Teaching weather and climate using laboratory experiments

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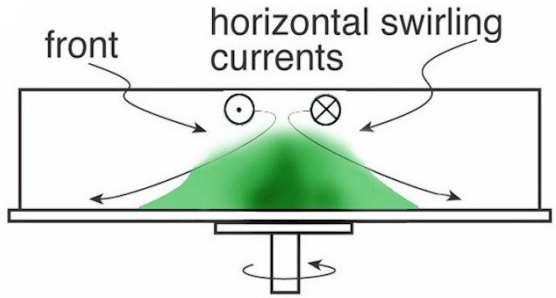


1. General remarks about use of laboratories in teaching weather and climate

2. Give an example of (what I believe to be) effective pedagogy using experiments

Three elements:
- Real-world data
- Experiment
- Theory

3. Goals of meeting

1. General remarks about use of laboratories in teaching

Laboratory experiments have made a huge contribution to the development of our field – G.I. Taylor etc

Experiments could be, but seldom are, a key element in teaching GFD, weather, climate….. in our schools and universities

Survey of US professors in Atmospheric Sciences

only 20% regularly use laboratory experiments
(and only a few % use rotating experiments)
majority (70%) never use experiments

Students see data manipulated over the web,
computer simulations or movie loops,
but rarely do they get their hands wet with real fluids.

Why?

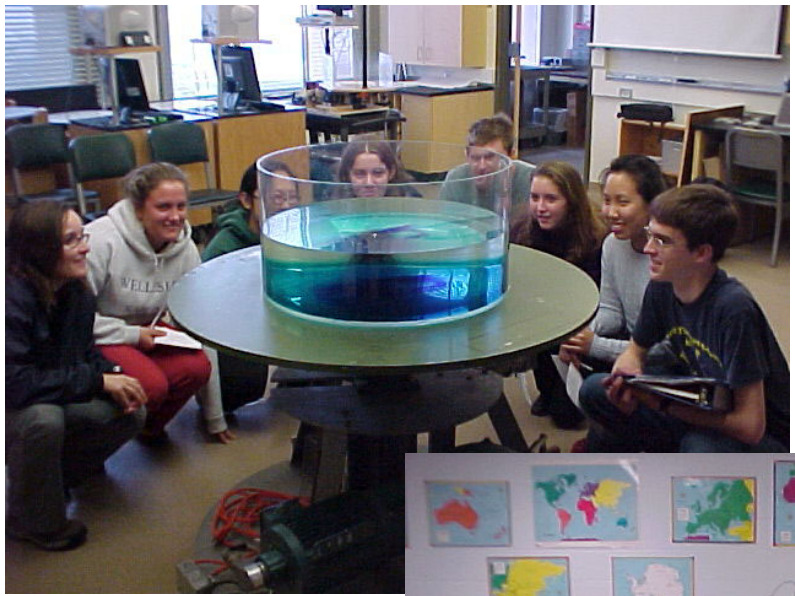
Many reasons, but following points are worth making:

- As our field has matured, it is has become dominated by large collaborative programs, field campaigns, large models, data streams……
- Drive to increasing detail: simulation rather then understanding
  SimEarth, virtual worlds
- It's perceived that one requires the backup of an extensive laboratory and much expertise to mount effective experiments.

What is an effective way to introduce the dynamics of a fluid on a **rotating** planet such as the earth?

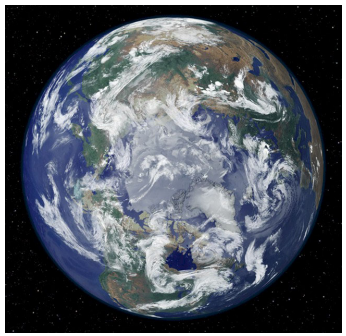
To whom? Undergraduates, Graduates

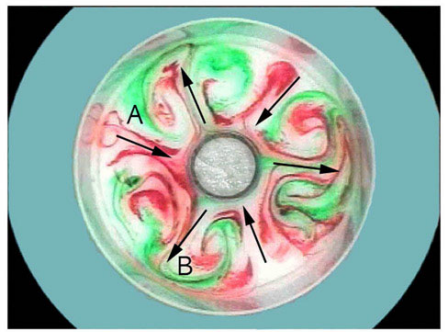
but also high school
and middle school students



I advocate combined use of:

- real world data
- simple, carefully designed laboratory experiments
  in context of relevant theory.





