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Evolution of Finite Vorticity Strips Using a Barotropic, Non-Divergent, Pseudo-Spectral Model

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The Model

Model based on the following momentum and mass-continuity equations in Cartesian coordinates:

$$\frac{\partial \zeta}{\partial t} + \frac{\partial(\psi,\zeta)}{\partial(x,y)} = \nu\nabla^2\zeta - \beta\frac{\partial \psi}{\partial y} \qquad (1)$$

$$\zeta = \nabla^2 \psi \qquad (2)$$

Solution Technique:

- Equations solved using spectral methods
- Method allows for efficient calculation of the derivatives
- The streamfunction ψ is used to derive the vorticity equation.

Model Specifications:

- 6400km x 6400km doubly periodic domain
- 512 x 512 grid points
- Ordinary diffusion with e-folding time of 1 hour for waves with a total wave number of 170

Objectives:

- Replicate the non-divergent, barotropic, pseudo-spectral model used in Schubert et al. (1999) in a MatLab environment.
- Examine the effects of finite vorticity strip length and width on the evolution of an *f*-plane vorticity field.
- Investigate the effects of β forcing on finite vorticity strips

Cases

Case 1: 1350km x 150km (*f*-plane)
Case 2: 2250km x 250km (*f*-plane)
Case 3: 3600km x 400km (*f*-plane)
Case 4: 2000km x 200km (*β*-plane)

References:

Guinn, T.A., and W.H. Schubert, 1993: Hurricane spiral bands. *J. Atmos. Sci.*, **50**, 3380-3403.
Schubert, W.H., et al. 1999: Polygonal eyewalls, asymmetric eye contraction, and potential vorticity mixing in hurricanes. *J. Atmos. Sci.*, **56**, 1197-1223.
Ferreira, Rosana Nieto, Wayne H. Schubert, 1997: Barotropic Aspects of ITCZ Breakdown. *J. Atmos. Sci.*, 54, 261–285.
Wang, Chia-Chi, Chia Chou, Wei-Liang Lee, 2010: Breakdown and Reformation of the Intertropical Convergence Zone in a Moist Atmosphere. *J. Atmos. Sci.*, 67, 1247–1260.
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Model Initialization

Initial Vorticity Field

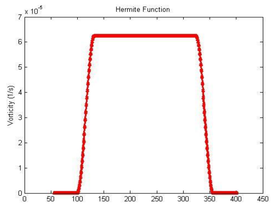
$$r = \begin{cases} \sqrt{a^2(|xt| - x1)^2 + (yt)^2} & \text{for } |xt| > x1 \\ |yt| & \text{otherwise,} \end{cases}$$

$$\zeta = \begin{cases} \zeta_0 & \text{if } r \le r1 \\ \zeta_0 H(r) & \text{if } r2 > r > r1 \\ 0 & \text{if } r \ge r2 \end{cases}$$

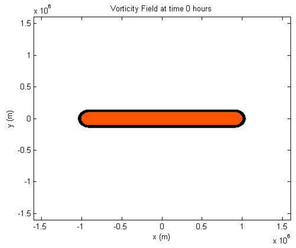
where $H(r) = 1 - 3w^2 + 2w^3$,

and $w \equiv \frac{r-r1}{r2-r1}$,

Vorticity Cross-section

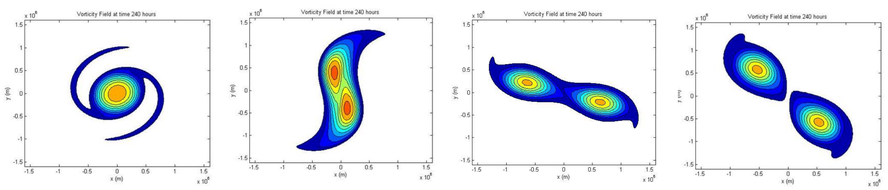


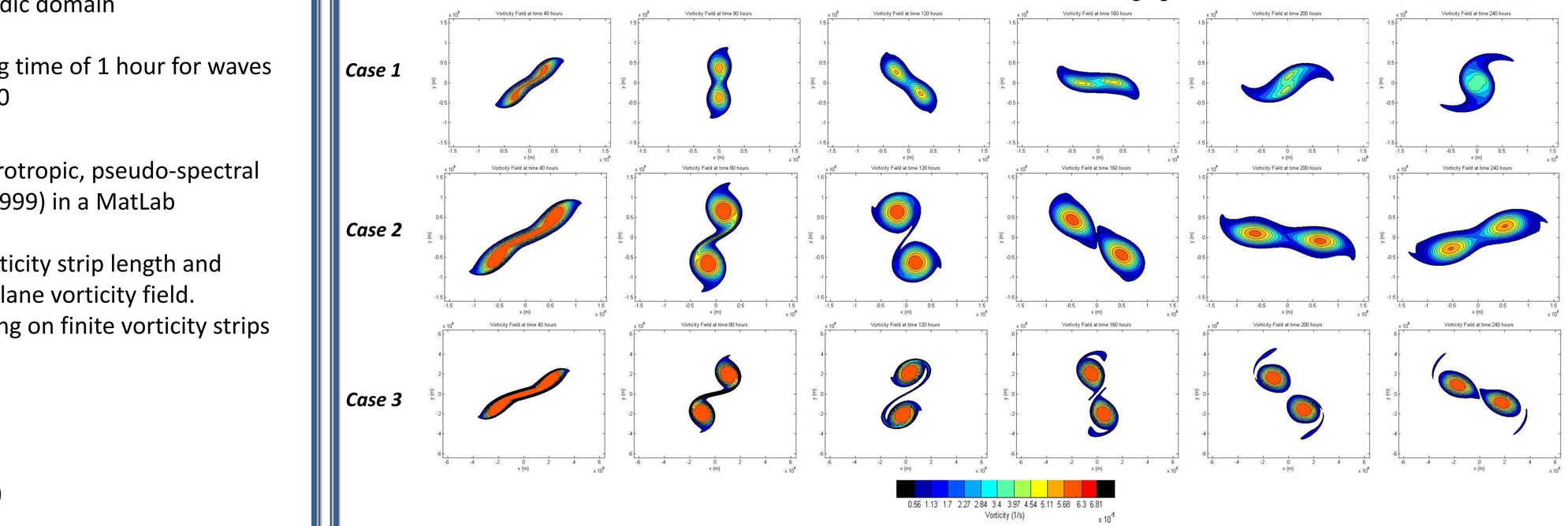
Vorticity Plan View



Vorticity Evolution Ratios				
Width (km)				
	One	Merging	Separate Centers	Independent Vortices
100	1–12	12–14	14–20	20+
150	1–9	9–11	11–14	14+
200	1–8	8–9	9–13	13+
250	1–6	6–7	7–11	11+
300	1–6	6–7	7–10	10+
400	1–6	6–7	7–9	9+

f-plane





β-plane