

# Applications of the TC motion concepts I

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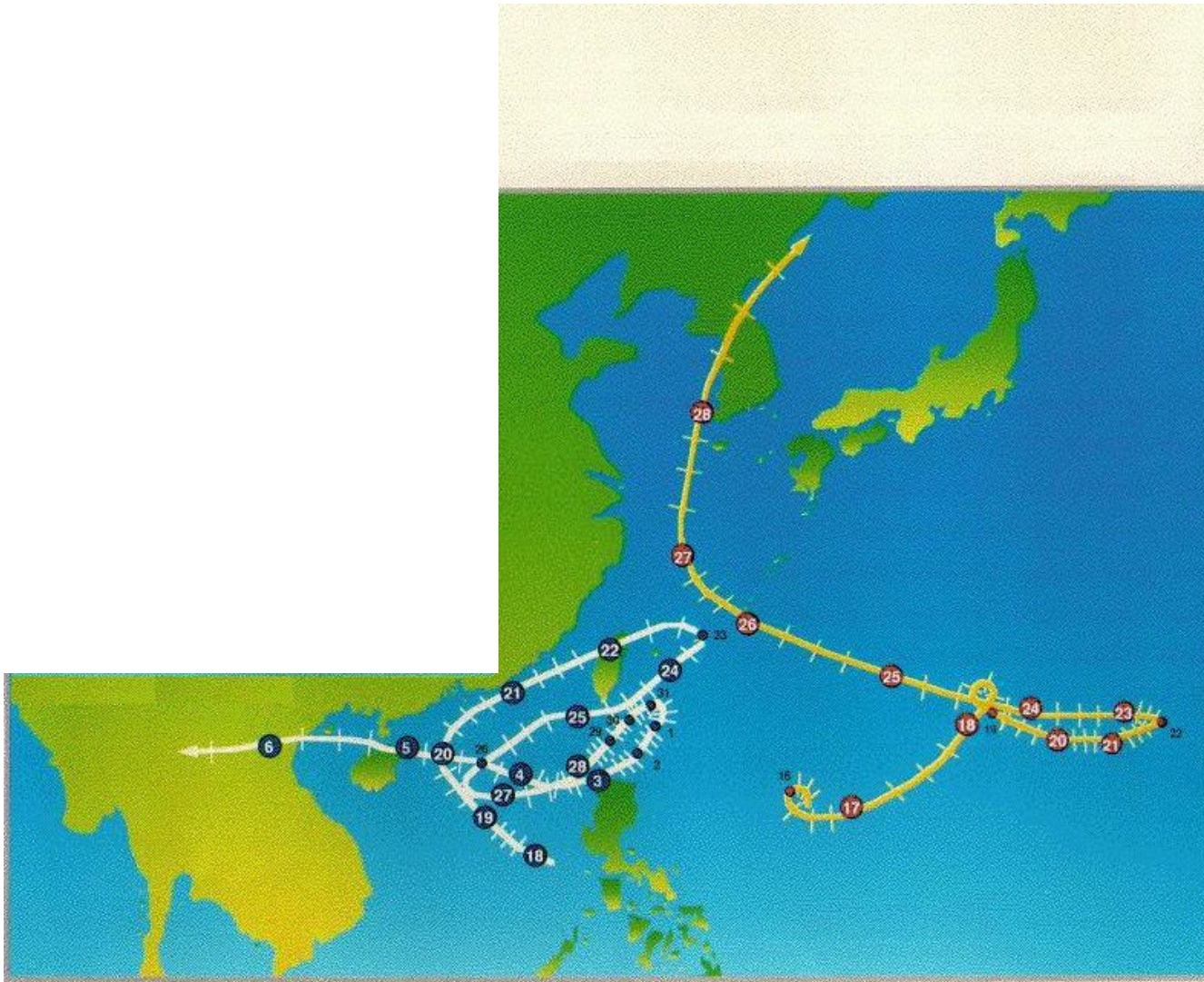
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# Outline

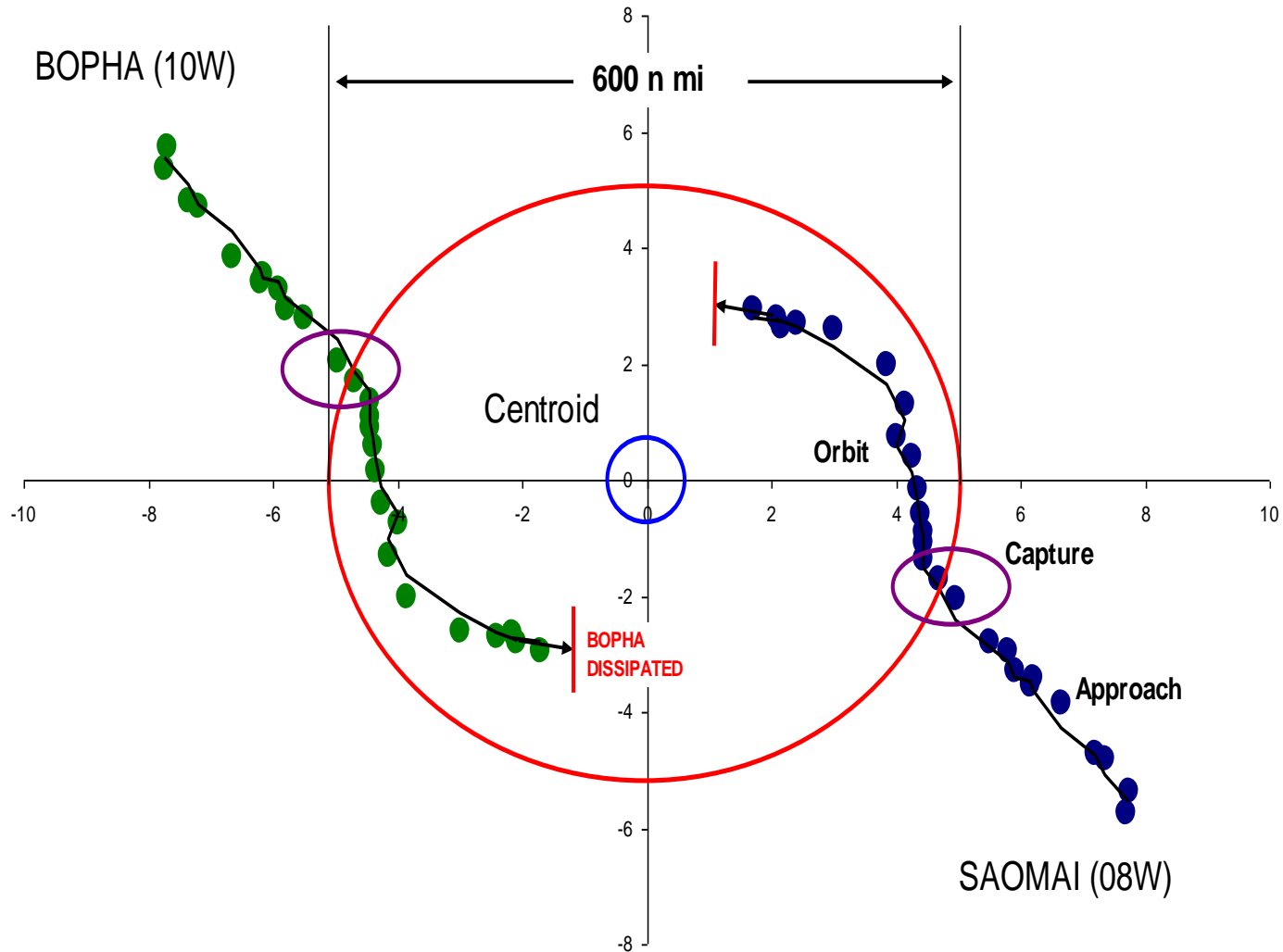
- Binary interaction
  - ❑ Barotropic concepts
  - ❑ Inclusion of baroclinic processes
- Recurvature

# Binary Interaction

# Binary interaction – Wayne and Vera (1986)

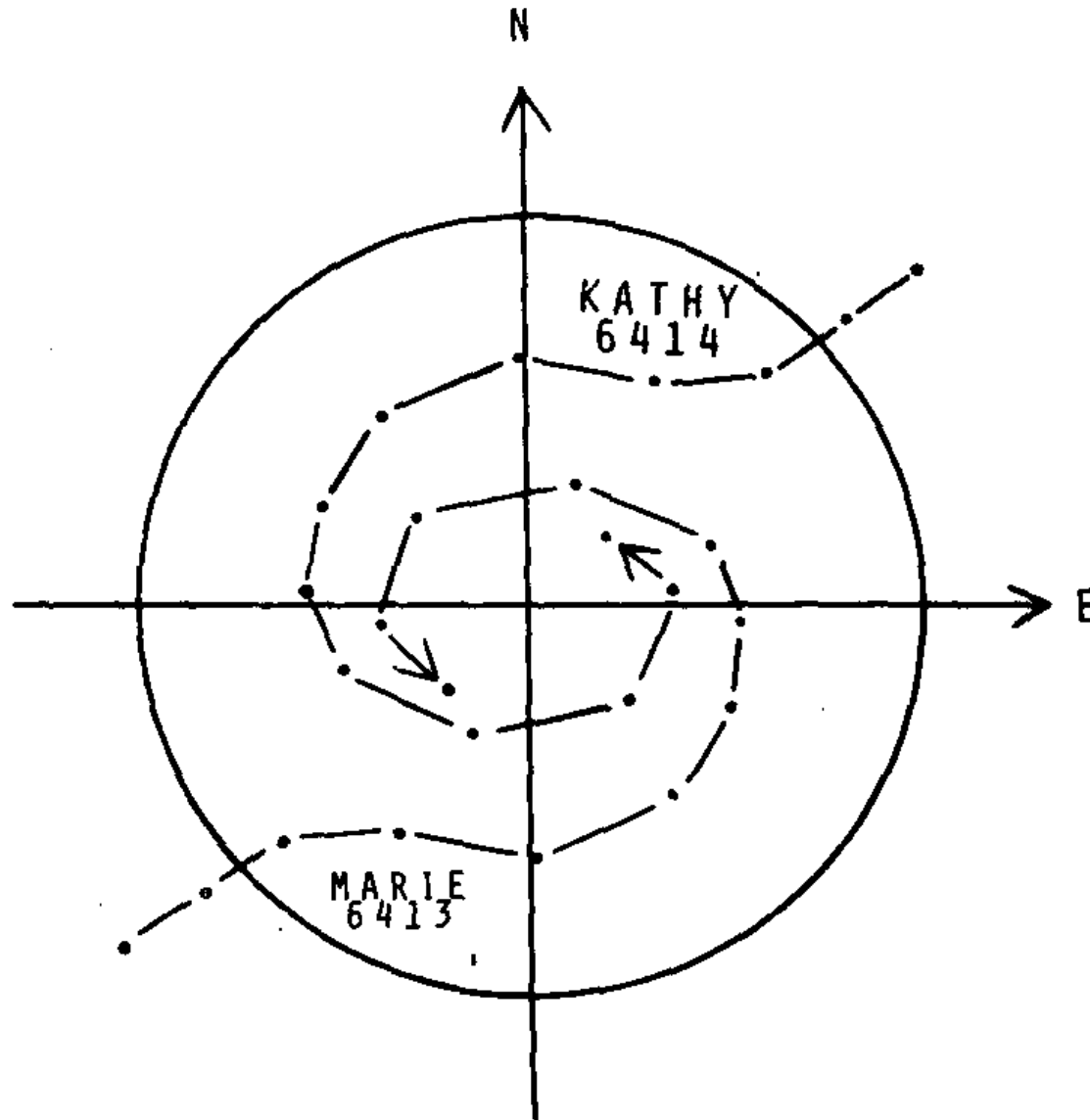


# Binary interaction – Bopha and Saomai (2006)

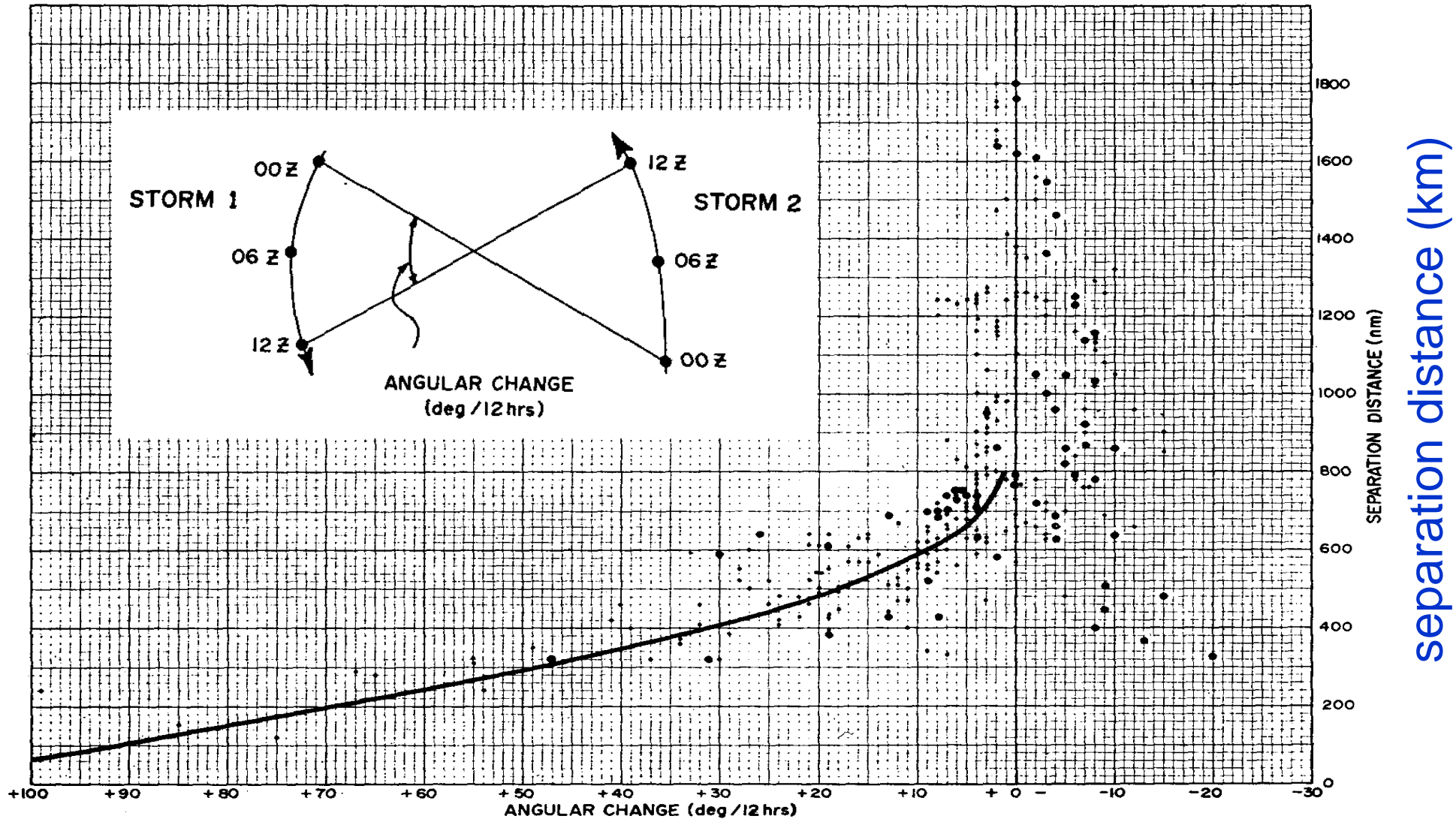


Courtesy of Mark Lander (U Guam)

