Shapiro-Keyser Frontal Cyclone Model

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Supplemental Reading: Shapiro and Keyser (1990) and Schultz et al. (1998)

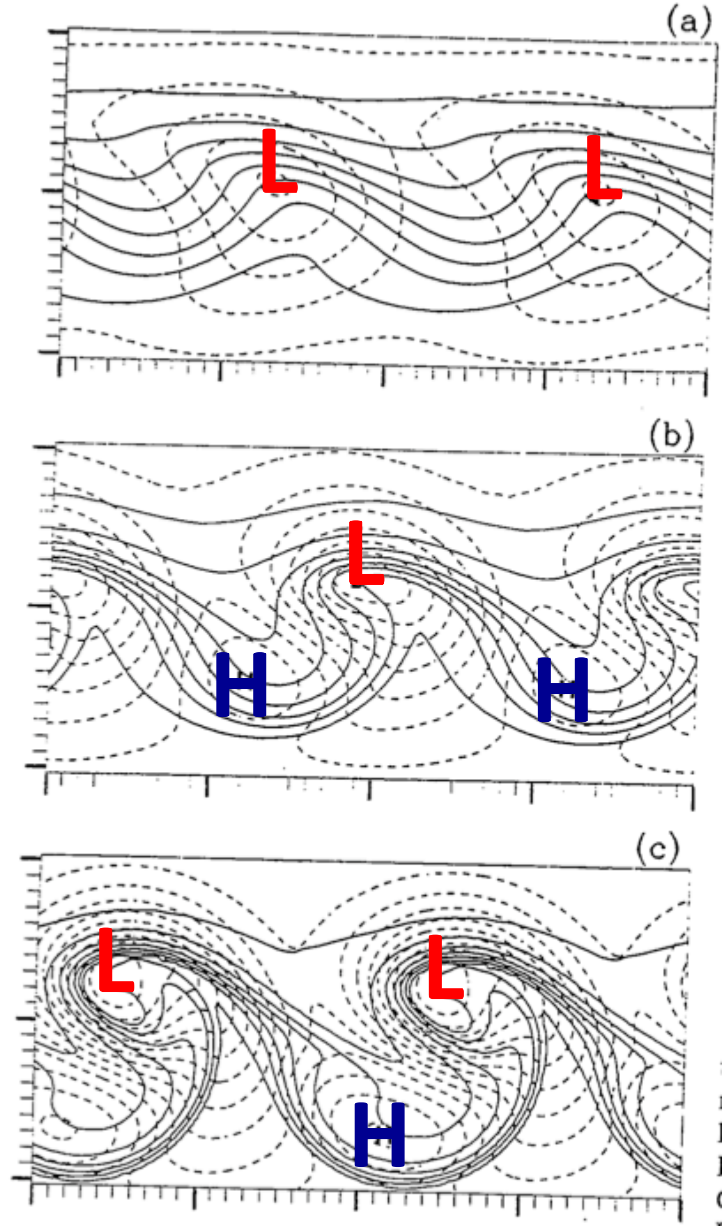
Shapiro–Keyser Model

- Integrates observational analysis (including aircraft) and numerical simulations of cyclones
- Numerical simulations include idealized and real-data simulations
- Developed for intense marine cyclones

Idealized Simulations

- Loss of cold-frontal baroclinity (frontolysis) near low center during early stages of cyclogenesis
  - Cold front never really forms

- Westward migration of warm-frontal baroclinity into polar airstream behind low center

