Modeling of Heat Induced Tropical Circulation

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About Myself

- Raised in Atlanta, GA via New York City
- 2^{nd} Year PhD Student in Atmospheric Science at Colorado State University under Dr. W. Schubert.
- Research Interests: Tropical Cyclone Intensity, Tropical Circulation Modeling, and Geophysical Fluid Dynamics
- Other Interests: Playing Music; Studying Economic Theory and Political Theory; Cooking; Playing and Watching Baseball

Motivation

- Over recent decades, interest in tropical meteorology has increased due to its impact in extratropical weather forecasting.
- Also, as more forecasting centers used global models for numerical weather prediction and climate studies, it became apparent that the tropical atmosphere was difficult to simulate.
- Improving the models for tropical atmospheric motion and circulation will also give the groundwork for improving global climate models as well.

Steady State Heat-Induced Tropical Circulation

- Gill (1980) constructed a model to explain the basic features of the response of the tropical atmosphere to diabatic heating.
- Much of the heating in the tropics is found over Africa, South America, and Indonesian region, which raises questions on the result of heating a limited area centered near the equator on tropical circulation.
- If heating is applied to a steady-state atmosphere and is small enough to use linear theory, then the response can be modeled in terms of equatorially trapped waves.
- The heating would create eastward Kelvin waves and slowly moving westward planetary waves, leading to an east-west asymmetry in tropical circulation.

The Basic Model

- Using linear theory, the tropical atmosphere can be modeled using the shallow water equations. To study the response to steady forces, dissipative processes are included by a small parameter ε.
- To solve, we expand the variables q, r, v, Q in terms of parabolic cylinder functions $D_n(y)$ to produce the steady state equations:
  - For n ≥ 0, $\varepsilon q_0 + \frac{dq_0}{dx} = -Q_0$

    $\varepsilon q_{n+1} + \frac{dq_{n+1}}{dx} - v_n = -Q_{n+1}$
  - For n ≥ 1, $\varepsilon r_{n-1} + \frac{dr_{n-1}}{dx} - n v_n = -Q_{n-1}$
  - For n ≥ 1, $q_1 = 0$