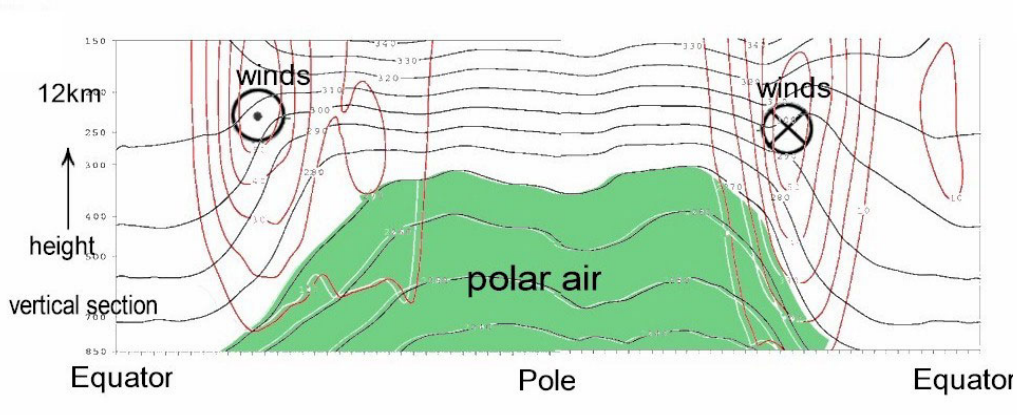
Observations ⟷ Models

Theory

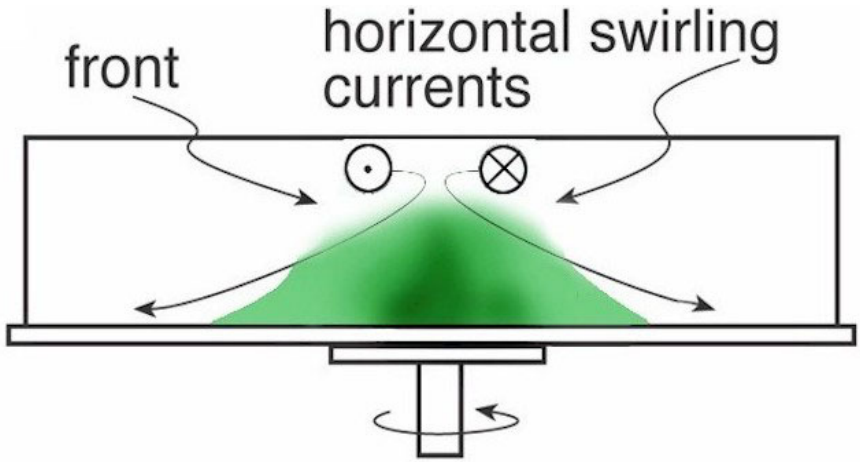
$$\frac{v_\theta^2}{r} + 2\Omega v_\theta + \Omega^2 r = g\frac{\partial H}{\partial r}$$