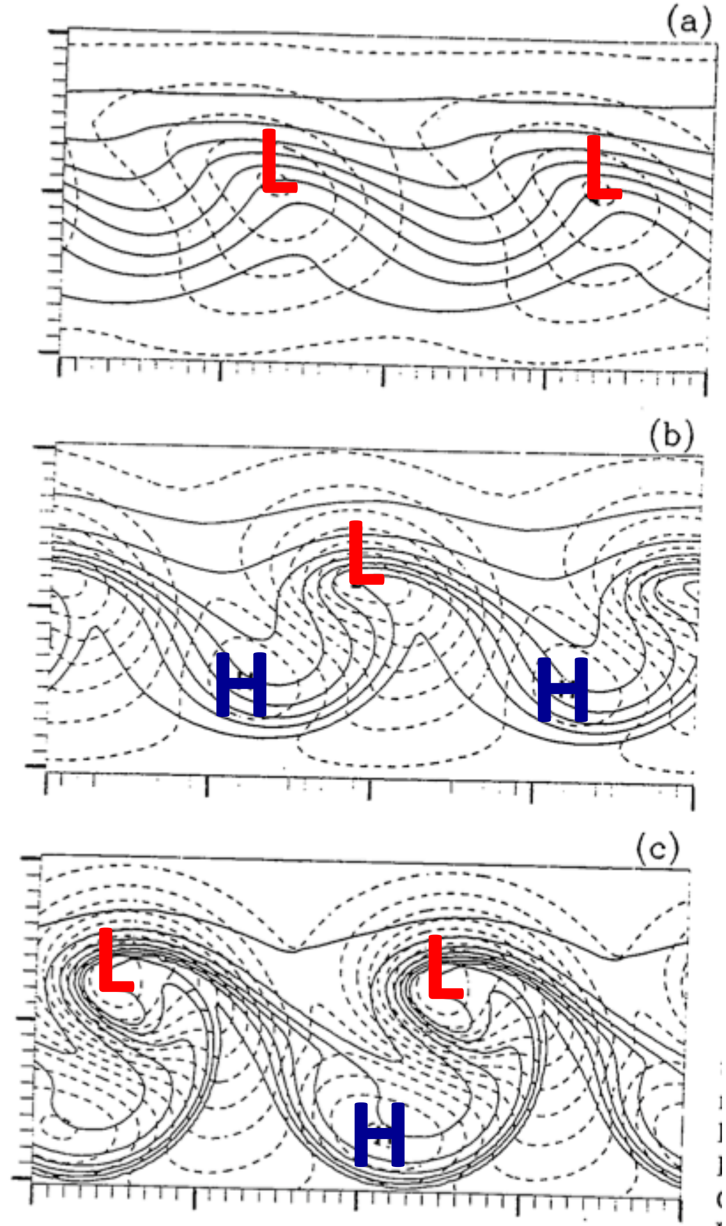


Source: Schar (1989), Shapiro and Keyser (1990)

Idealized Simulations

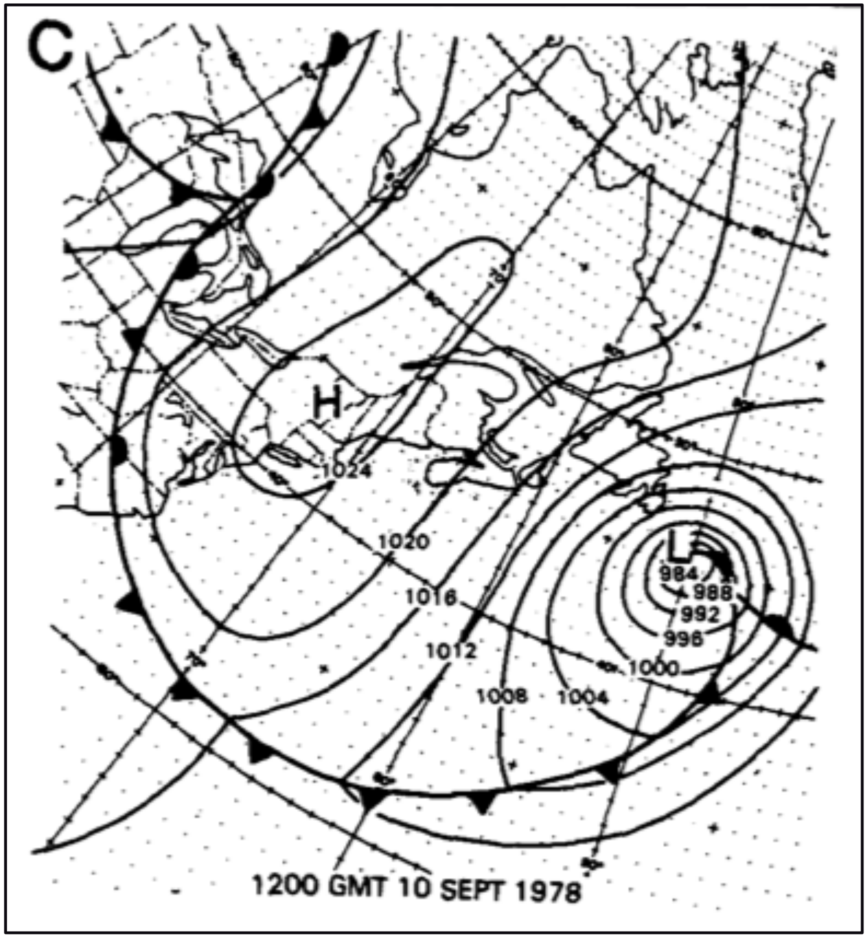
- Formation of a *warm-core seclusion* in the post-cold-frontal air