# Binary interaction – Marie and Kathy (1964)

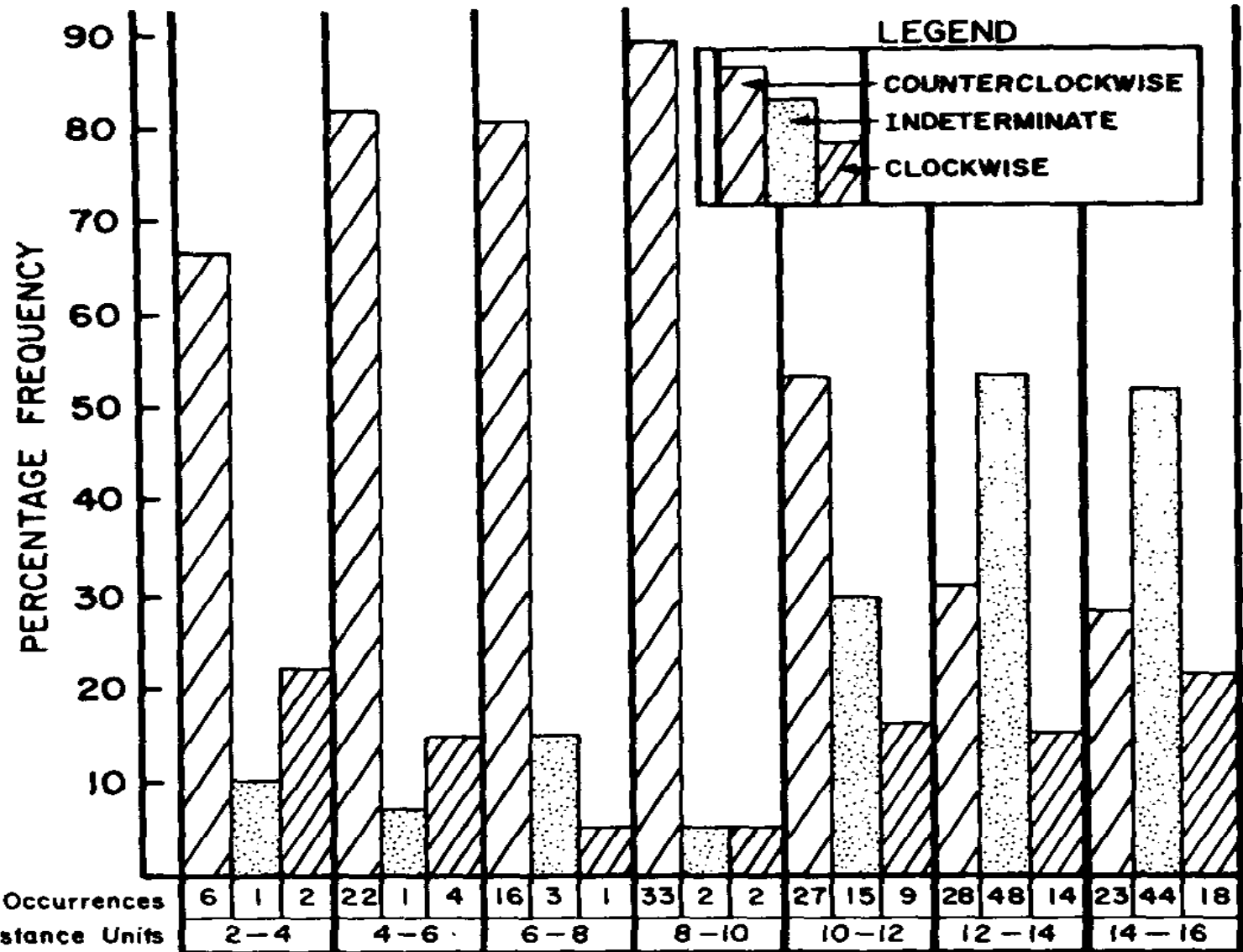


# Angular change vs separation distance



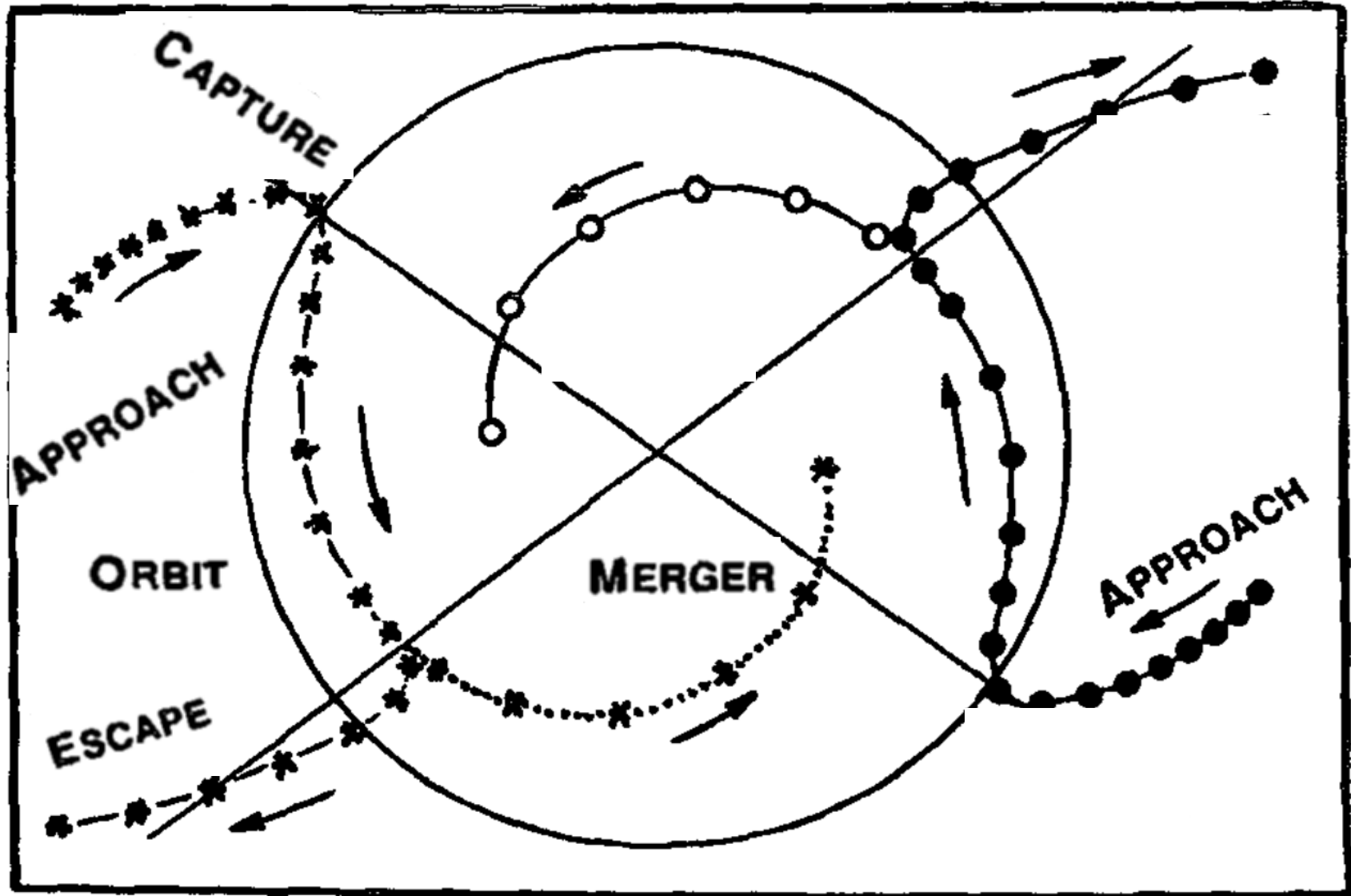
Angular change (degrees/12 hours)

# Direction of rotation



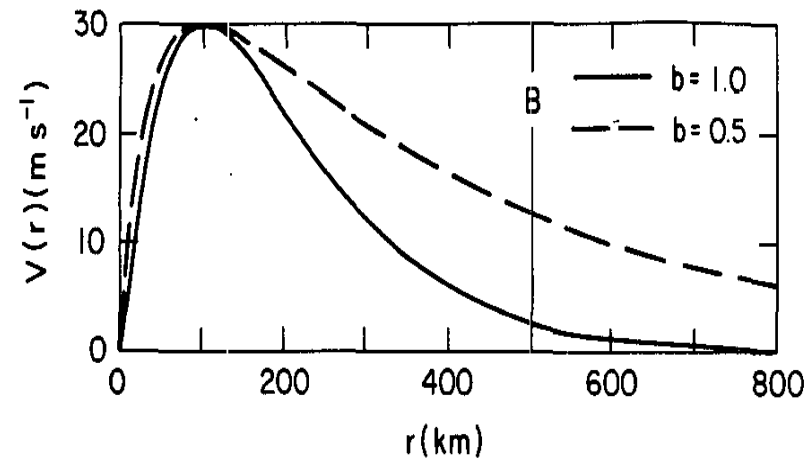
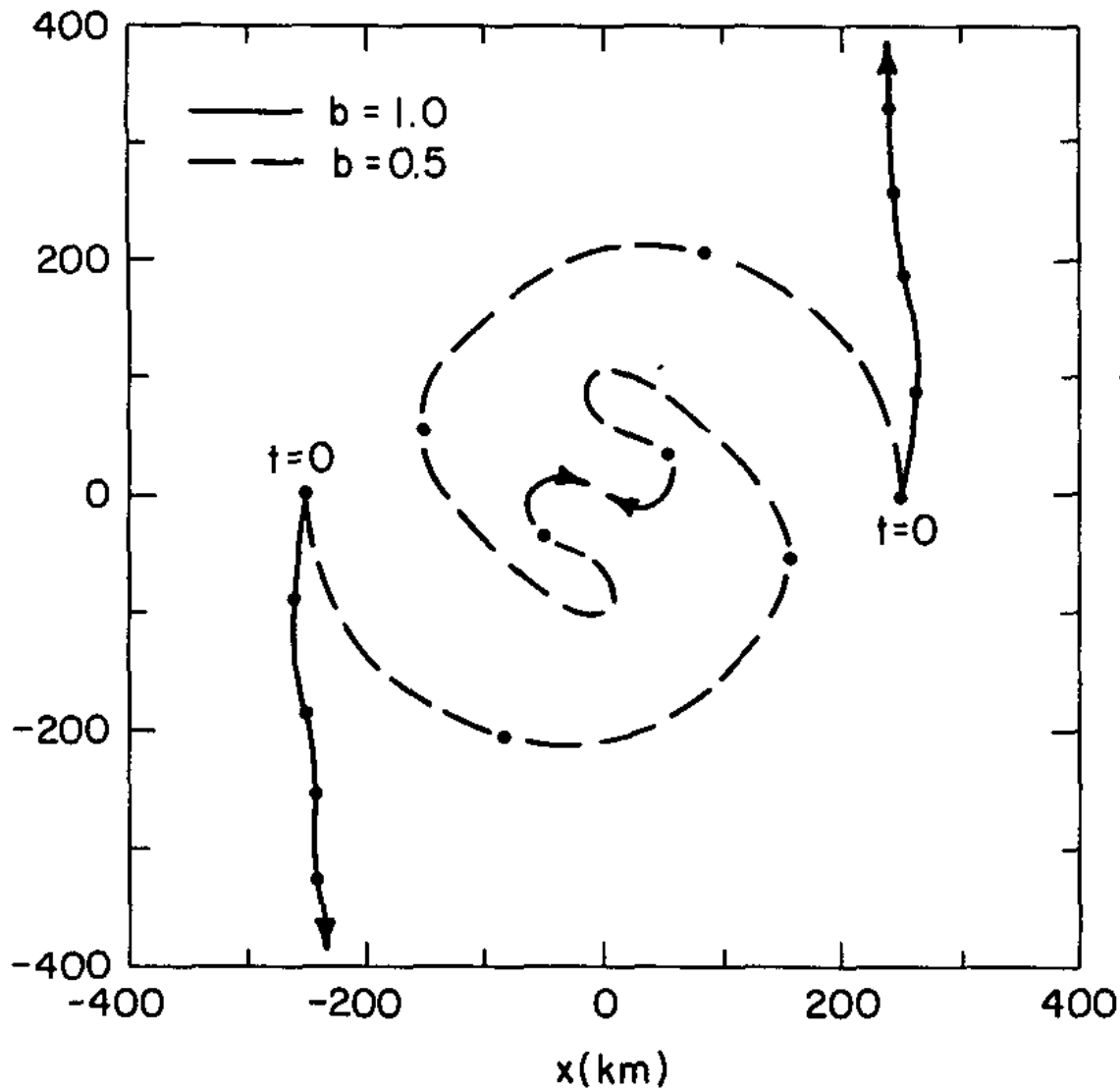