2. Example: Thermal wind

Atmospheric data



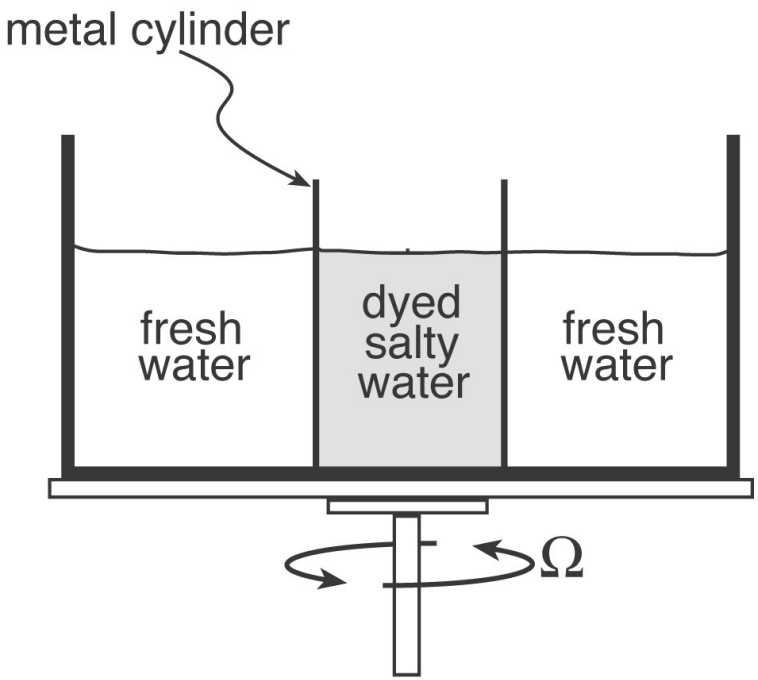
Laboratory experiment

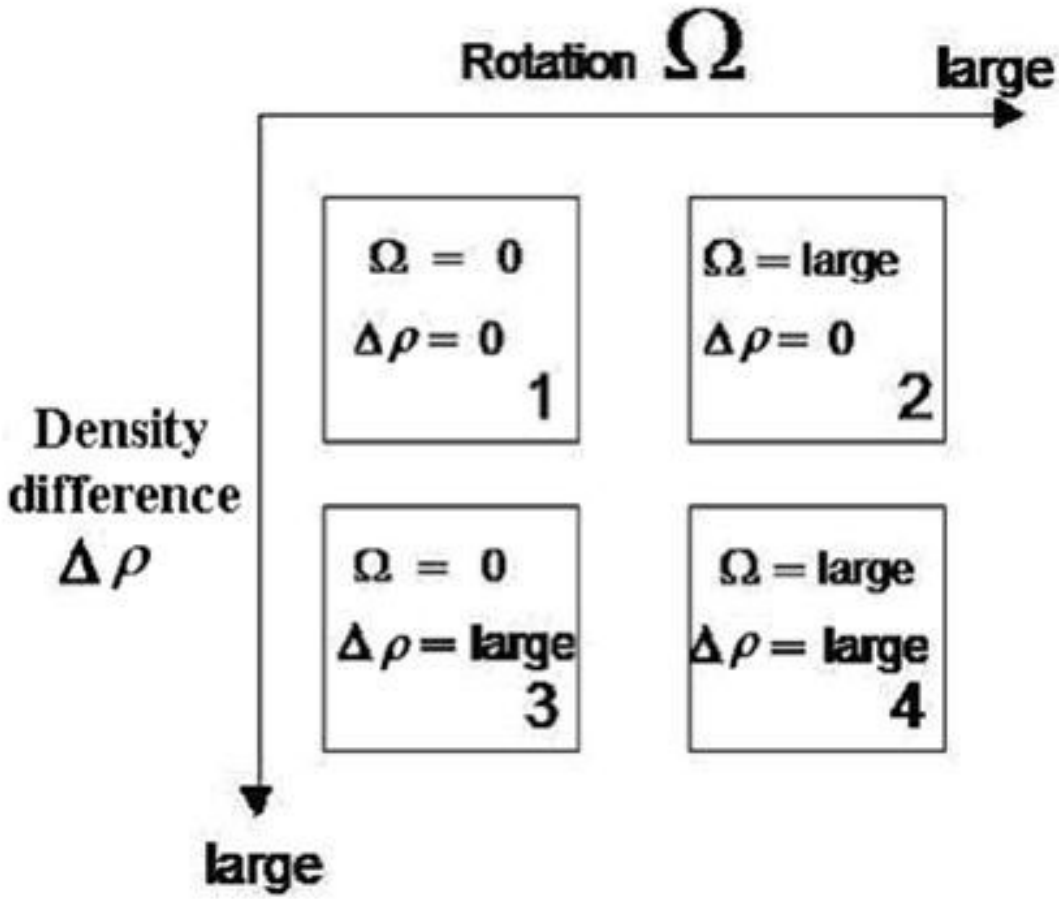


Theory

$$\frac{\partial u}{\partial p} = \frac{R}{fp}\left(\frac{\partial T}{\partial y}\right)_p$$