- Strongest baroclinity occurs within the *bent-back warm front* to rear of low center



Source: Schar (1989), Shapiro and Keyser (1990)

Real-Data Simulations QEII Storm

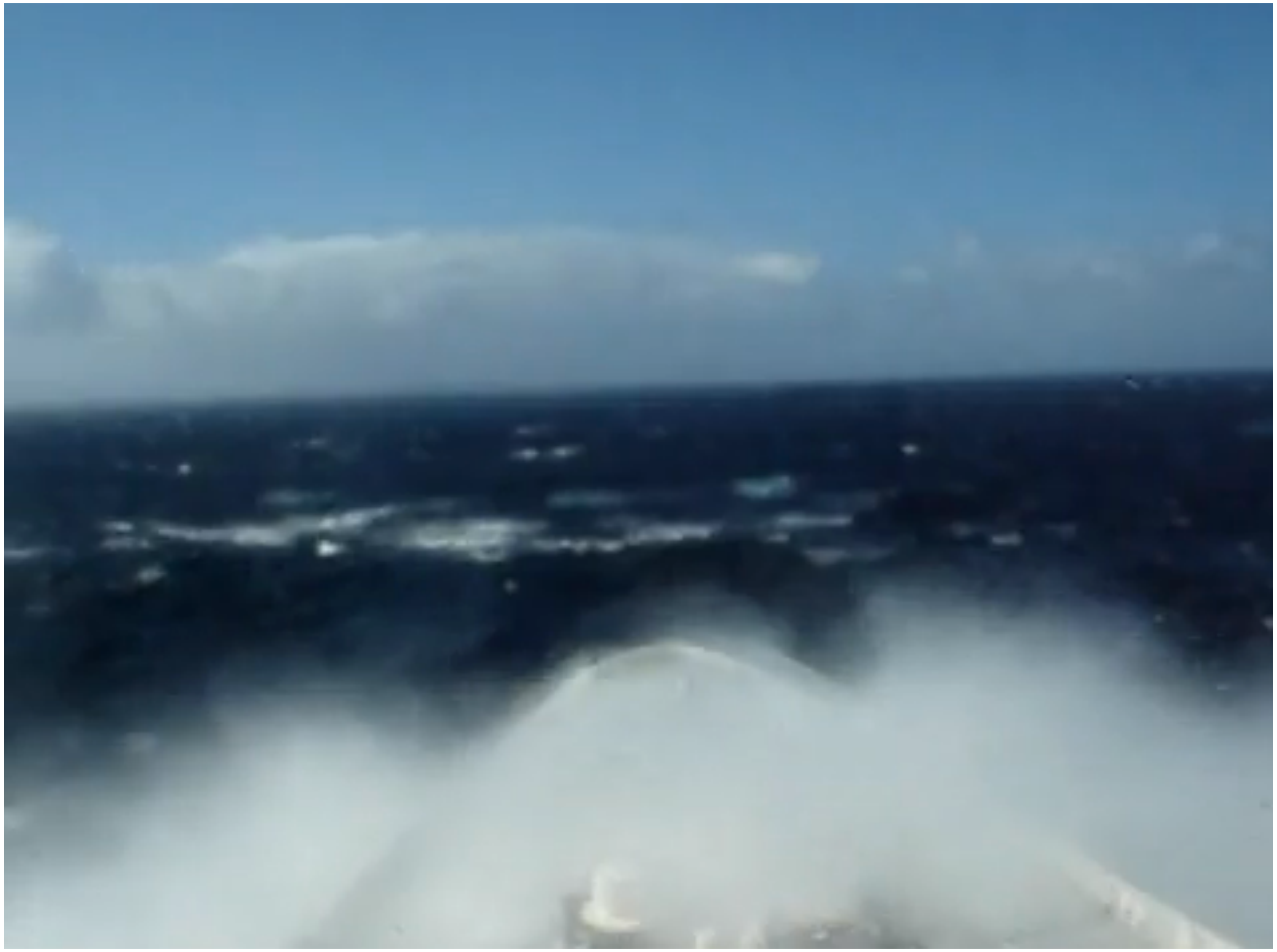


QE-II Cyclone
Poorly Forecast

QE II Ocean Liner (NOT A CRUISE SHIP)
Battered during QE II Storm
The dragger *Captain Cosmo* lost at sea

