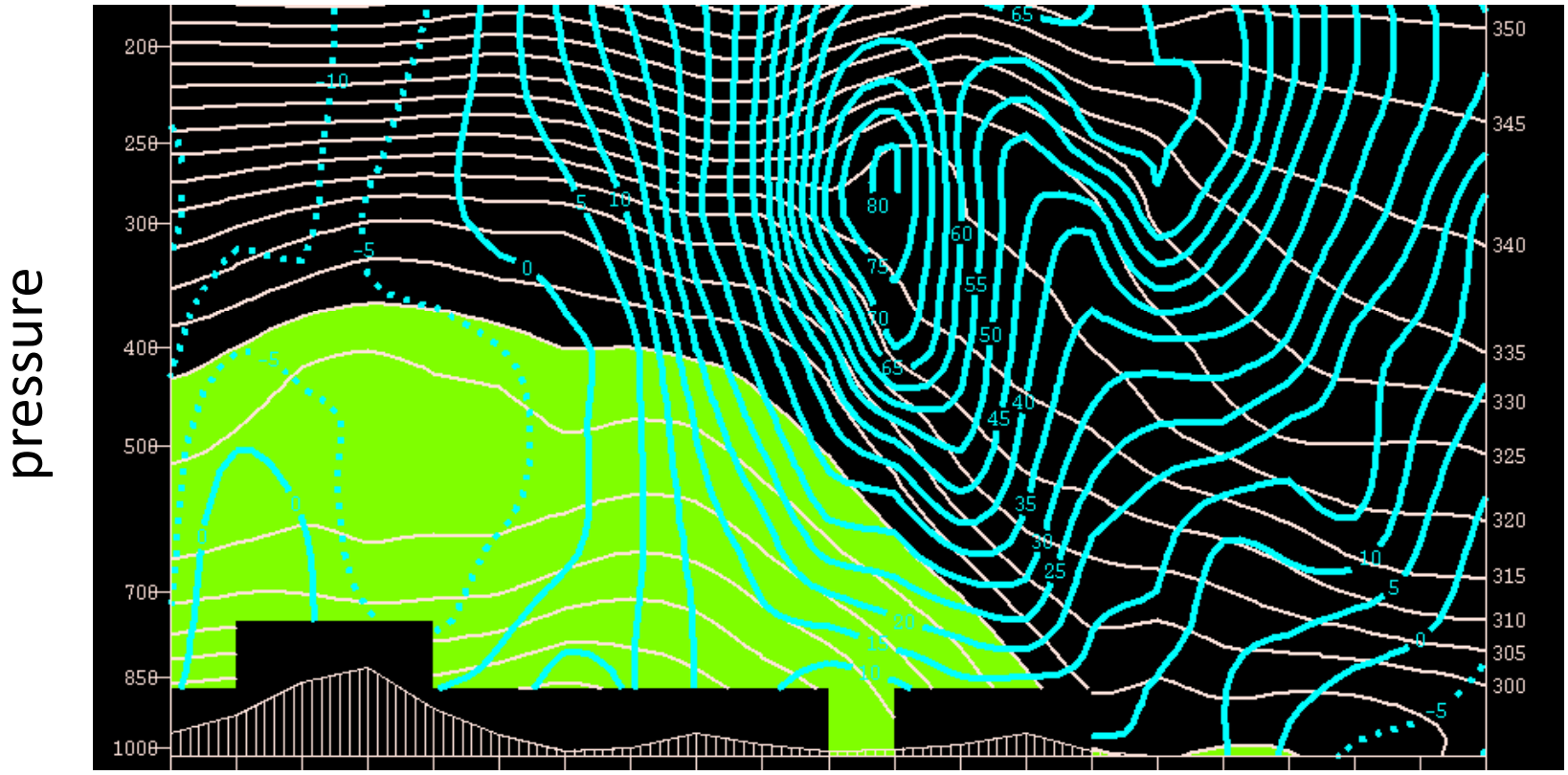




$$v_2 - v_1 = g\frac{\rho_2 - \rho_1}{\rho_2}\frac{\tan\gamma}{f}$$

5. Analyze real world observations

X-section across polar front to validate Thermal Wind



Potential temperature and zonal wind

