Instabilities of a barotropic rotating shear layer

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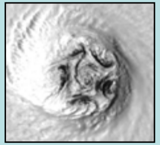
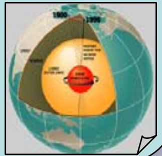
1. Real World Background

- Barotropic instability seems to play a key role in hurricane intensification. Meso-vortices are triggered by strong horizontal shears in the eye wall. [KS]

- Such a mechanism happens wherever a rapidly rotating, homogeneous fluid is confined within physical boundaries, as for e.g. in the outer core of the Earth. [SR]



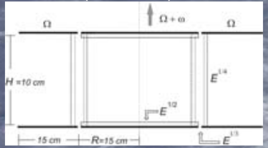


- Axisymmetric model;
- Grid stretched in *z*, but not in *r*;
- Right cylindrical geometry;
- differential rotation in both inner disks. [c.f. lab experiment]

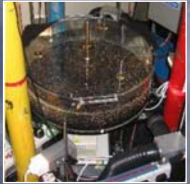
Comparison is made between different sets of (*Ro, E*). [*E* fixed for each ±*Ro* pair]

2. Experiment

Stewartson shear layers (X-section)



Lab.



Flow parameters:

$$\omega = \pm|\omega| \ , \ \Omega > 0$$

$$Ro \equiv \frac{R\omega}{2\Omega H} \ , \ E \equiv \frac{\nu}{\Omega H^2}$$

Quasi-Geostrophic theory can *not* account for all past research results !

forcing	[HT]	[FR]	[H]
Ro > 0	$m \le 7$	$m \le 8$	$m \le 8$
Ro < 0	$m \le 2$	$m \le 8$	$m \le 3$

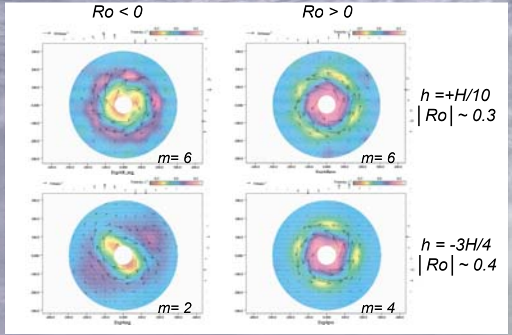
[*m* = azimuthal wavenumber]

Asymmetric
Inner disk height ≠ FR

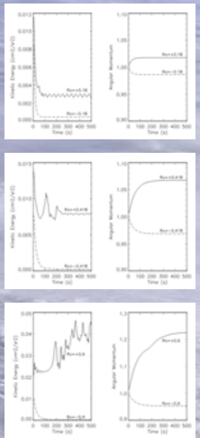
3. Experimental Results

[effects of stepped topography]

- How big are the effects? [c.f. internal disk position]
- The top inner disk was moved *up* (+) or *down* (-) by *h,* wrt rigid outer annular surface.



4. Navier-Stokes 2D Model Results

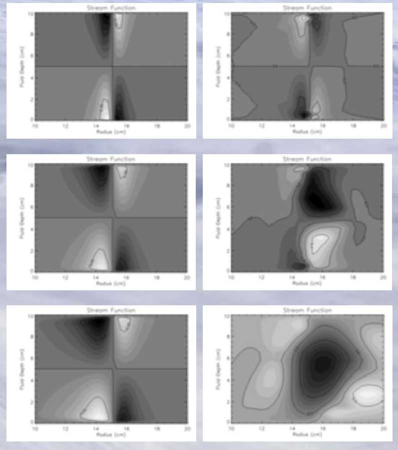


Time evolution of kinetic energy and angular momentum

corresponding Snapshots of meridional stream function

- ■ positive
- ■ ~ 0
- □ negative

|Ro| , E



5. Conclusions

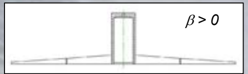
➢ Experiments indicate that, for discontinuous depth changes, a significant ± *Ro* asymmetry occurs if $h > |Ro| \cdot H$. This must happen when topographic effects become relevant.

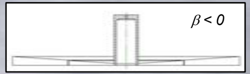
➢ NS 2D shows the importance of ageostrophic effects in the $E^{1/3}$ shear layers. For |*Ro*| > 0.18 circulation becomes asymmetric wrt sign of *Ro*. For Ro ≥ +0.4, flow develops toroidal structure associated with a centrifugal instability (resembling Taylor-Görtler vortices) – also seen in lab. experiments.

6. Future

[in the Lab.]

β-effect?
Sloping end walls
(X-section)





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[KS] Kossin, J.P. & Schubert, W.H., 2001, *J. Atmos. Sci.*,**58**, 2196-2209. [SR] Song, X. & Richards, P.G., 1996, *Nature*,**382**,221-224.

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