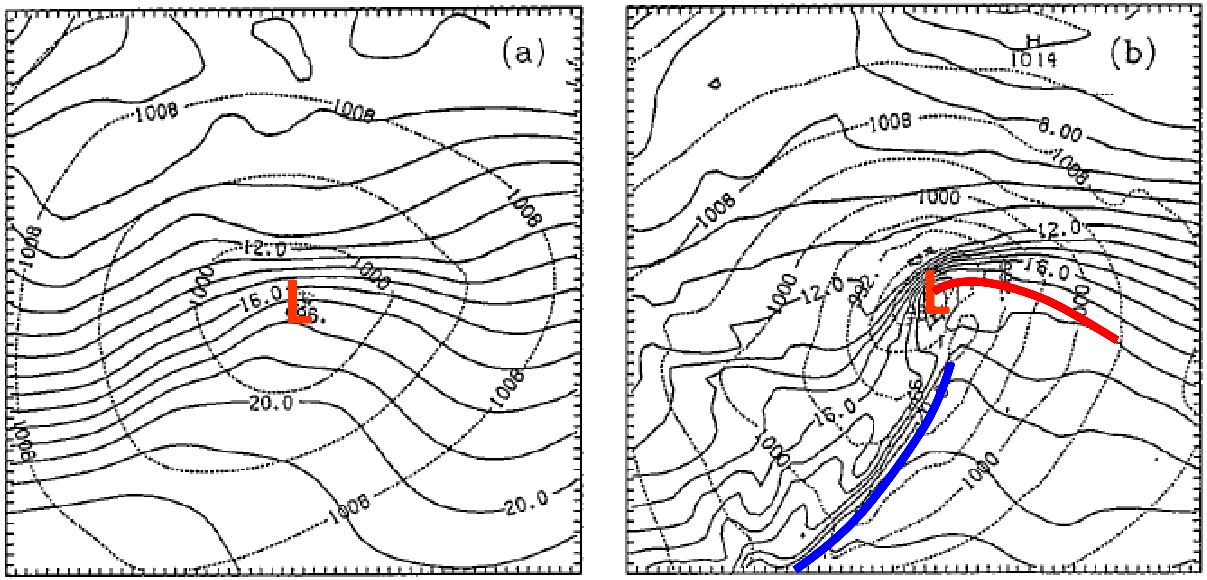
Source: Wikipedia Commons, Gyakum (1983), Uccellini (1986)