EXAMPLE: FRONTS

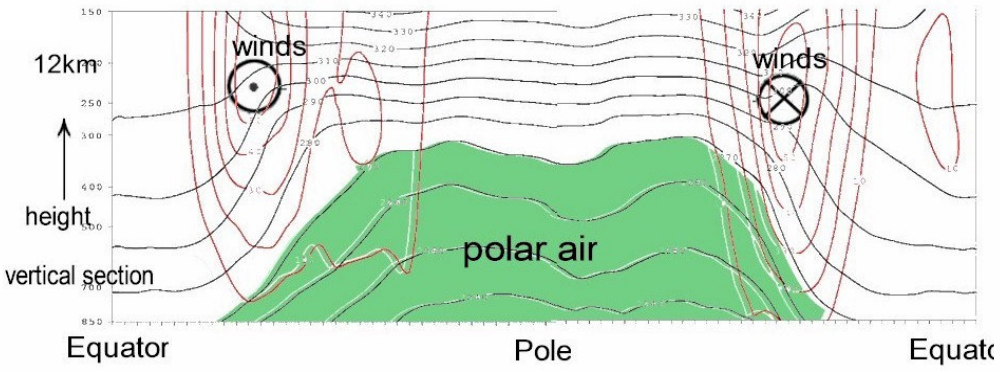
Finally, connect the dots!

Theory

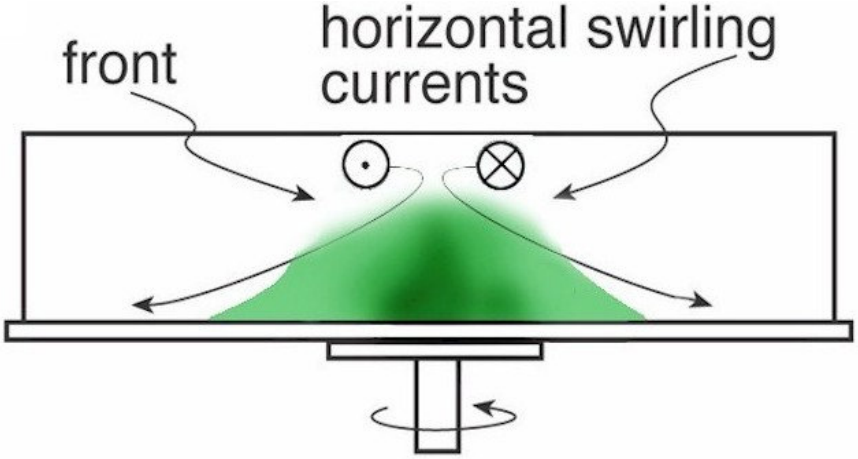
$$\frac{\partial \vec{u}_g}{\partial z} = -\frac{R}{fp}\hat{z} \times \nabla T$$