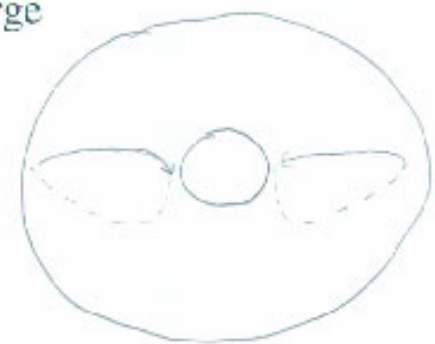
Experiment

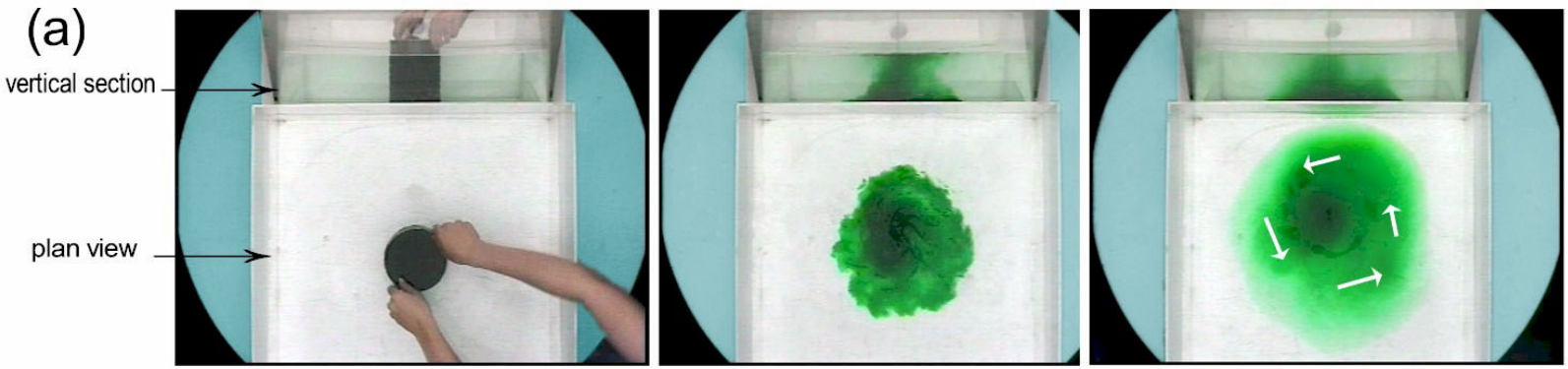

metal cylinder
fresh water
dyed salty water
fresh water
Ω

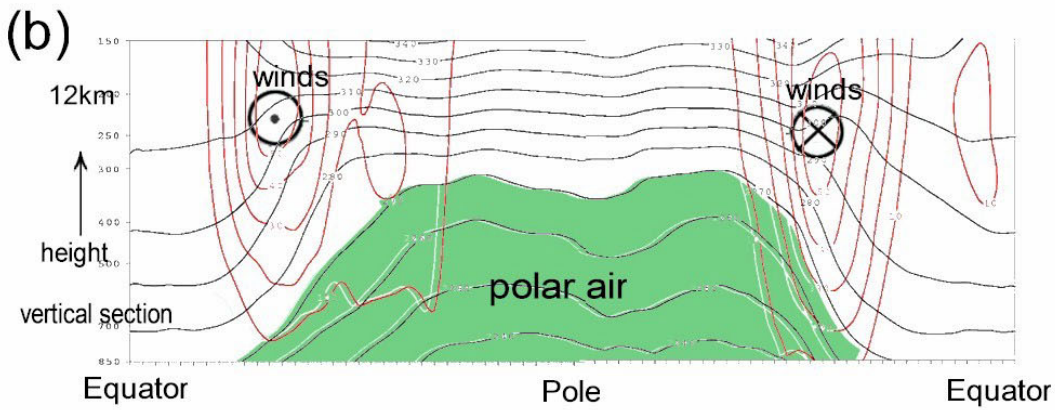

Rotation Ω
large
Density difference Δρ
Ω = 0
Δρ = 0
1
Ω = large
Δρ = 0
2
Ω = 0
Δρ = large
3
Ω = large
Δρ = large
4
large

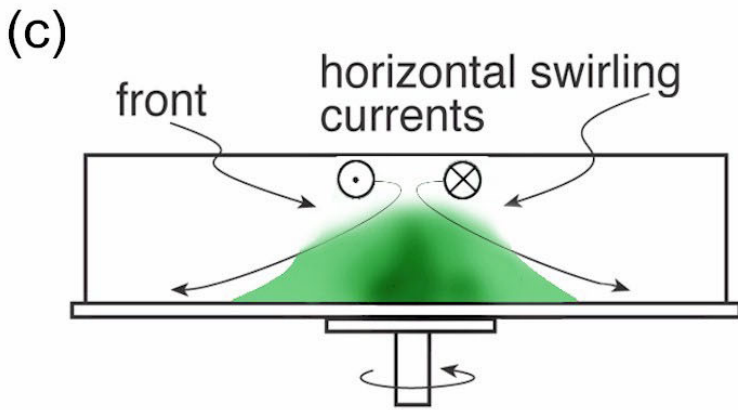
Encourage students to make predictions

Rotation=0 DT=0 1	Rotation=large DT=0 2
Rotation=0 DT=large 3	Rotation=large DT=large 4