Real-Data Simulations QEII Storm



Source: http://www.youtube.com/watch?v=XS-KZXiV8DQ

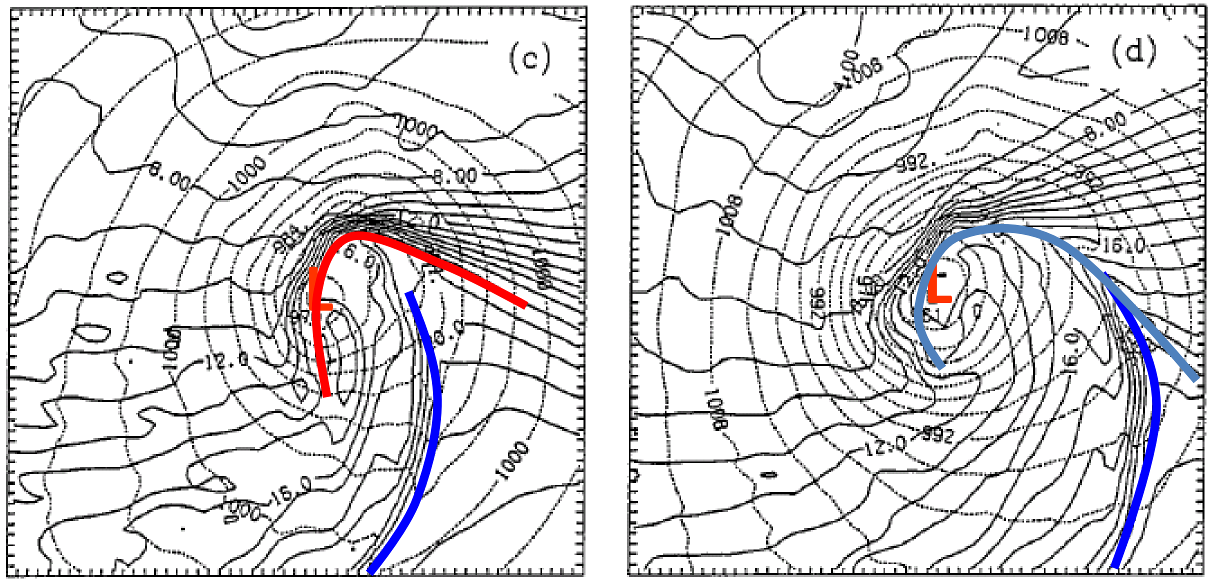
Real-Data Simulations QEII Storm



- Incipient cyclone forms within broad baroclinic zone
  - This may be a bit exaggerated given how initial conditions are created
- Contraction of warm and cold frontal baroclinic zones
- “Fracturing” of previously continuous frontal zone near low center

Source: Shapiro and Keyser (1990)

Real-Data Simulations QEII Storm

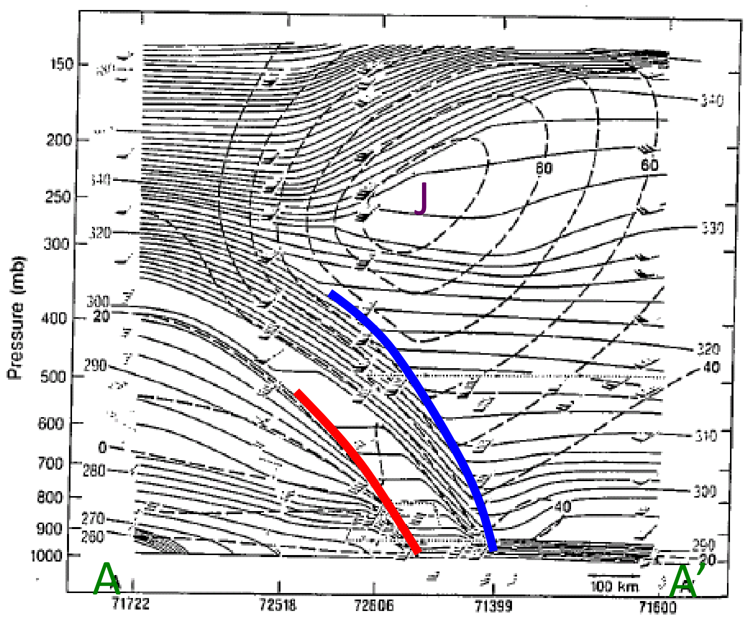


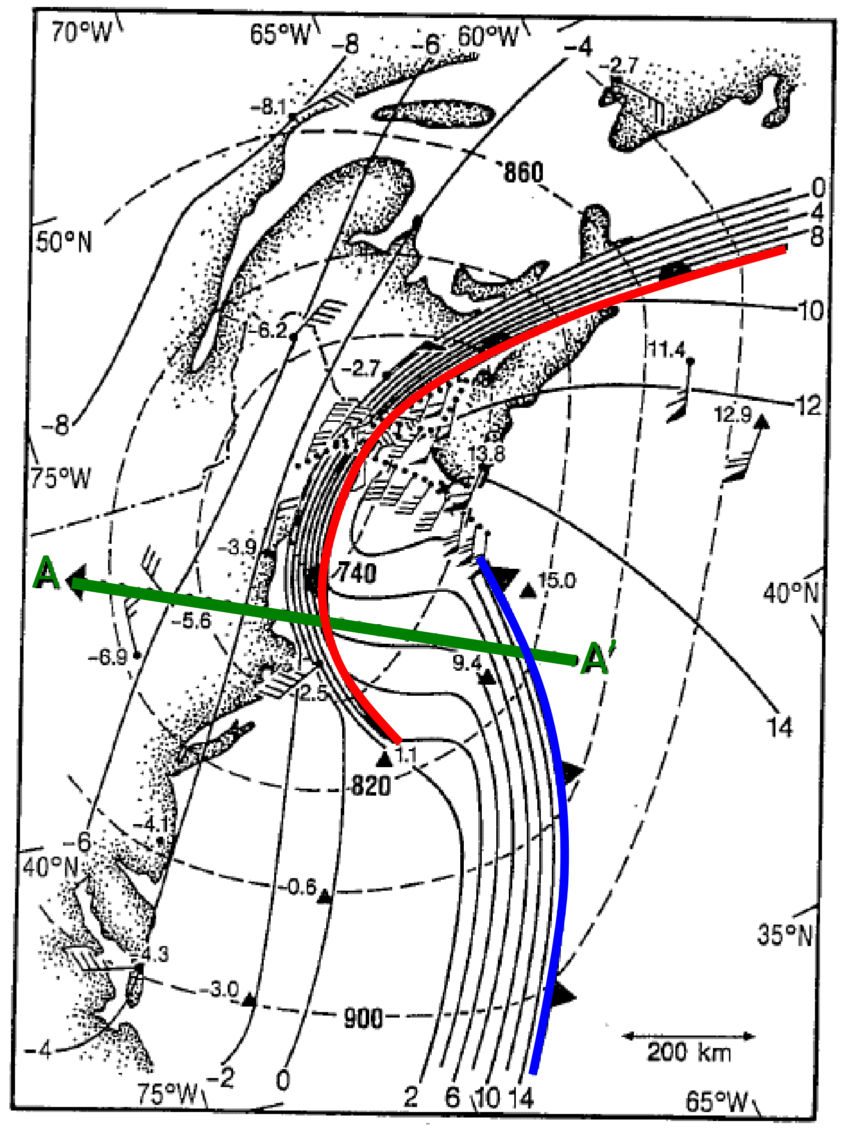
- Narrowing of warm sector
- Westward development of warm front into northerly airstream behind low (T-bone stage)
- Formation of warm core seclusion
  - Not from warm-sector air