# Binary interaction

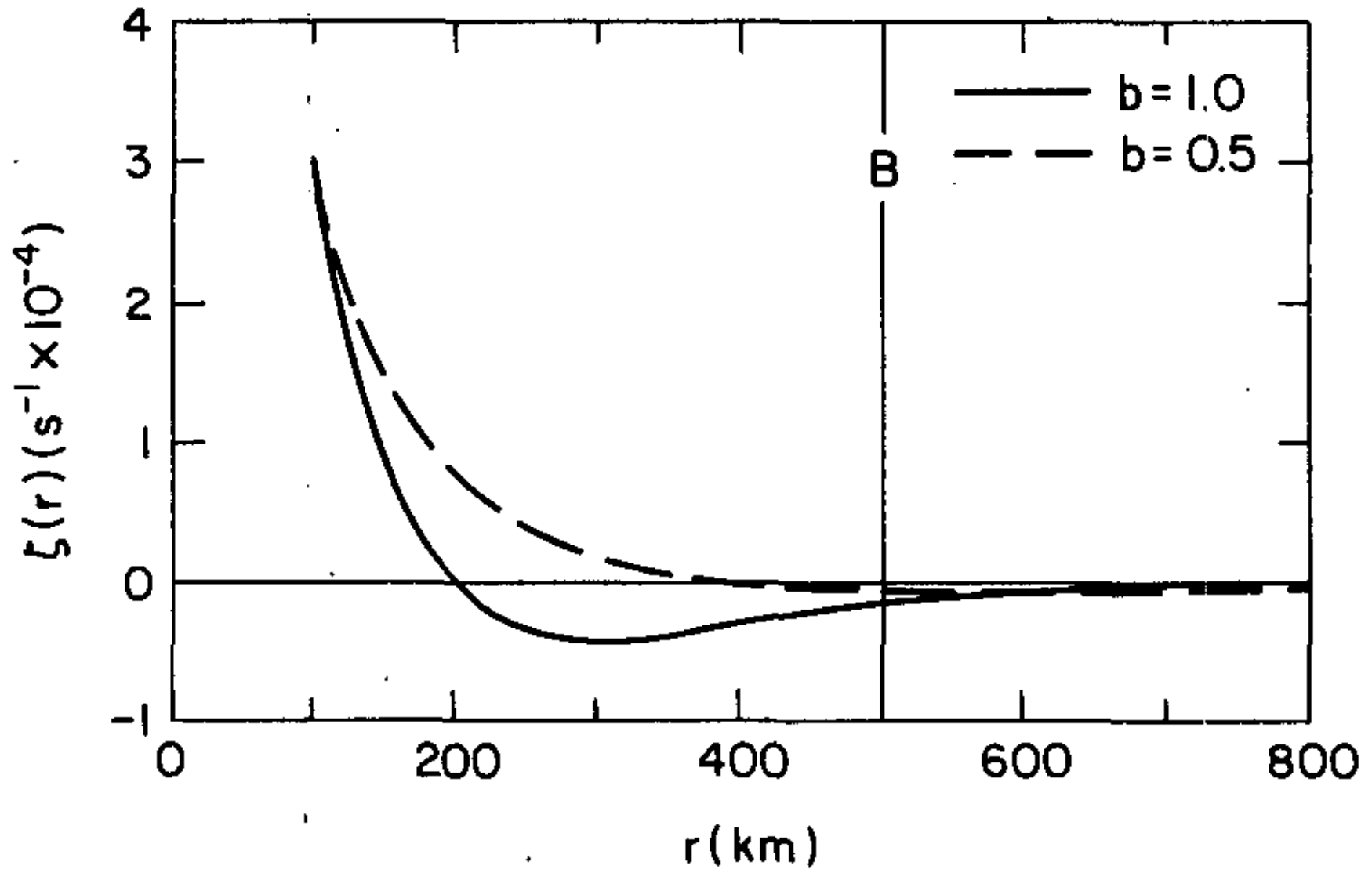


# Barotropic concepts

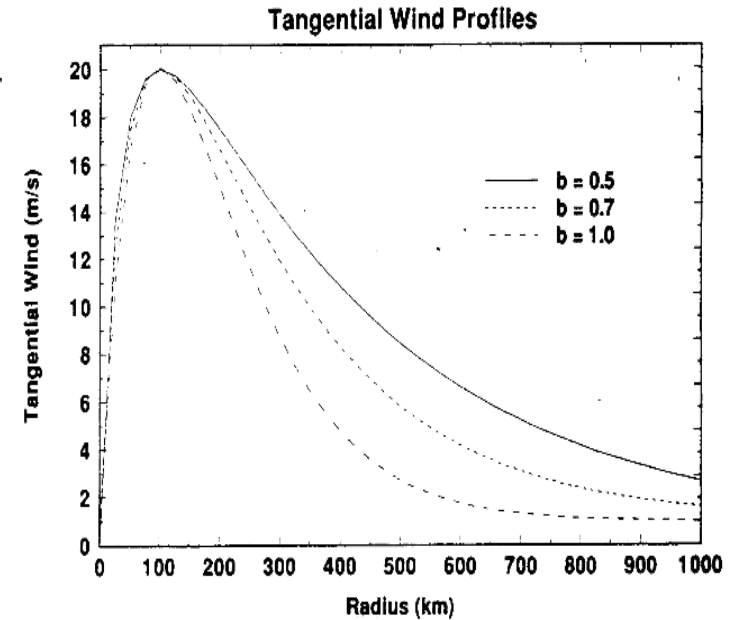
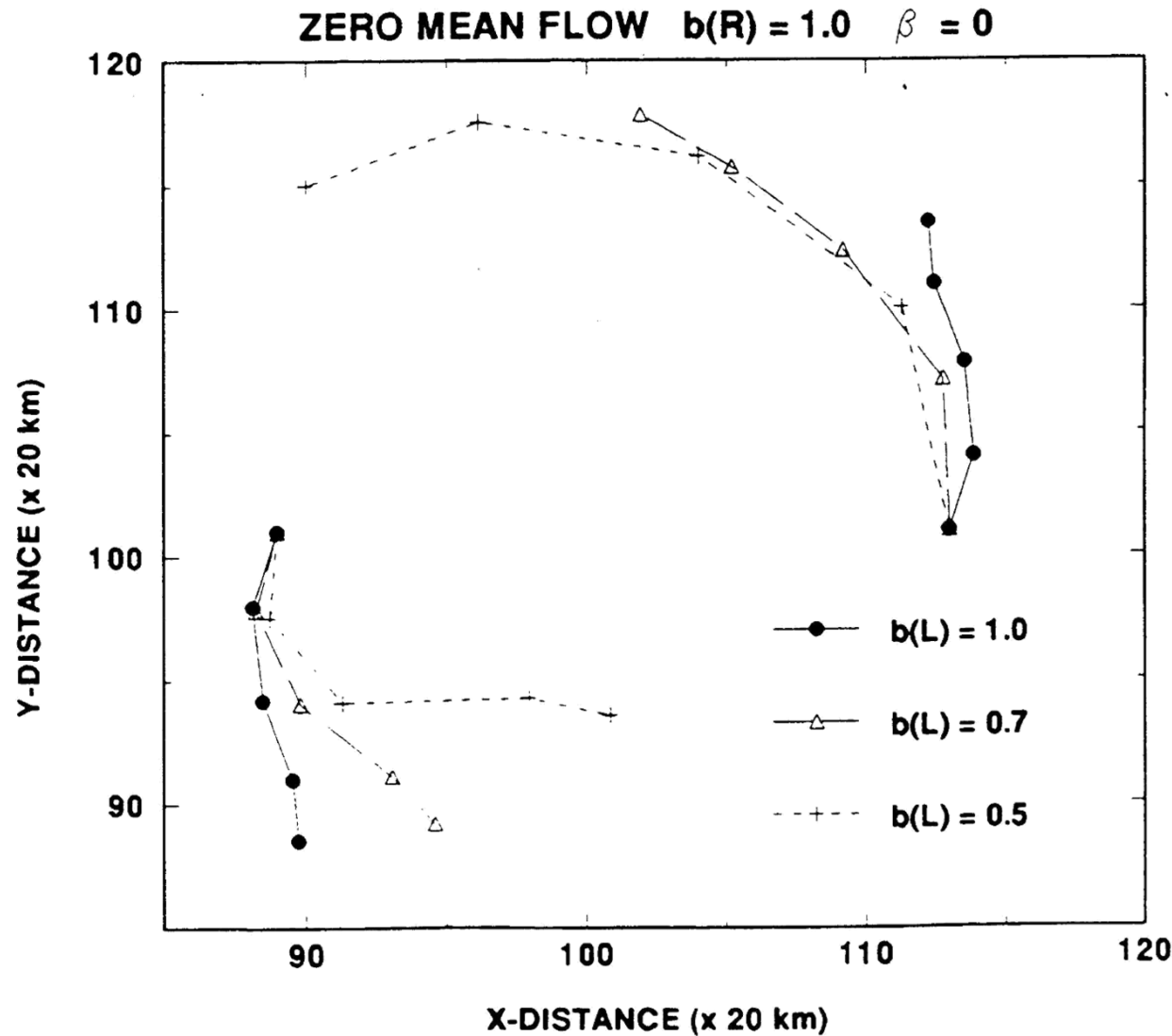
# Binary interaction – f plane