    $r_{n-1} = (n+1) q_{n+1}$

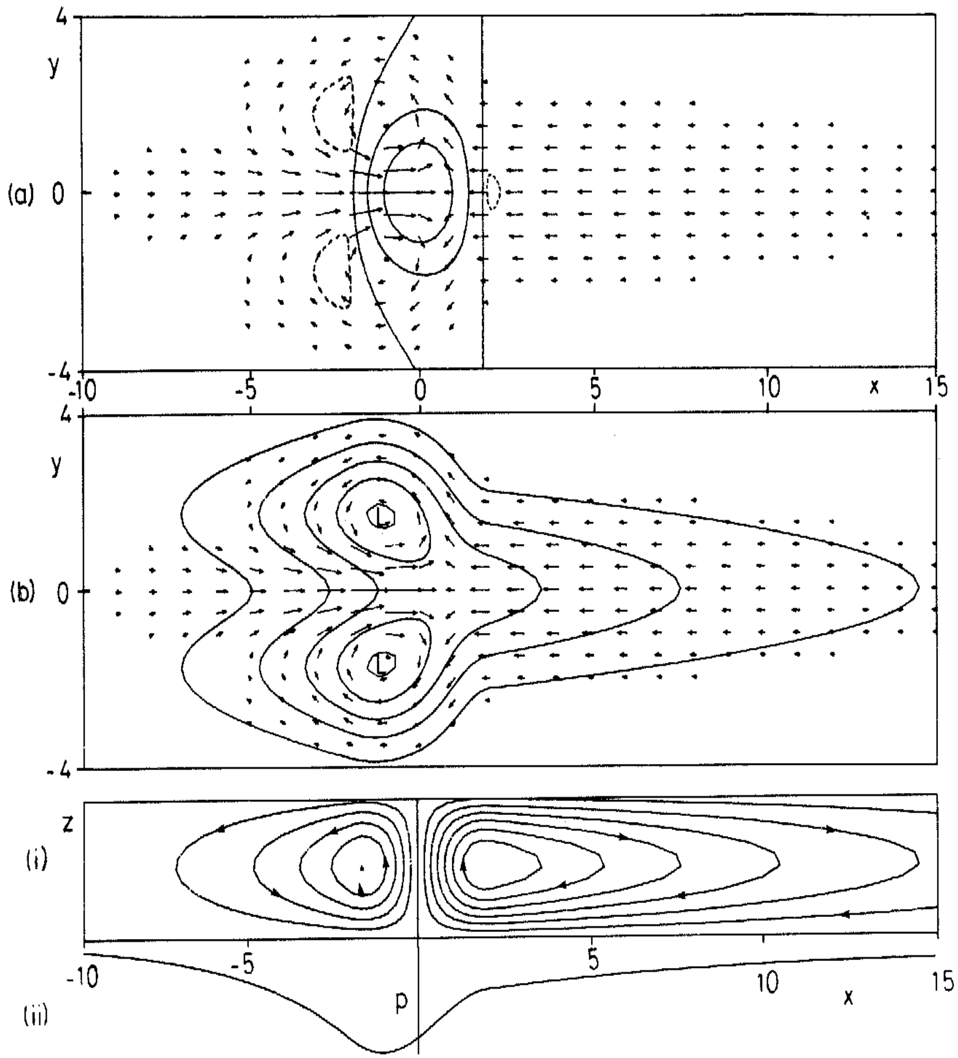
$q = p + u$

$r = p - u$

$w = \varepsilon p + Q$

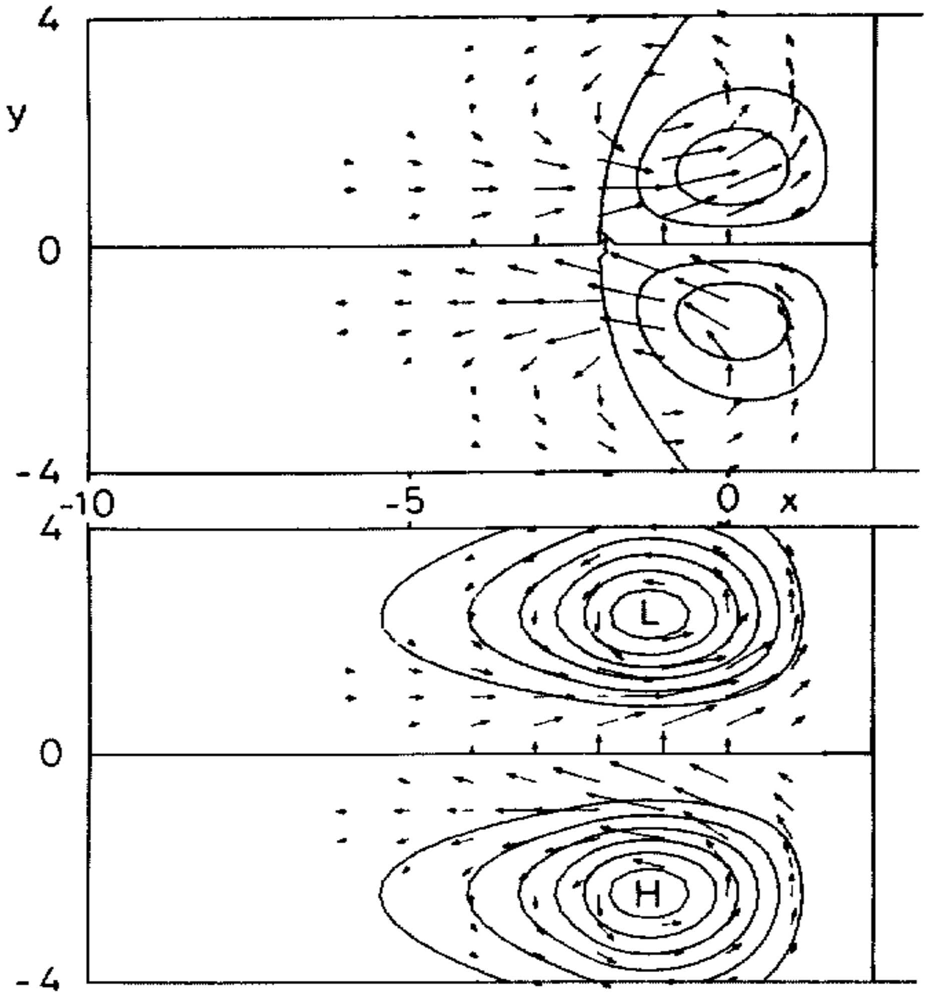
$(D_0, D_1) = (1, y)\, e^{-\frac{1}{4}y^2}$