$$v_2 - v_1 = g\frac{\rho_2 - \rho_1}{\rho_2}\frac{\tan\gamma}{f}$$

Observations



Model



MID-LATITUDE GENERAL CIRCULATION DEMO

MID-LATITUDE GENERAL CIRCULATION DEMO

Theory

$$H = 2\pi a \cos\varphi \frac{c_p}{g} \int [\overline{v'T'}] dp$$

$$L_f \frac{\Delta m}{\Delta t} = 2\pi\rho c_w \int [\overline{v'T'}] dz$$

Observations

Model

ASSESSMENT

Instructor Comments

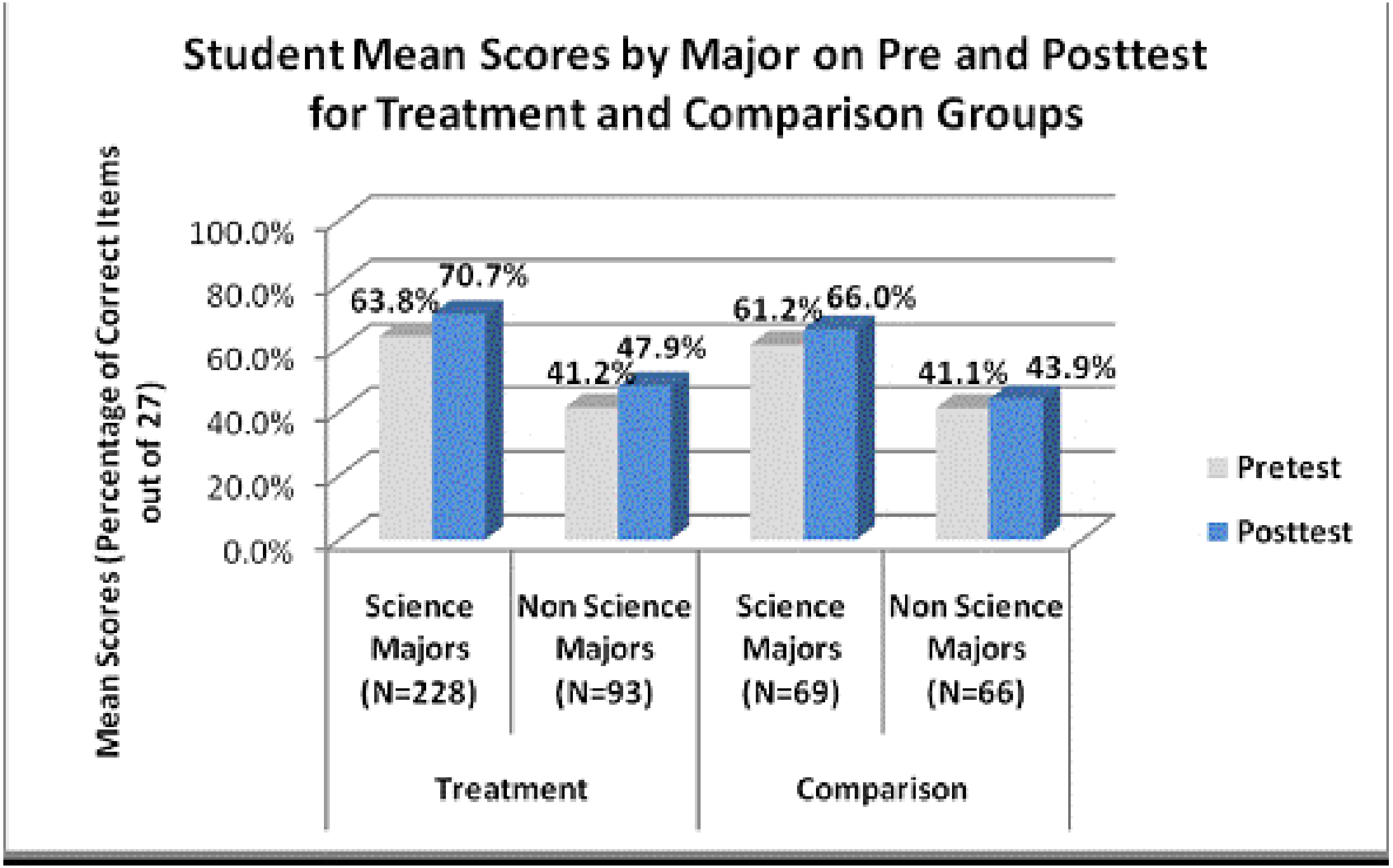
- Prompted students to work in teams to solve problems
- Deepened student engagement and motivation
- Prompted greater class discussion and questions

Student Comments

- Helped reinforce theory
- Enjoyed doing own experiments
- “Show us more hands on experiments like these!”

ASSESSMENT

Students participating in laboratory components benefited more compared to those with no lab



RESOURCES

http://paoc.mit.edu/labguide/

Flier on RAMADDA

Illari, L., and coauthors, 2009: Weather in a Tank: Exploiting laboratory experiments in the teaching of meteorology, oceanography, and climate, *Bull. Amer. Meteor. Soc.*, accepted.

Students participating in laboratory components come from diverse backgrounds