# Relative vorticity

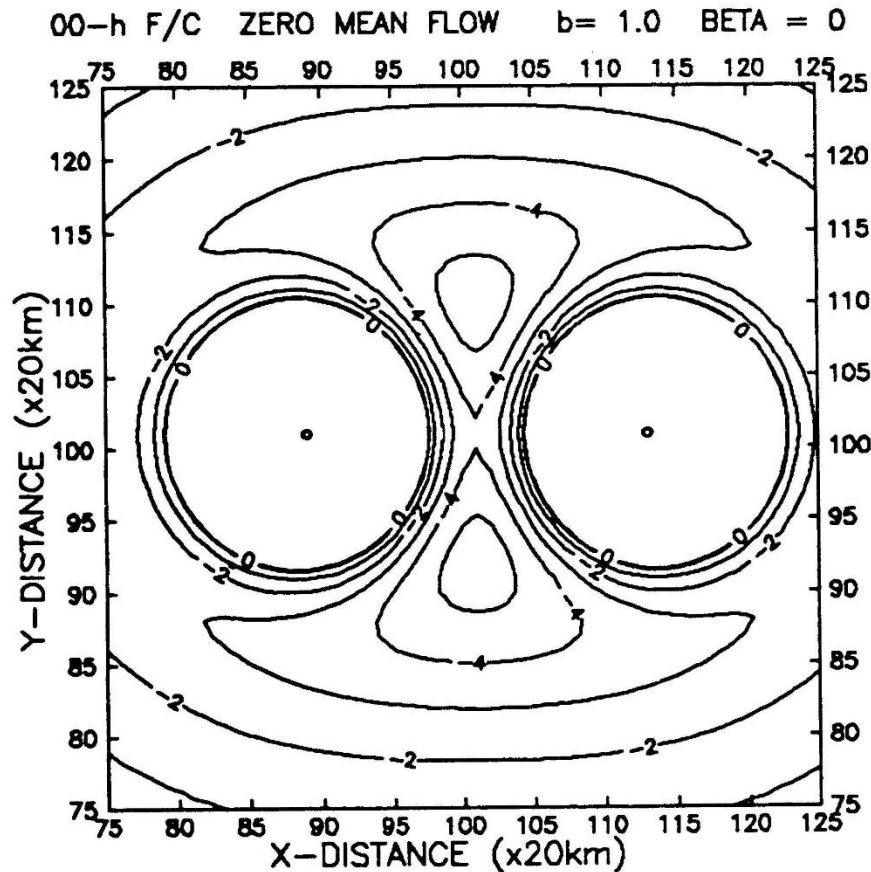


# Binary interaction – f plane

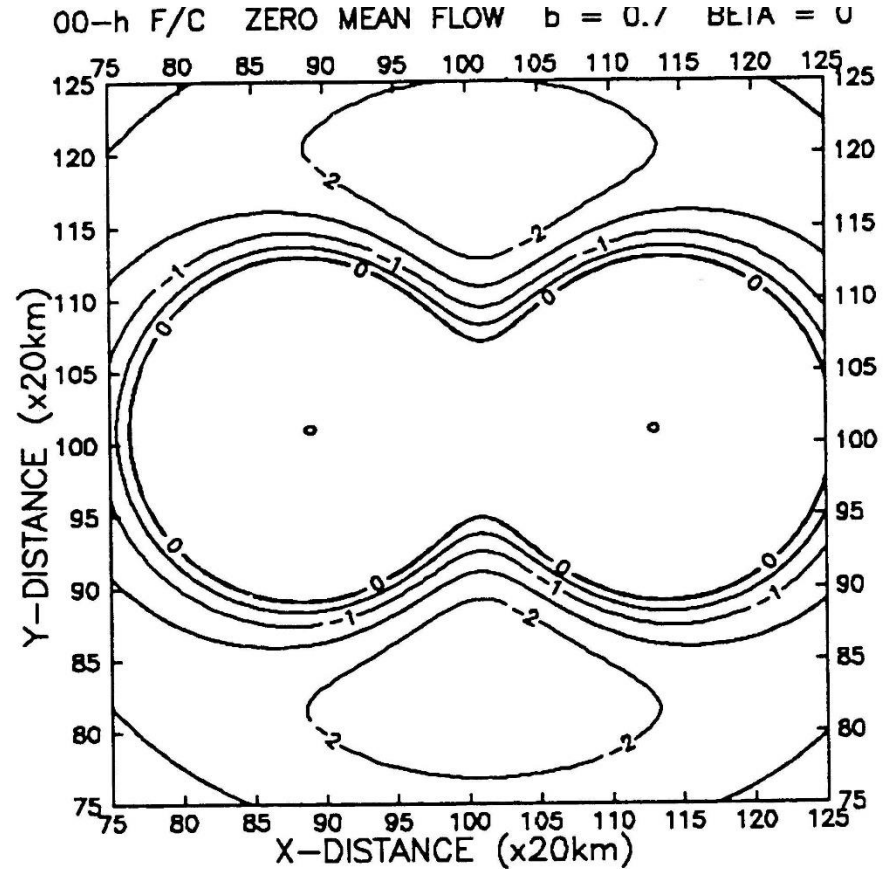


# Relative vorticity distribution

$b = 1.0$



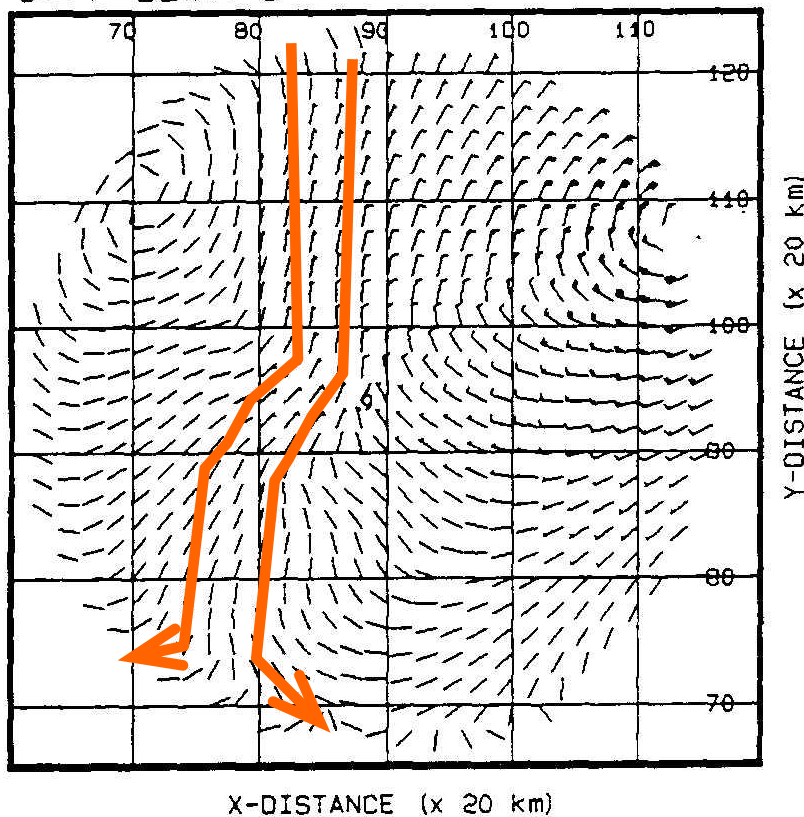
$b = 0.7$



# Asymmetric Flow after 12 h (left vortex)

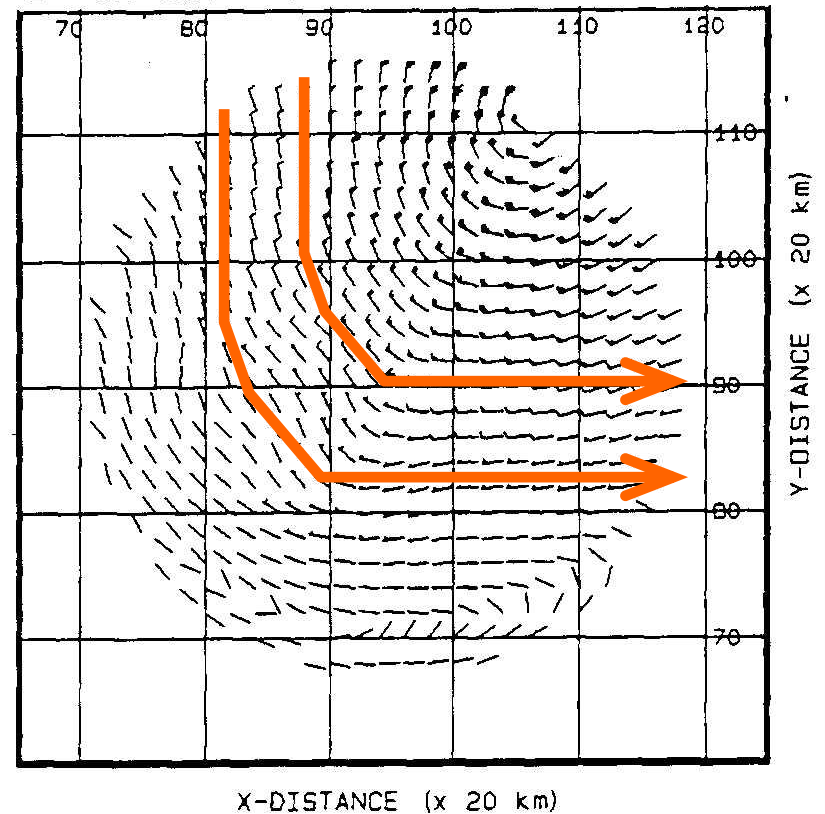
$b = 1.0$

12-h F/C AWIND  
 $b = 1$  BETA = 0



$b = 0.7$

12-h F/C AWIND  
 $b = 0.7$  BETA = 0



$$\frac{\partial \zeta}{\partial t} = \underbrace{-\mathbf{V}_a \cdot \nabla \zeta_s}_{\text{AASV}} - \underbrace{\mathbf{V}_s \cdot \nabla \zeta_a}_{\text{SAAV}} - \underbrace{\mathbf{V}_a \cdot \nabla \zeta_a}_{\text{AAAV}}$$

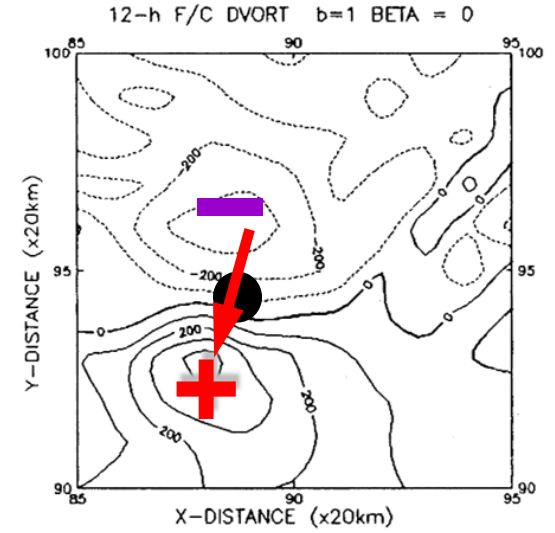
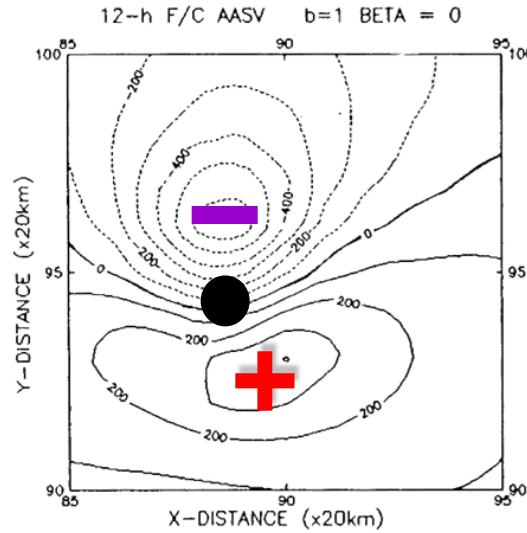
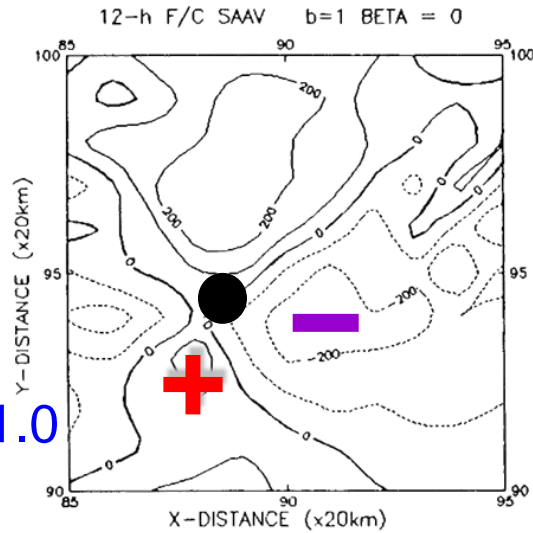
Asymmetric  
Advection of  
Symmetric  
Vorticity

Symmetric  
Advection of  
Asymmetric  
Vorticity

Asymmetric  
Advection of  
Asymmetric  
Vorticity



# Terms in the Vorticity Equation

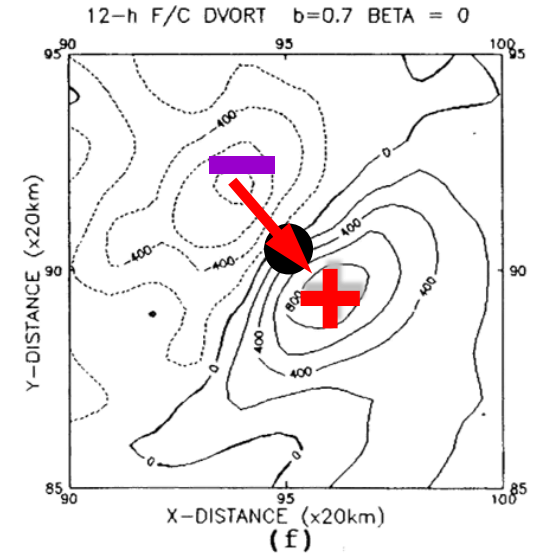
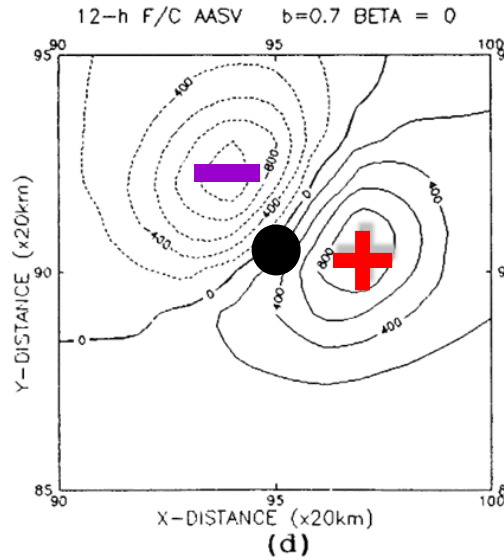
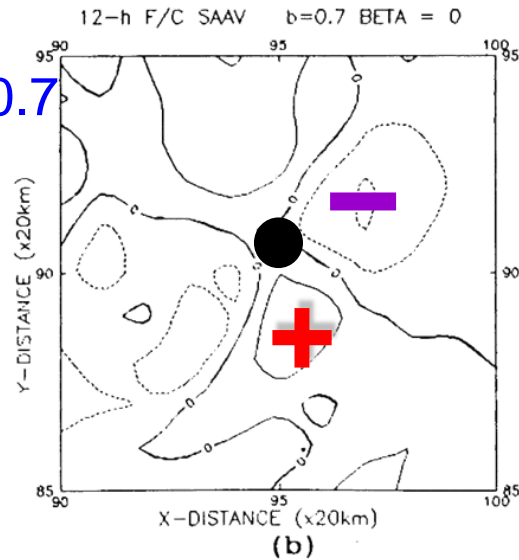