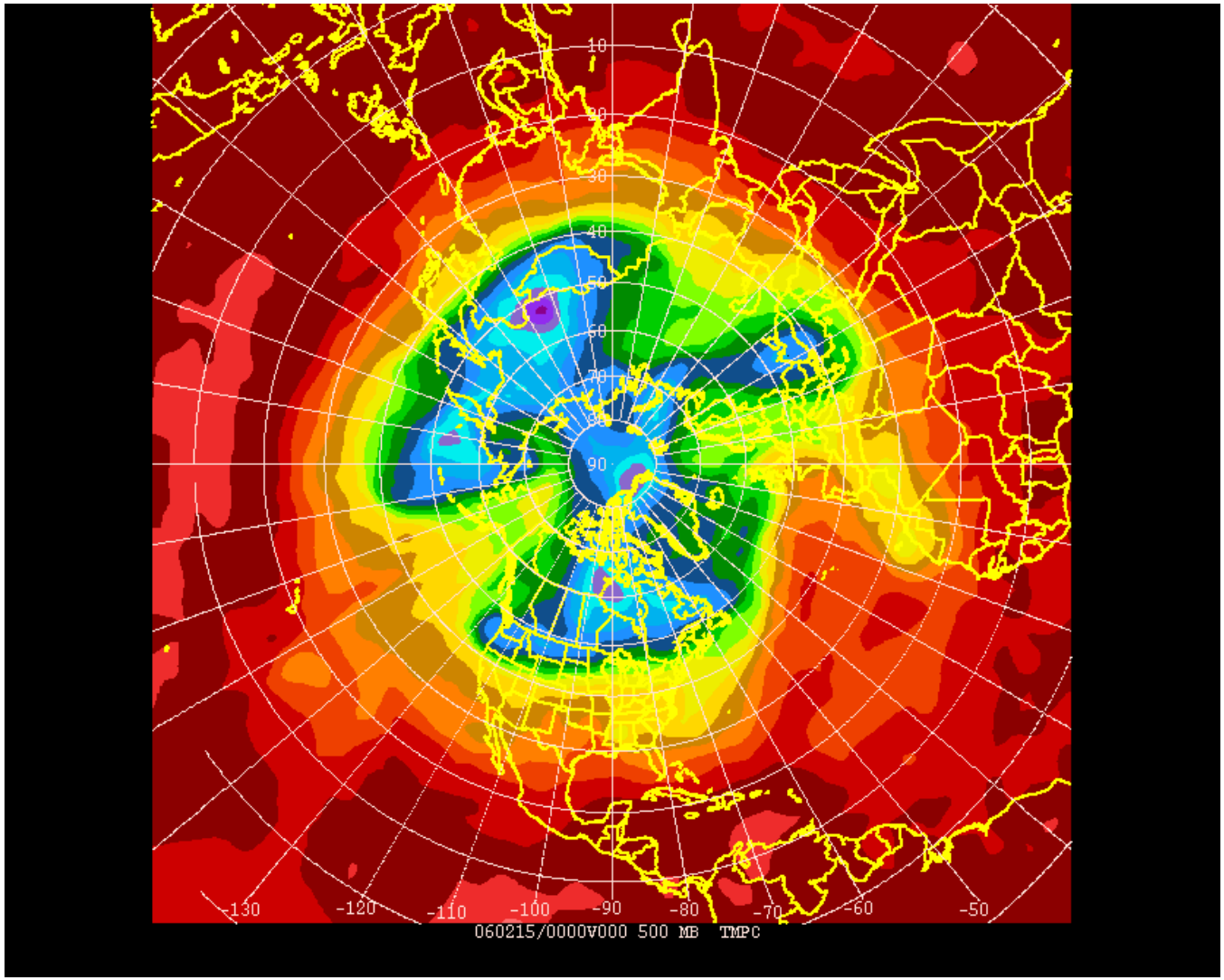


Real time data, section and jet