Source: Shapiro and Keyser (1990)

Aircraft Obs of Marine Cyclones

- Frontal T-bone and cold-frontal fracture near low center

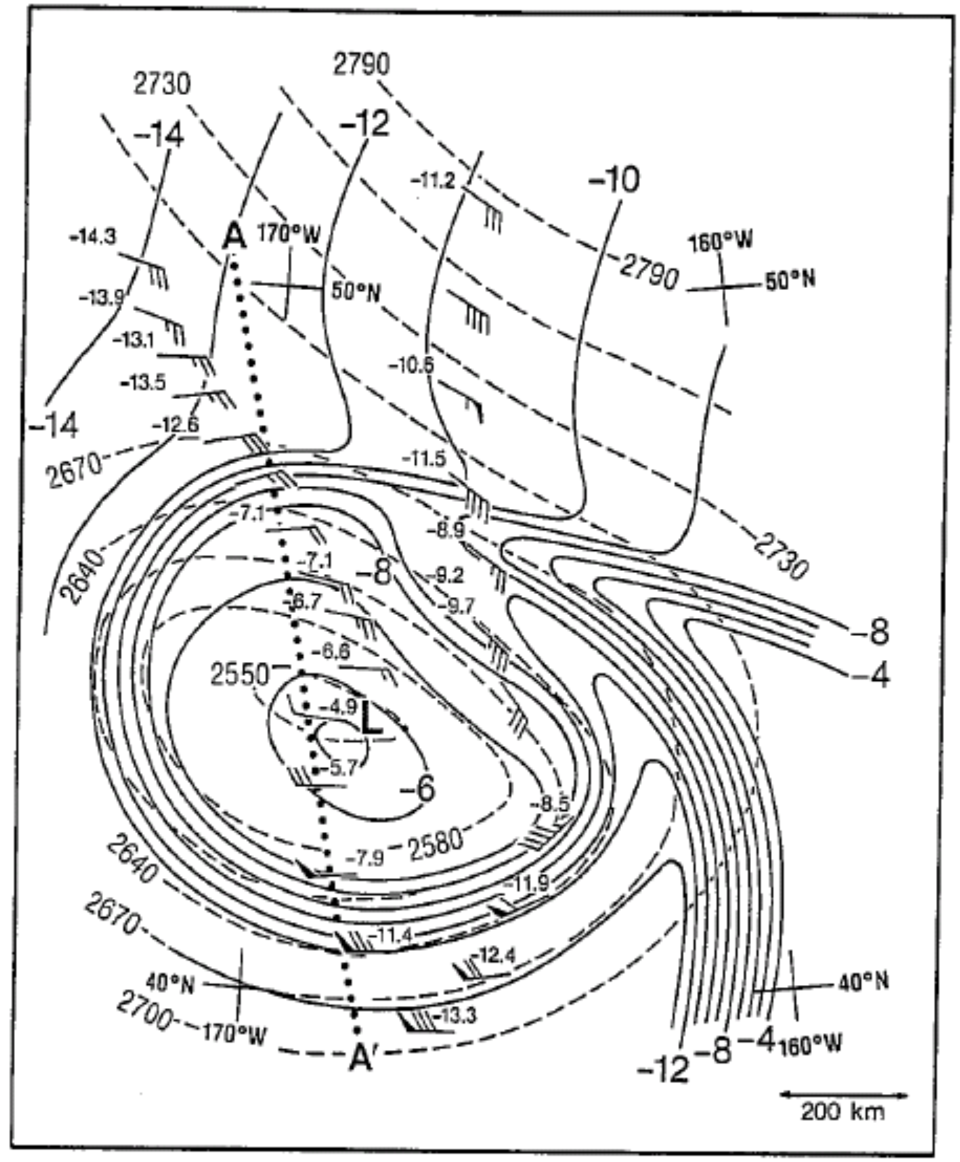




Source: Shapiro and Keyser (1990)