$b = 1.0$

**SSAV**

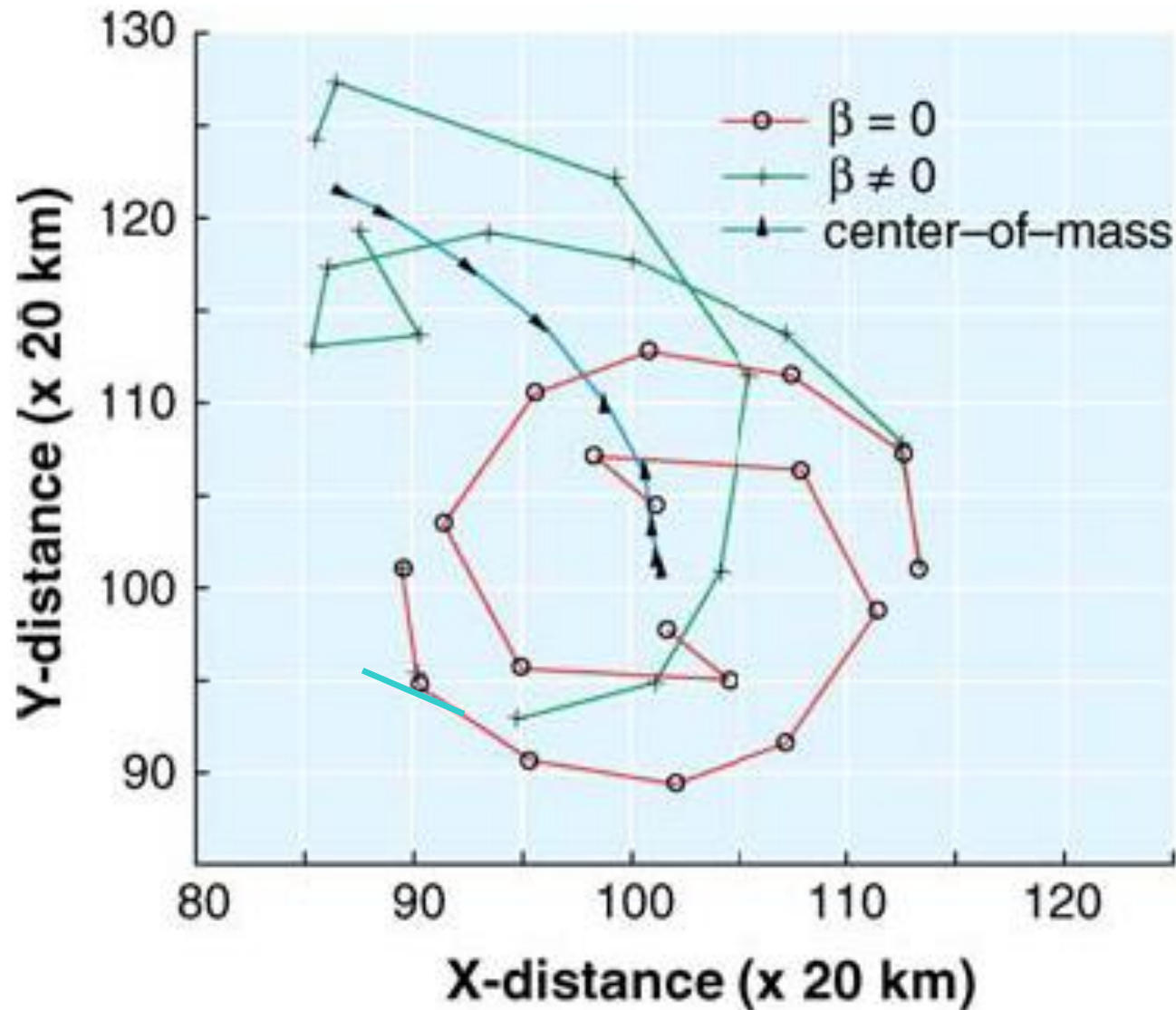
**AASV**

$\partial \zeta / \partial t$

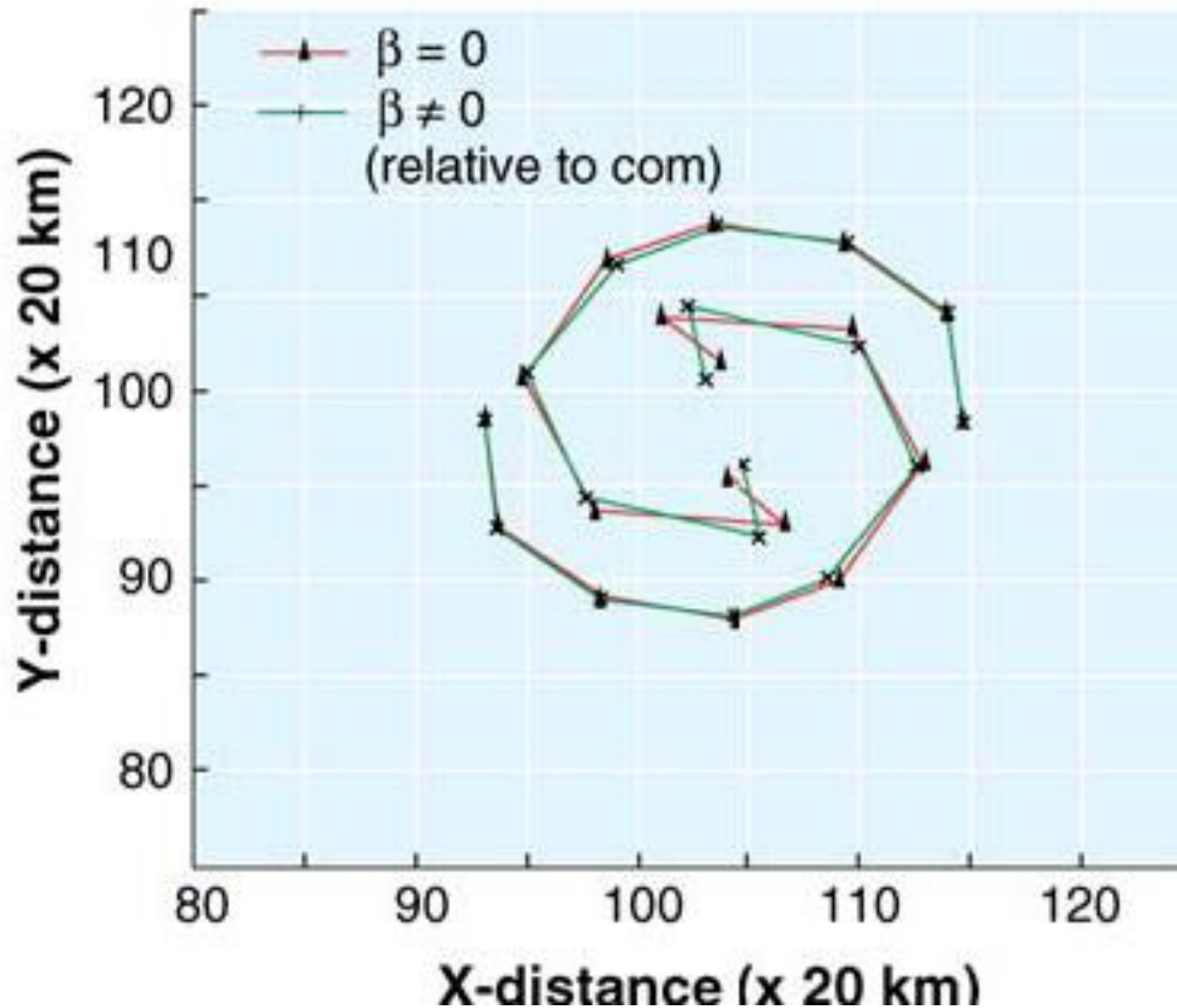


$b = 0.7$

# Binary interaction – $\beta$ plane

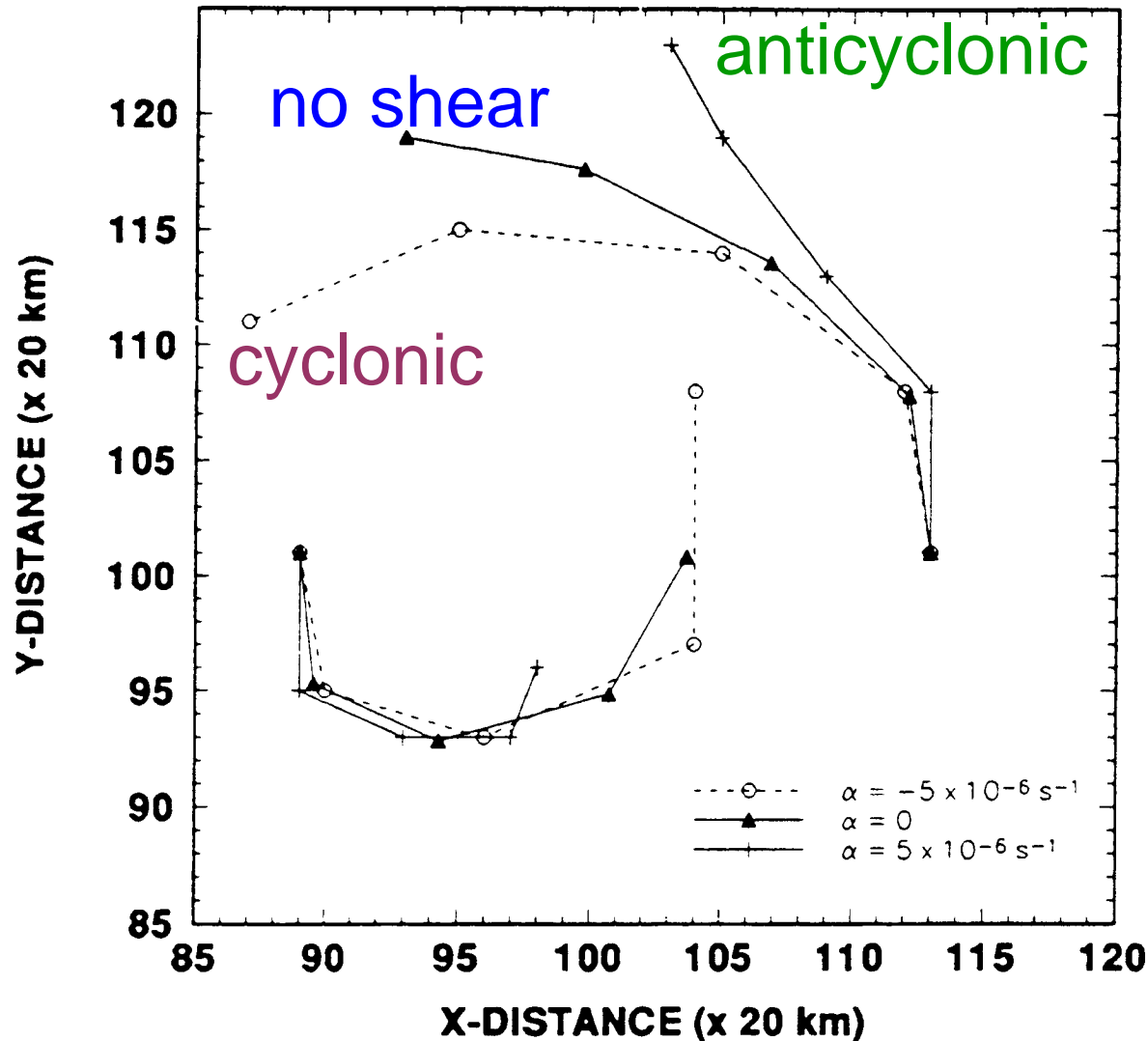


# Binary interaction – $\beta$ plane



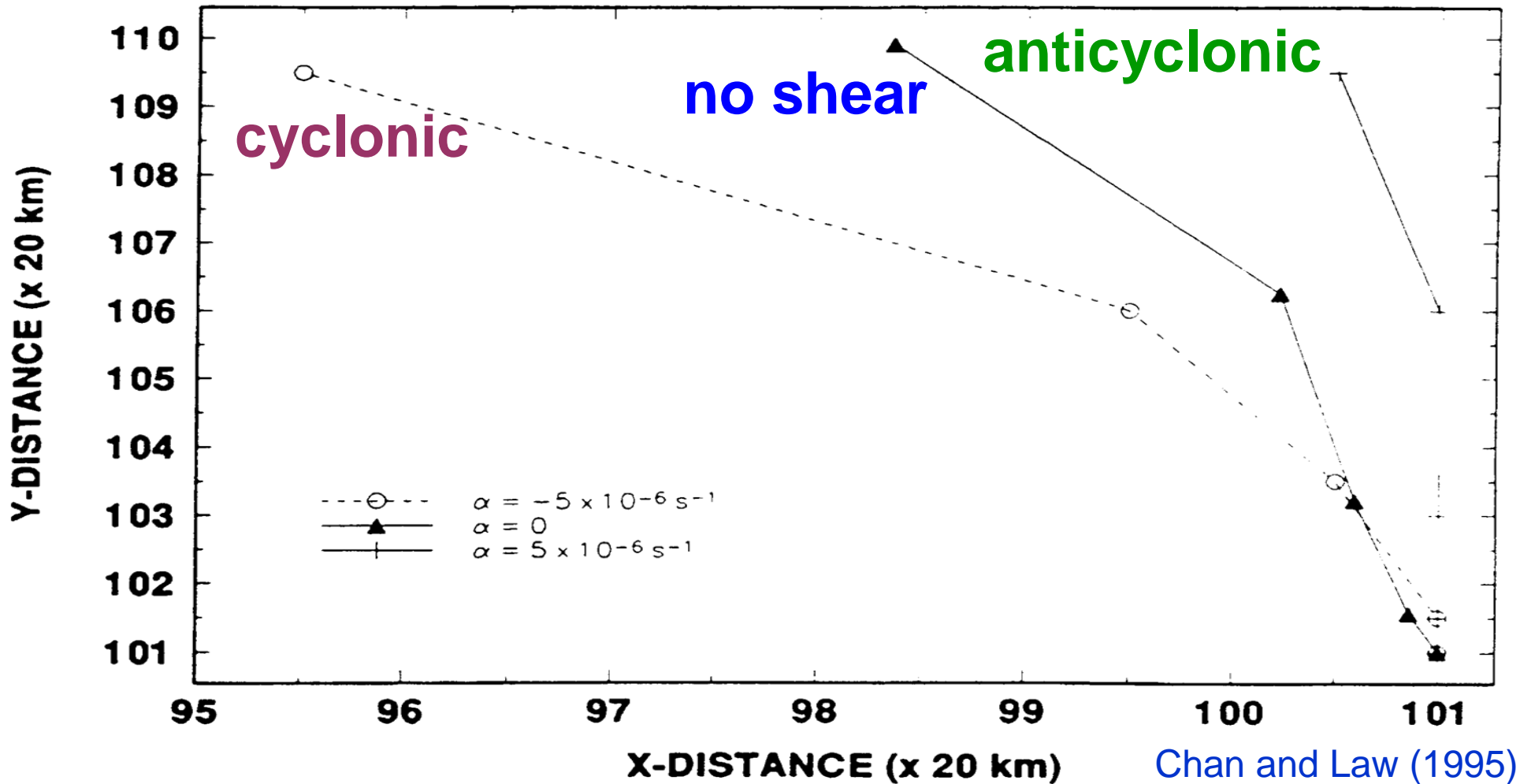
# Binary interaction in a horizontally sheared flow