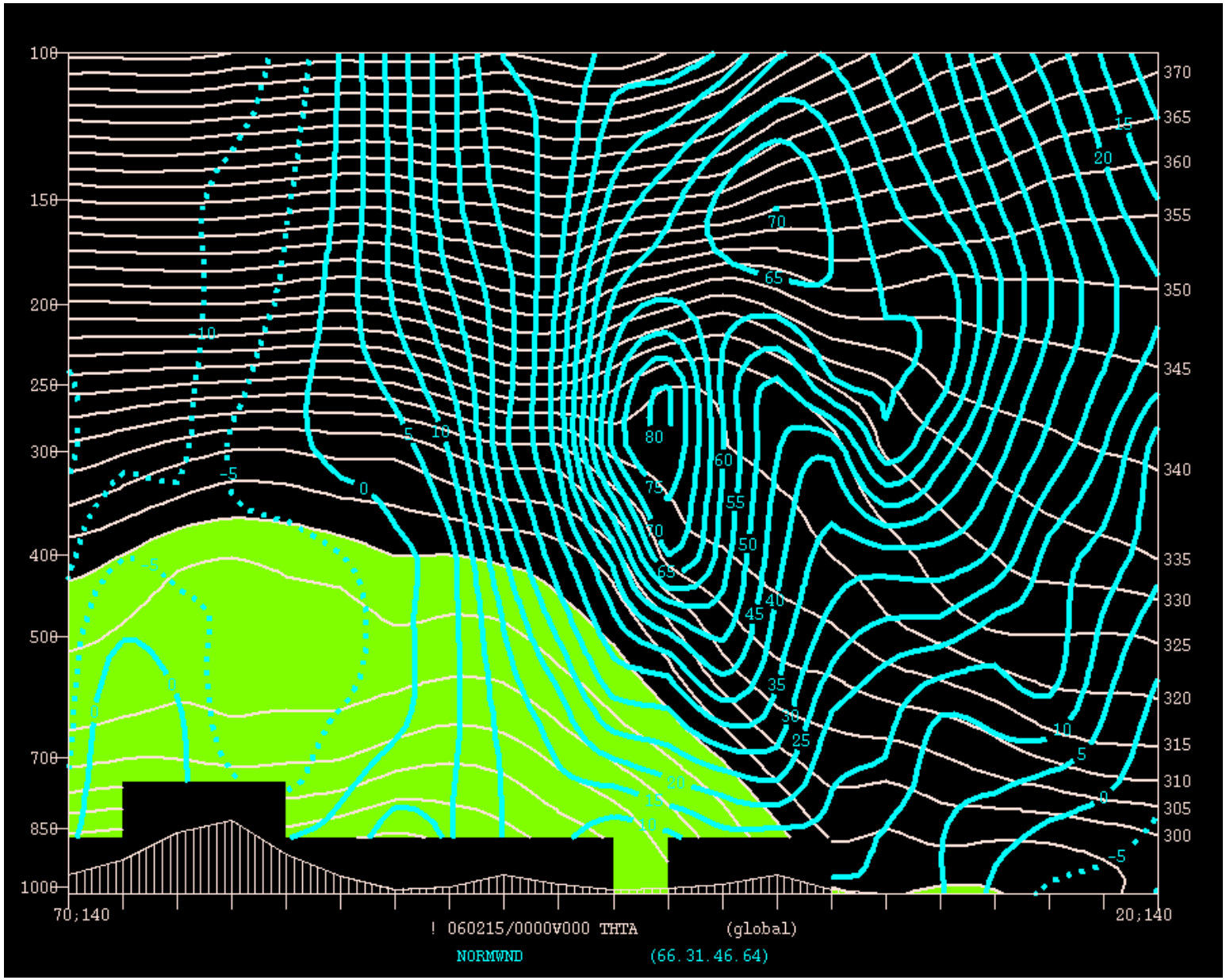
Observations

15 Feb, 2006

500mb T