Aircraft Obs of Marine Cyclones

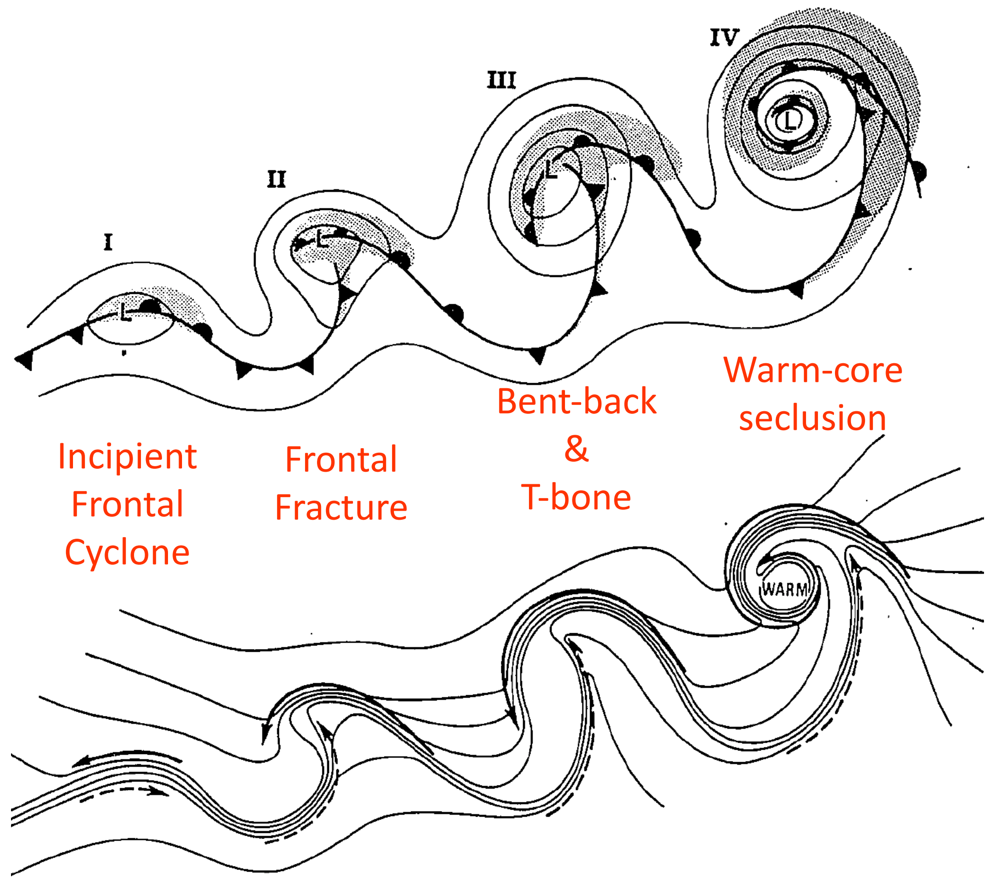
- Warm-core seclusion



Source: Shapiro and Keyser (1990)