$$b = 0.7 \quad \beta \neq 0$$



# Binary interaction in a horizontally sheared flow - movement of the centre of mass

24 h tracks of the COM of the vortices  
 $b = 0.7$

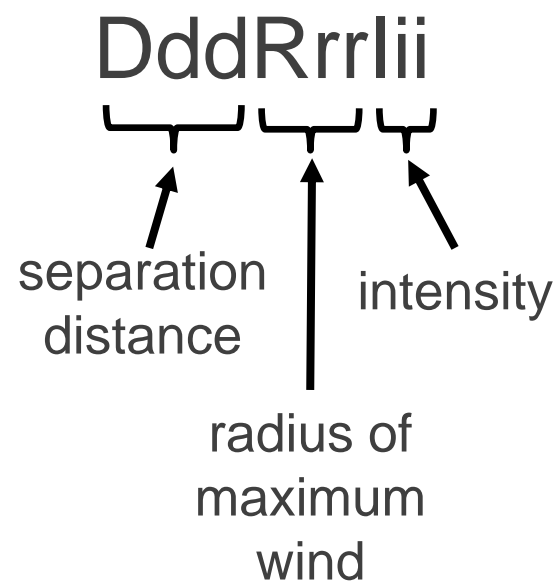
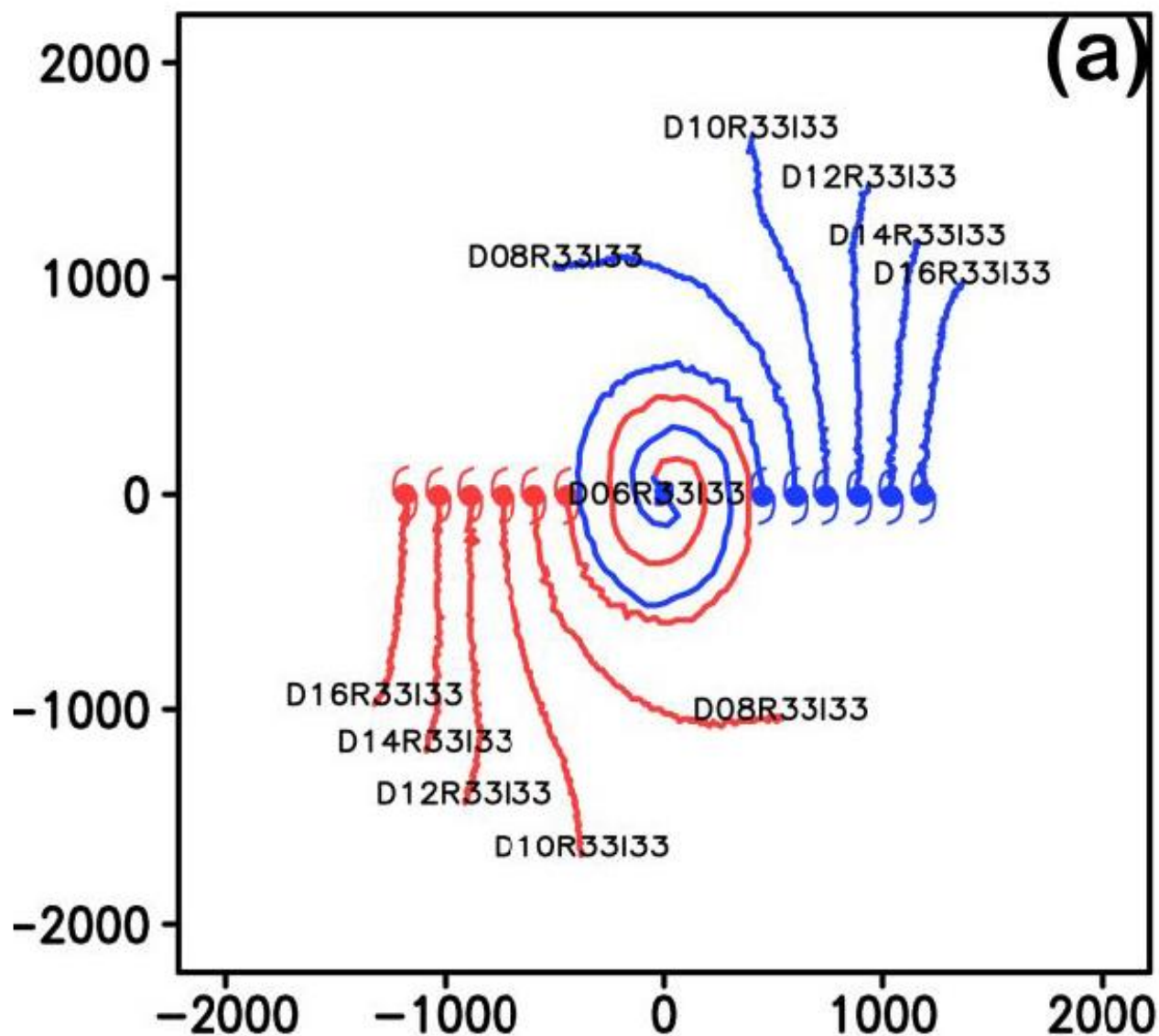


## Summary

- Binary interaction depends on the relative vorticity distribution of the two vortices.
- The two vortices interact with each other while the binary system moves as a large cyclonic vortex (towards the northwest in the NH) under the beta effect.
- A background sheared flow (cyclonic or anticyclonic) can modify the relative track of the two vortices

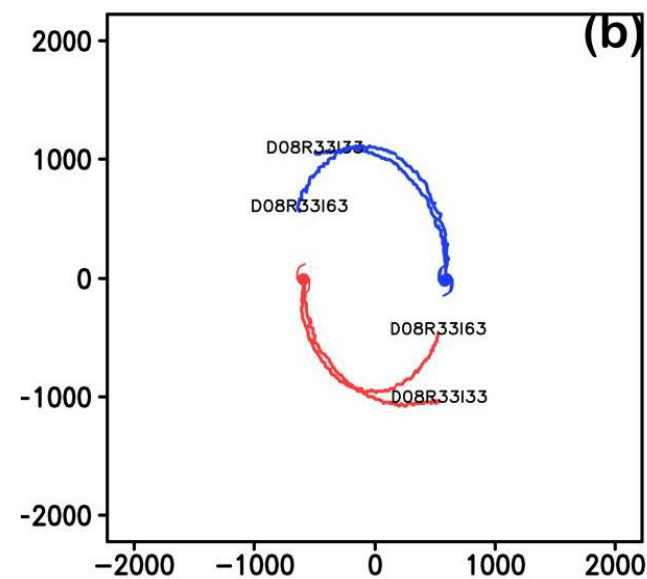
# Baroclinic concepts

# Binary interaction – identical vortices

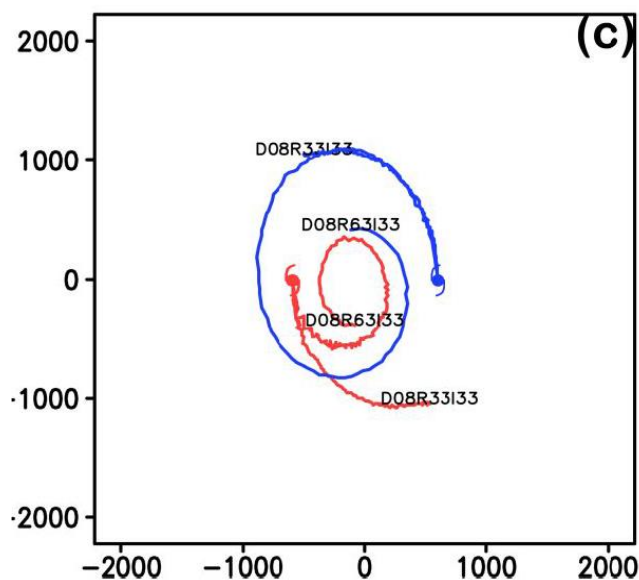




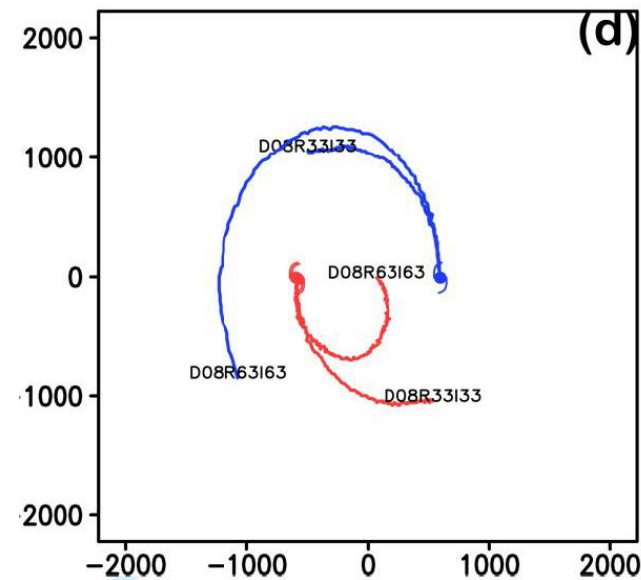
# Binary interaction – non-identical vortices