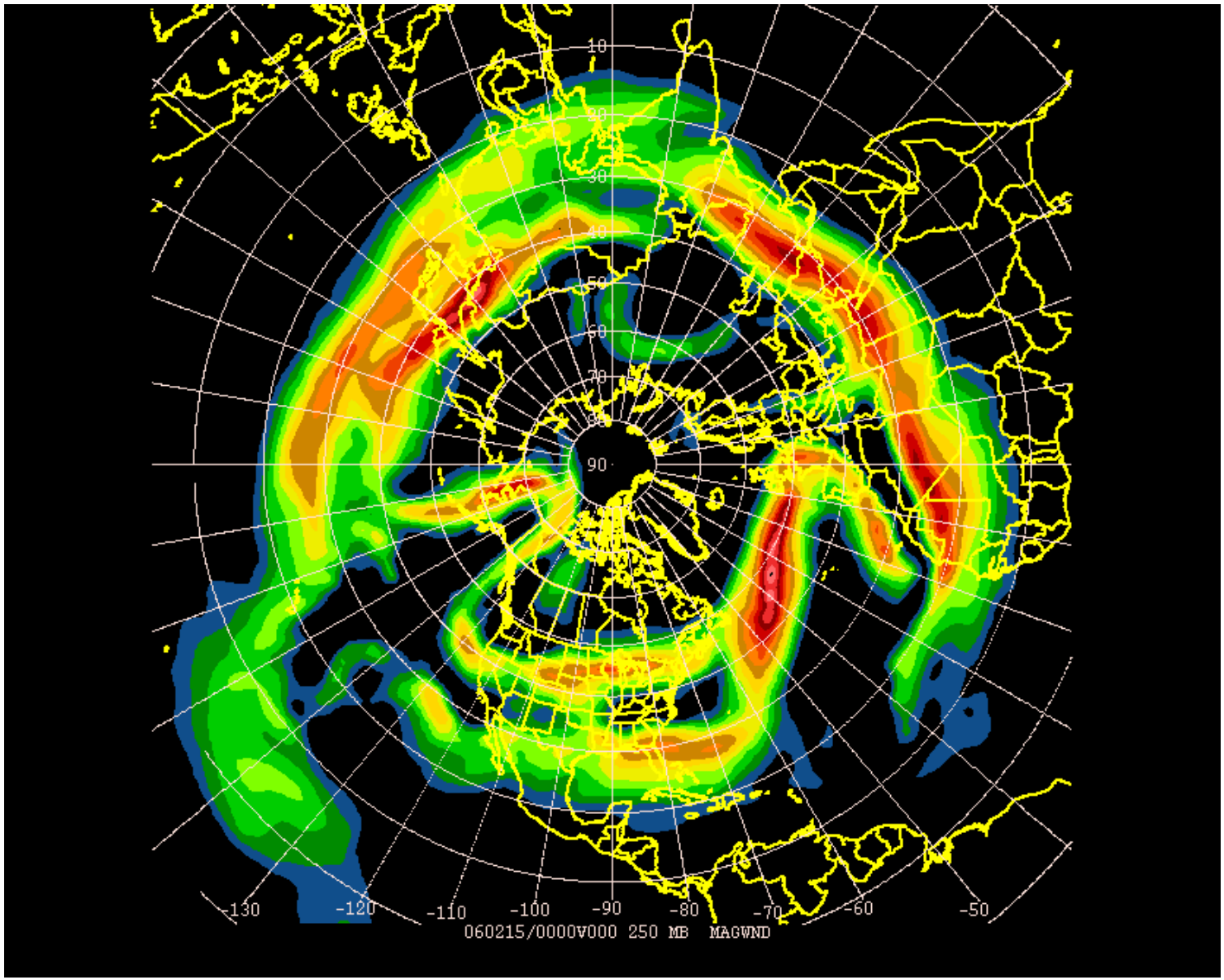
15 Feb, 2006 potential temperature and zonal wind