Case 1: Symmetric Forcing



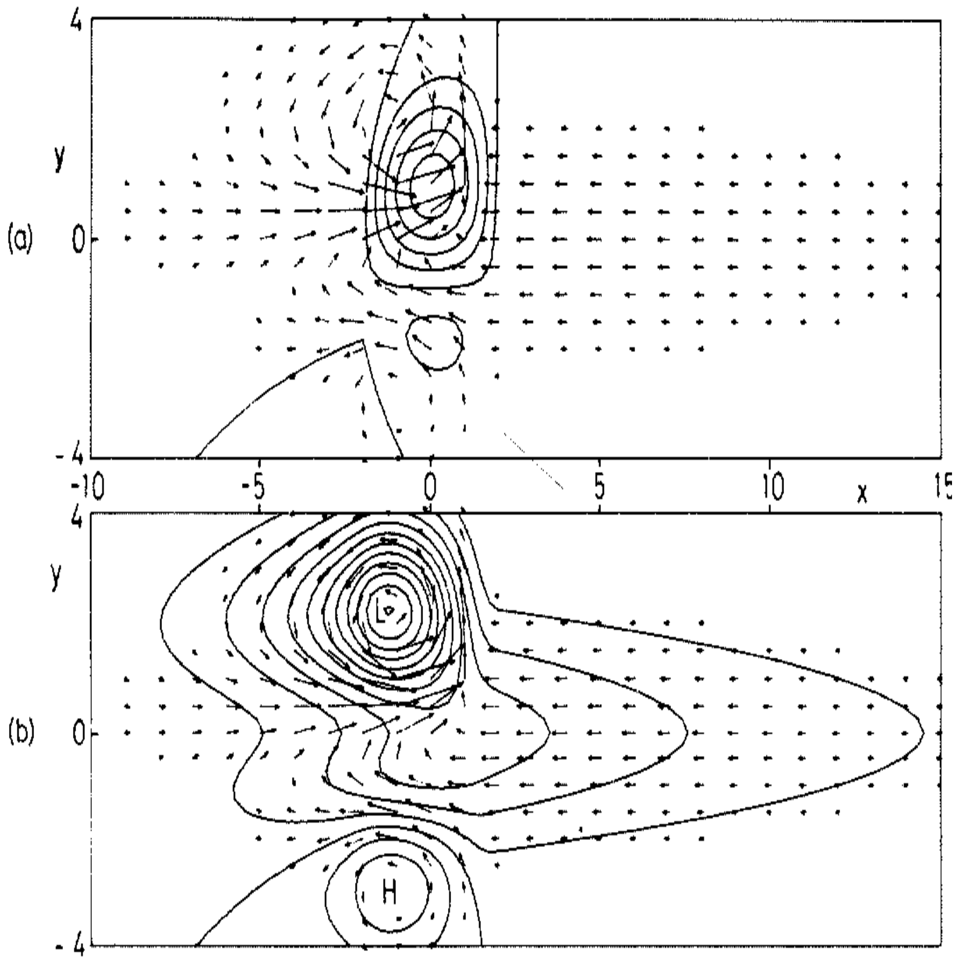
- Here, $Q(x,y) = F(x)D_0(y)$ where $F(x) = \cos(kx)$ in the heating region and $F(x) = 0$ elsewhere.
- The first node (n=0) represents a damped Kelvin wave
- If forcing is taken over the Indonesian area, this represents the Walker circulation
- The second node (n=1) represents a damped planetary wave, moving at 1/3 of the speed of the Kelvin wave

Case 2: Asymmetric Forcing



- Here, $Q(x,y)= F(x)D_1(y)$ where $F(x) = \cos(kx)$ in the heating region and $F(x) = 0$ elsewhere.
- The n=0 mode corresponds to a mixed planetary-gravity wave.
- Because long mixed waved don't propagate, there is no effect to the east of the forcing region.
- The n=2 mode corresponds to a long rapidly decaying planetary wave.

The General Solution



- East of the heating region, the flow is due entirely to the symmetric forcing.
- West of the heating region, westerly inflow is concentrated in the heating region, while easterly flow is found south of the equator.
- A strong low to the west of the heating region with a high in the Southern hemisphere.

Further Questions

- Other effects that have been studied are:
  - The effect of a zonal mean wind on heat induced tropical circulation
  - The time scale of geostrophic adjustment on heat induced tropical circulation
  - The nonlinear effects on heat induced tropical circulation