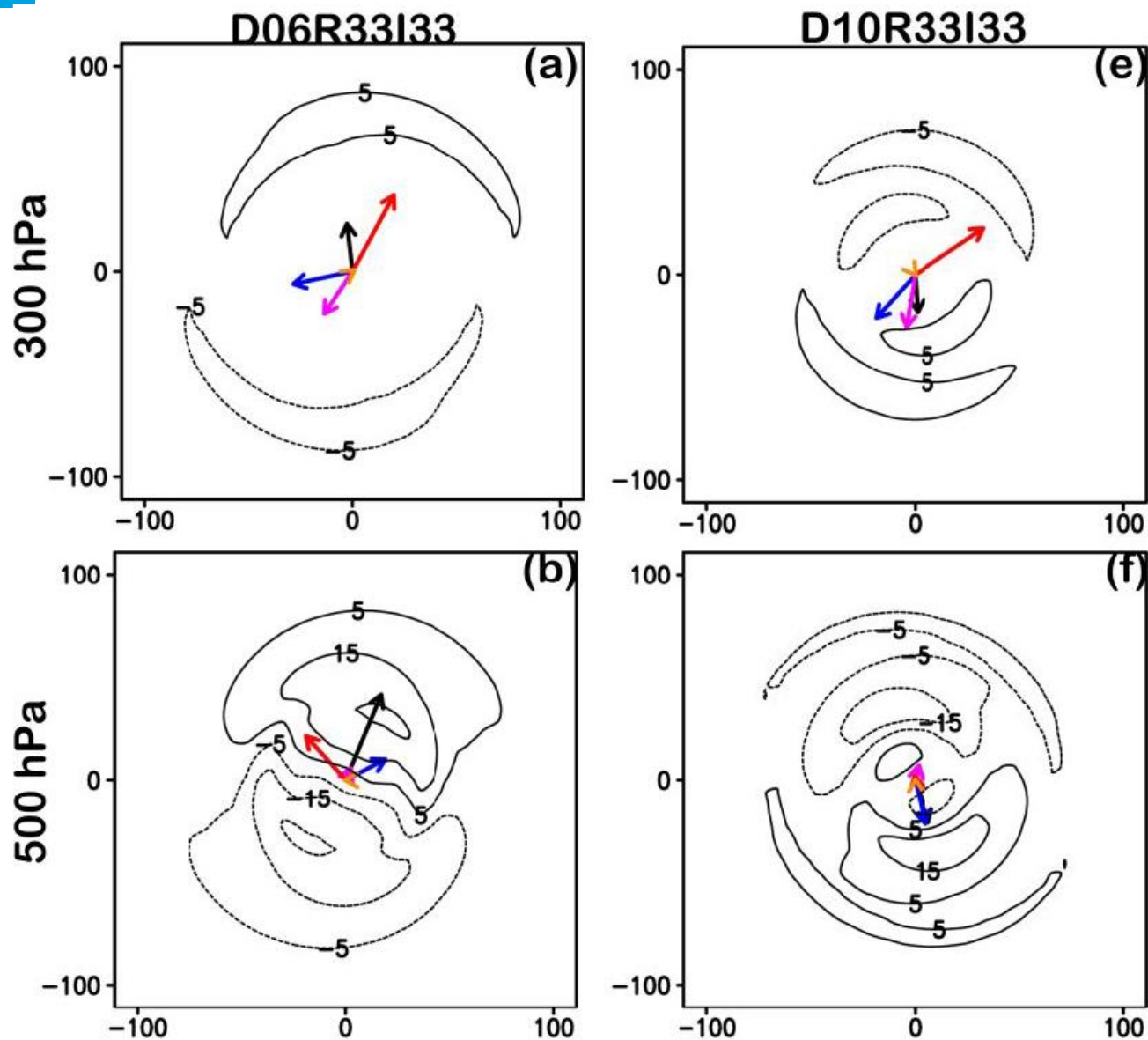
Higher intensity



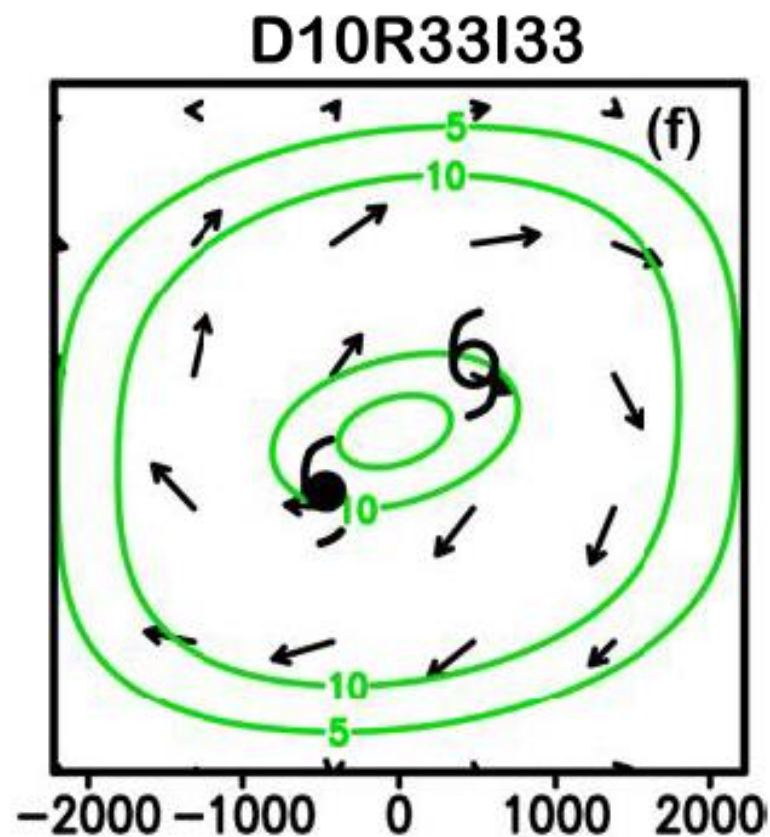
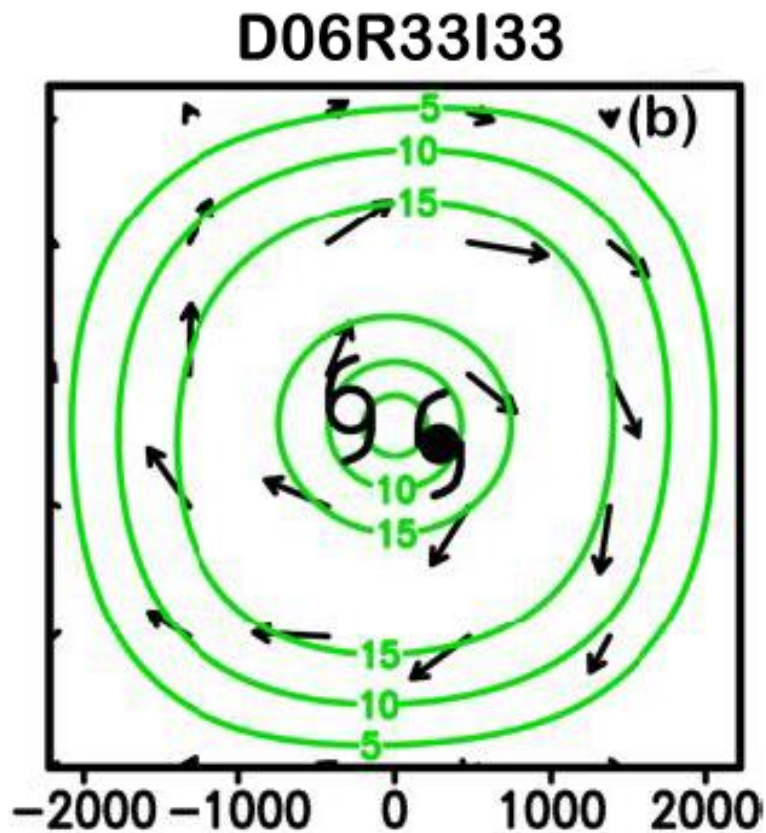
Larger

Higher intensity  
and larger

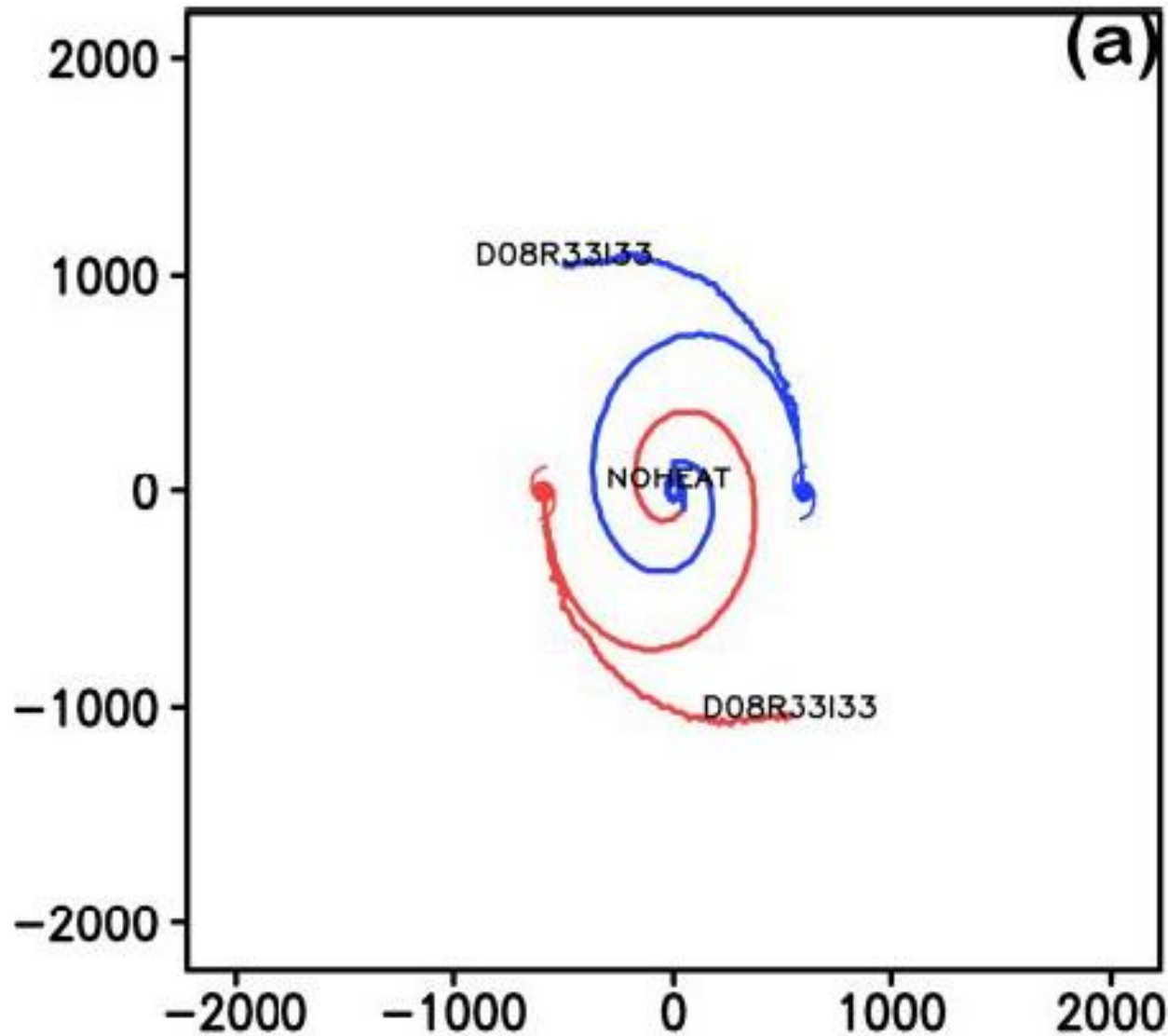
# PVT and vectors – identical vortices at 48 h



# Vertical wind shear at 48 h (200-850 hPa)

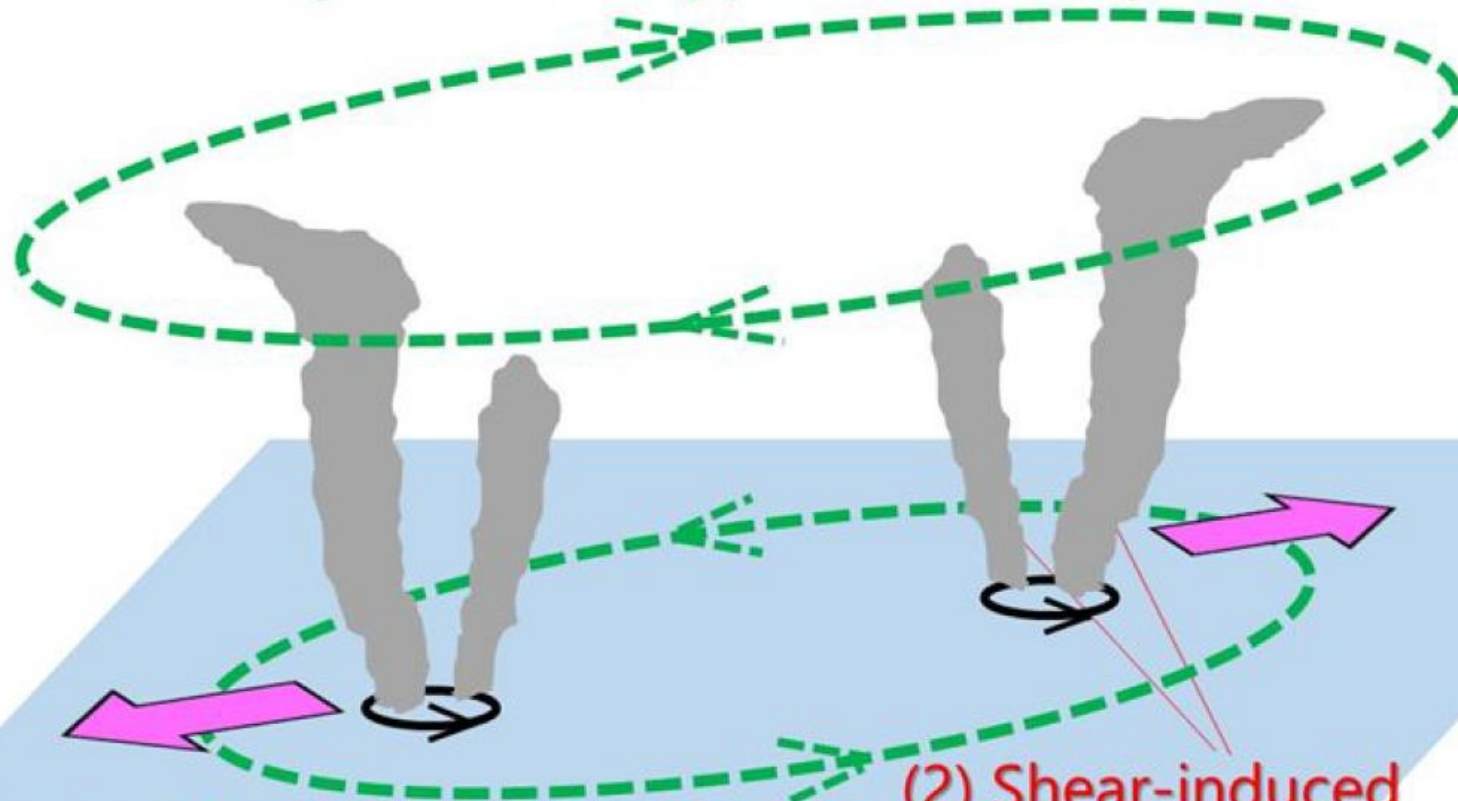


# No heating experiment



# Modification of binary interaction due to VWS

(1) Lower-level cyclonic and upper-level anticyclonic circulations



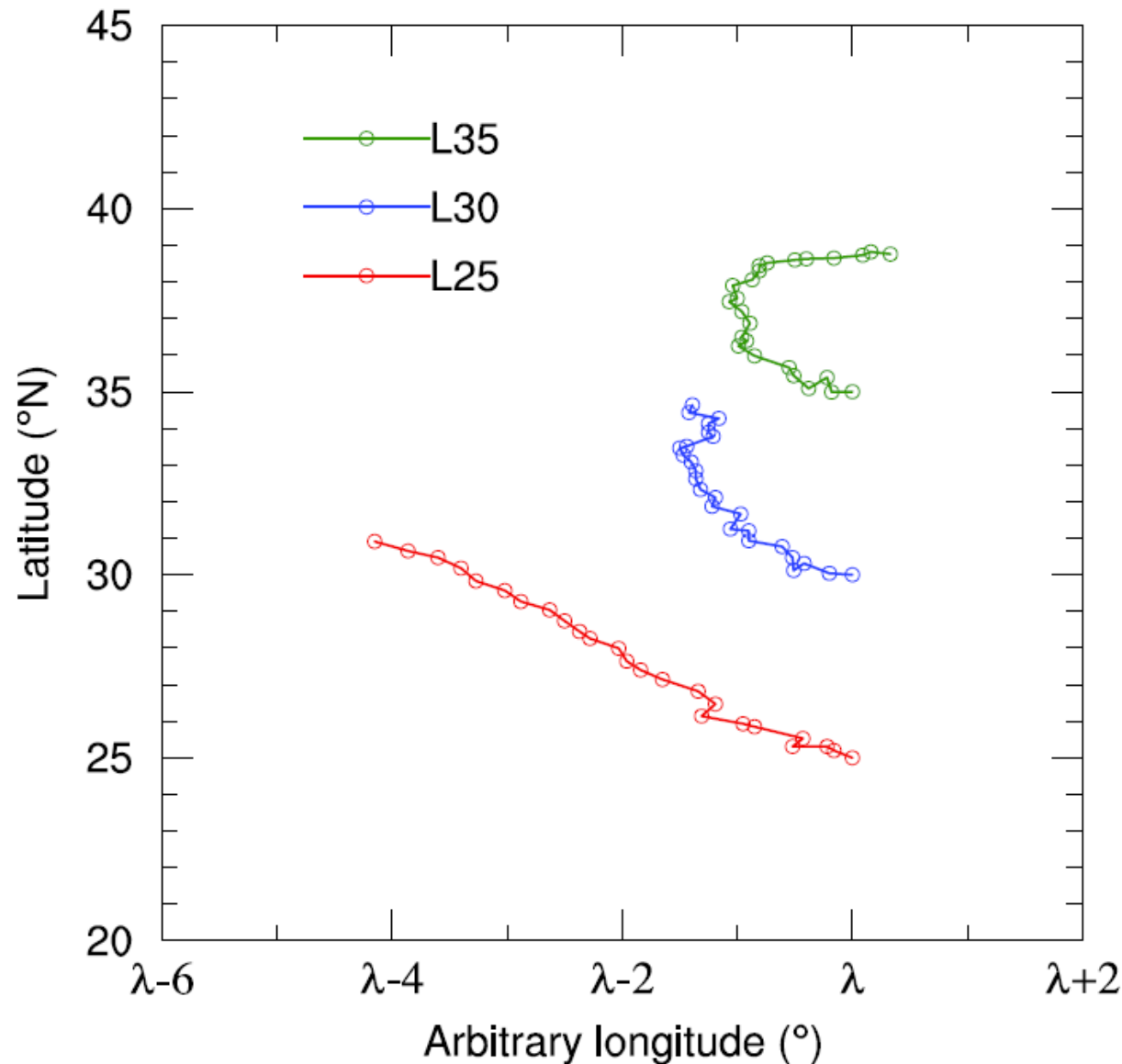
(3) Modifying TC track

## Summary

- Binary interaction can be modified by the vertical wind shear (VWS) generated by the upper-level flow associated with the anticyclonic circulation of the two vortices.
- Asymmetric convection due to the VWS then modifies the diabatic heating term in the PV tendency and changes the tracks of the two vortices
- Binary interaction therefore cannot be completely explained by barotropic concepts.