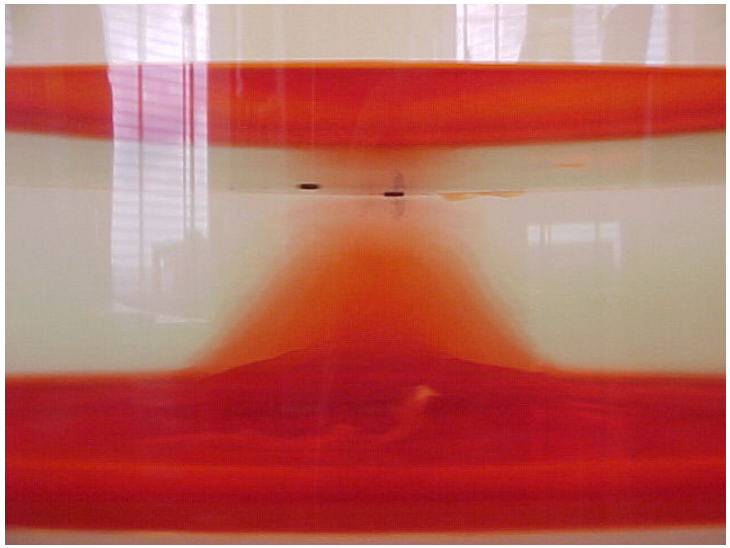
Pole Eq

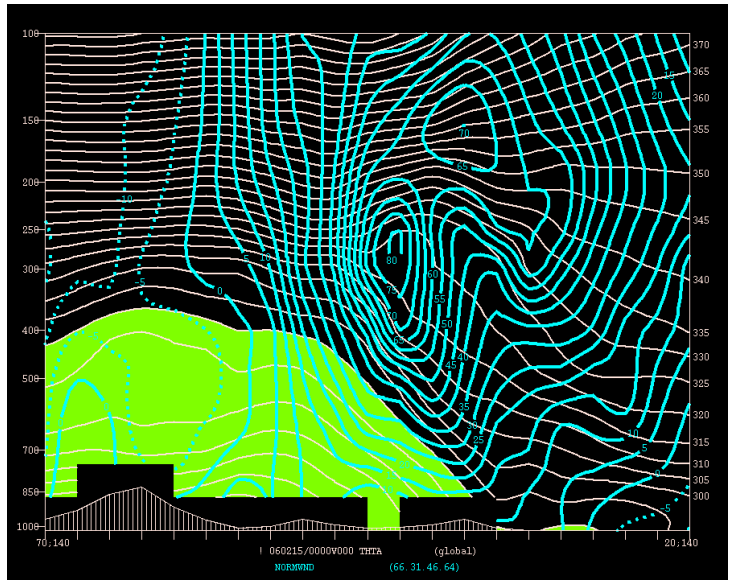
15 Feb, 2006

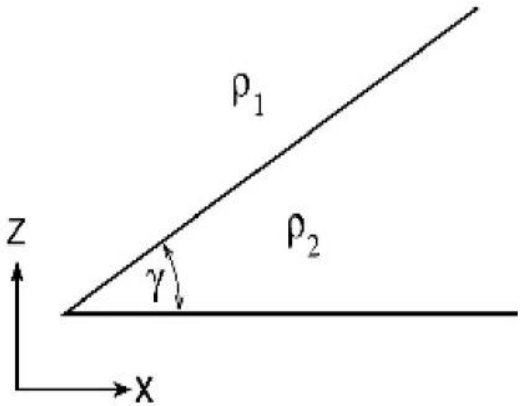
250 mb wind



Theory







$$\tan\gamma = \frac{f(v_1 - v_2)}{g\left(\frac{\rho_2 - \rho_1}{\rho_2}\right)}$$

Margules Formula

non- dimensional numbers: $R_o = \frac{V}{2\Omega L}$ $\frac{L_\rho}{L} = \frac{\sqrt{g'H}}{2\Omega L}$

Such approaches to teaching weather and climate are being explored in an ongoing NSF-funded project called:

http://www-paoc.mit.edu/labguide/introduction.html

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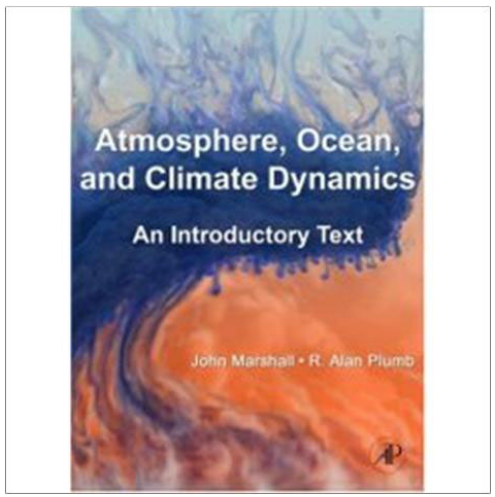
UMass Dartmouth, A.Tandon
University of Wisconsin – Madison, G. McKinley, M. Morgan
Johns Hopkins University, T. Haine, D. Waugh
Millersville University, R. Clark , T. Sikora

Our Education consultant is Dr Kathie Mackin.

Also the subject of a new undergraduate text book

Atmosphere, Ocean and Climate Dynamics: an introductory text
published by Academic Press

John Marshall and Alan Plumb (2007)



3. Goals of the meeting

To bring people together,
exchange ideas on cost-effective experimental designs,
curriculum development and evaluation.

Discuss what works and doesn't work.

Build a network of common resources.