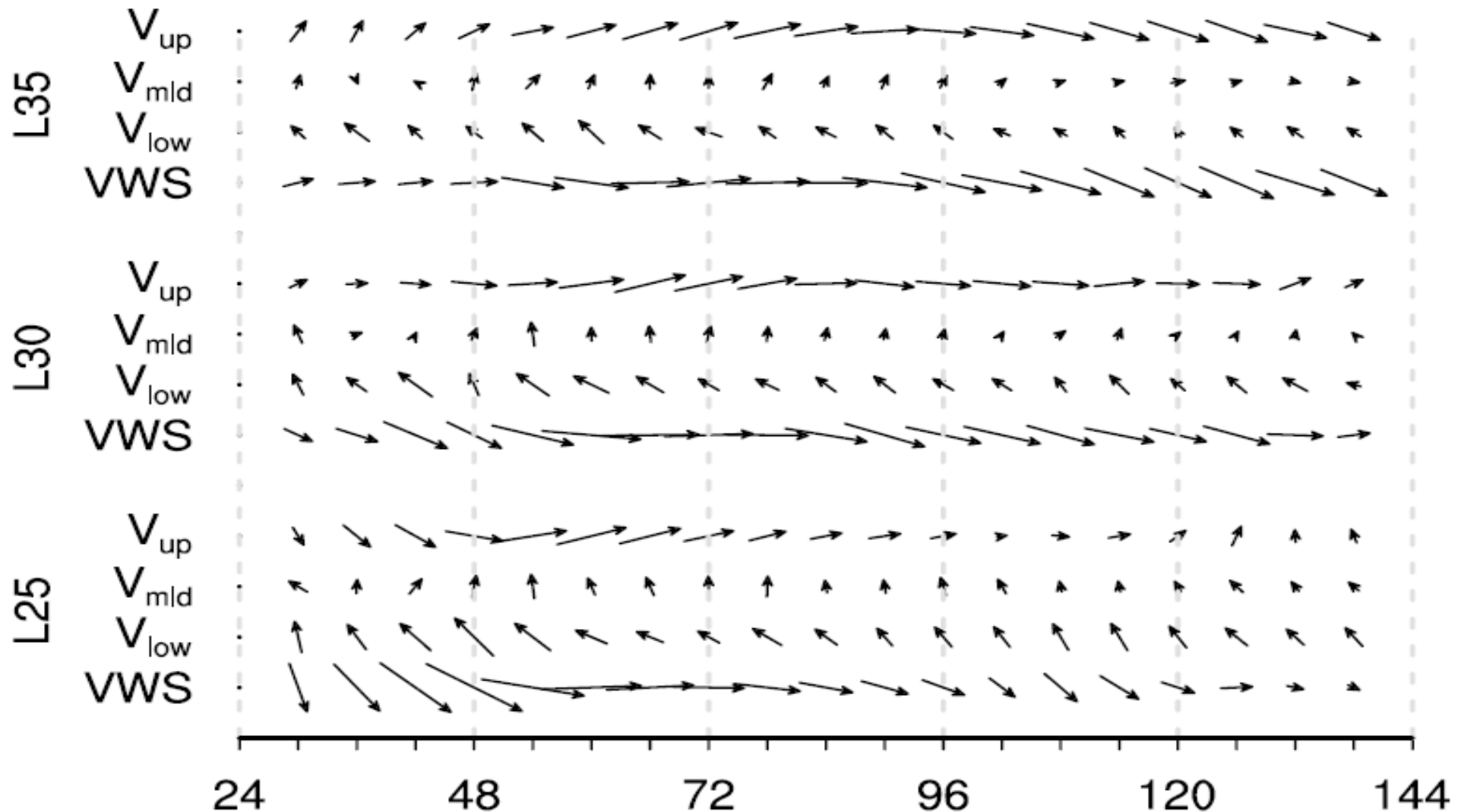
# Recurvature

# Tracks at various latitudes (beta plane, no background flow)





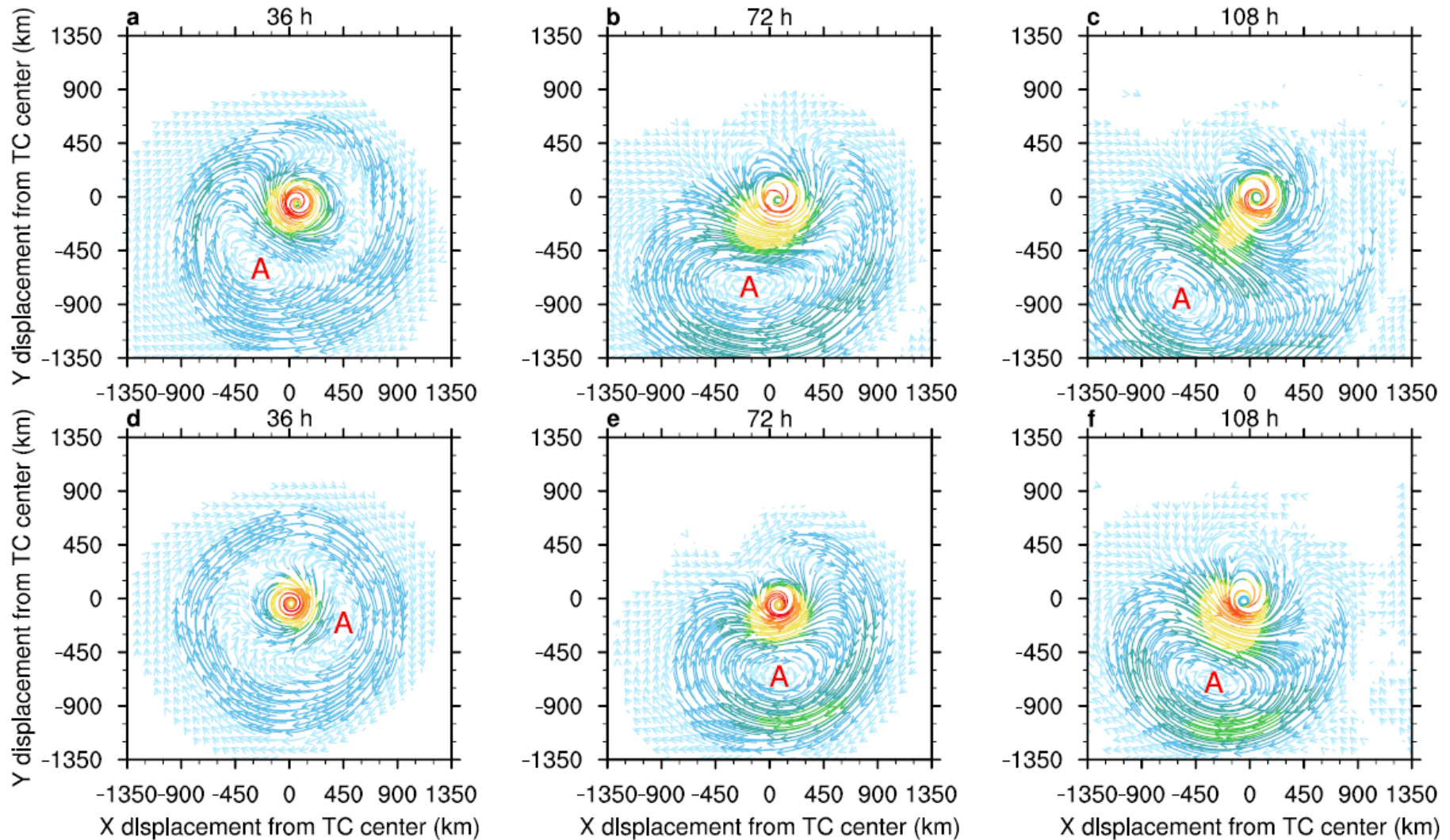
# Vertical wind shear



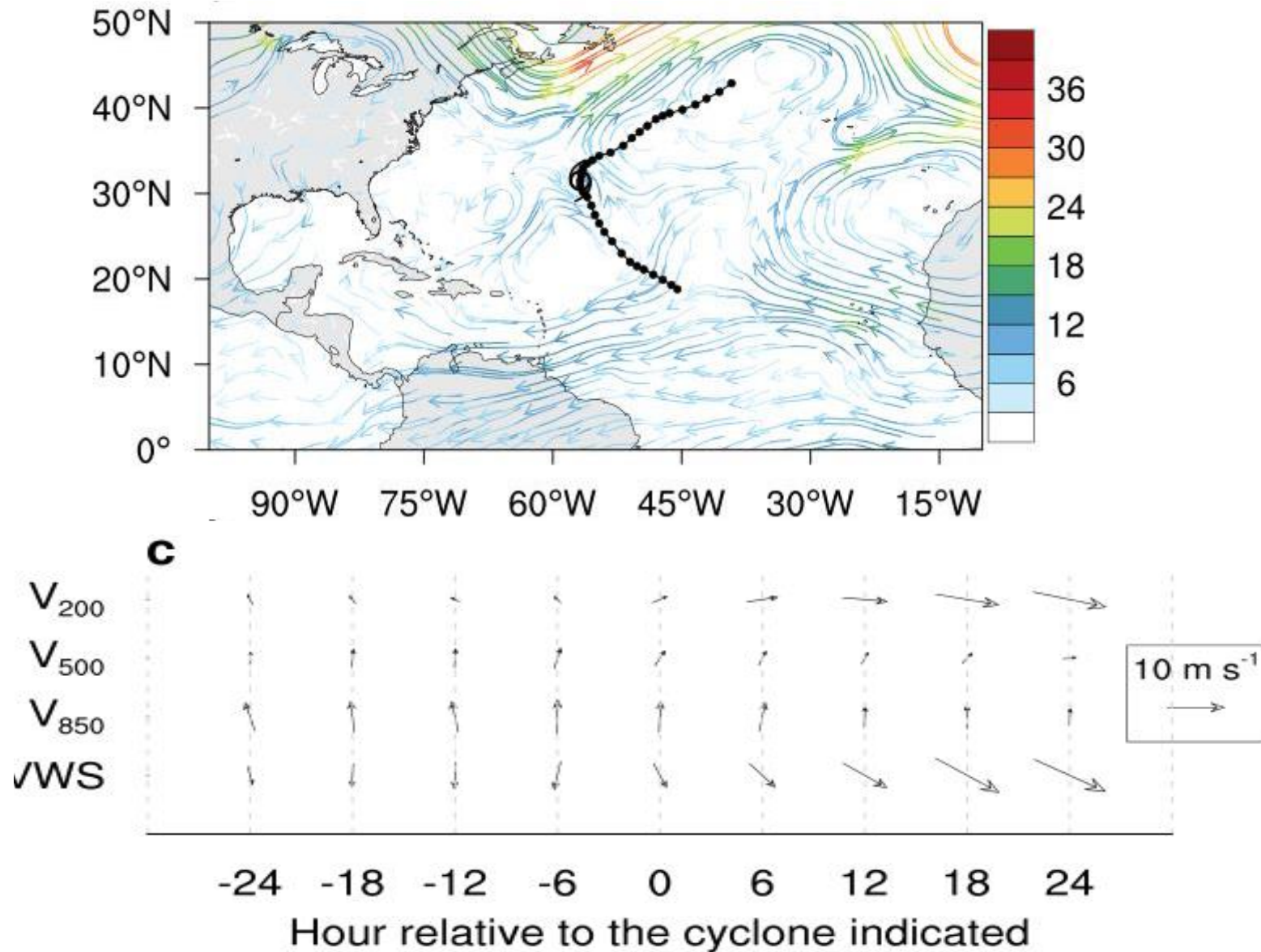
## Upper tropospheric flow

L25

L35



# Example



## Summary

- Differential beta effect in the vertical can modify the upper tropospheric flow and thus change the horizontal advection of potential vorticity and VWS, as well as the distribution of convection.
- A TC can therefore recurve even in the absence of an environmental steering flow.