Resulting Conceptual Model

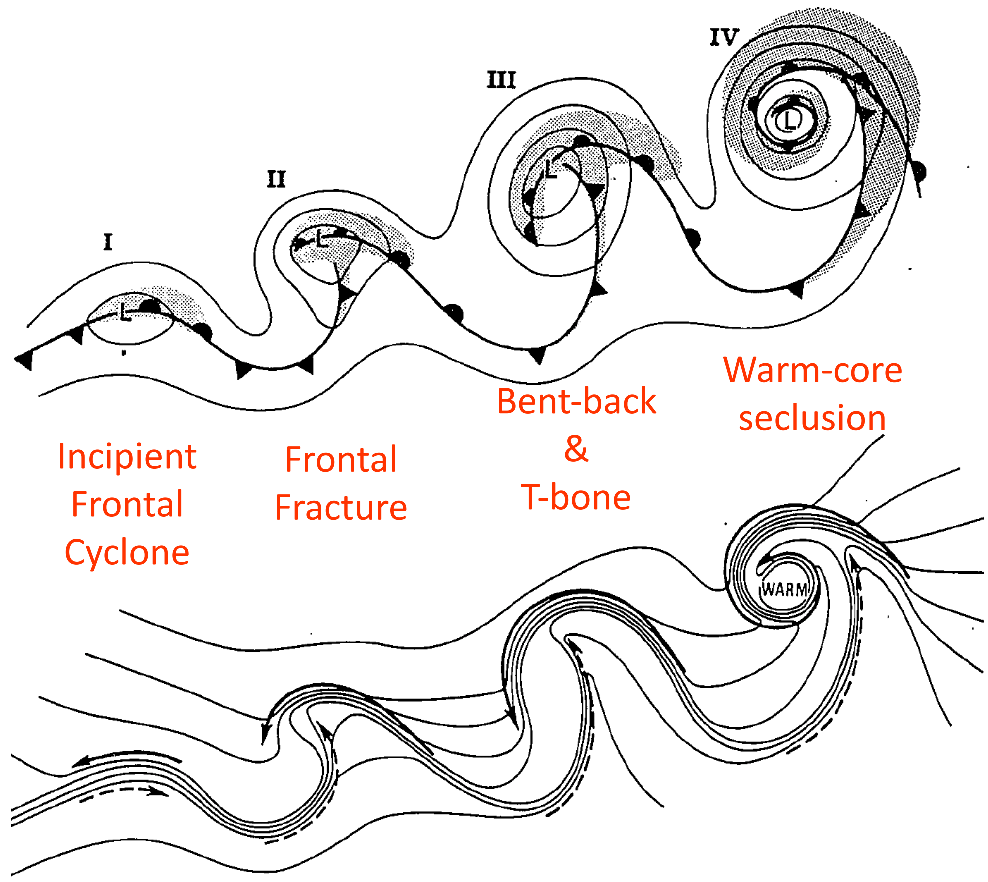
- Incipient frontal cyclone
  - Continuous & broad frontal zone representing birthplace of frontal cyclone
- Frontal fracture
  - "Fracture of frontal zone near low center
  - Contraction of warm and cold frontal gradients



Source: Shapiro and Keyser (1990)

Resulting Conceptual Model

- Frontal T-bone and bent-back front
- Warm-core seclusion
  - Forms in polar air, not from warm sector



Source: Shapiro and Keyser (1990)

Debate about S–K Model

- Completely ignores occlusion process
- Frontal fracture overstates what is actually occurring–a weakening of the cold front near the low center
- Nomenclature of bent-back warm front causes confusion
- Conceptualization of Godske et al. (1957) may be just as good
- Perhaps a spectrum of life cycles are possible and either Shapiro and Keyser (1990) or Godske et al. (1957) are useful depending on the situation?

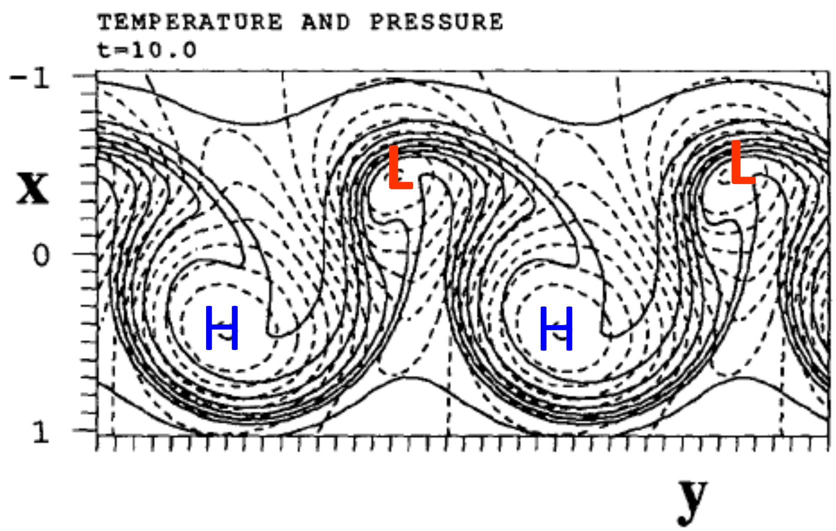
Source: Shapiro and Keyser (1990)

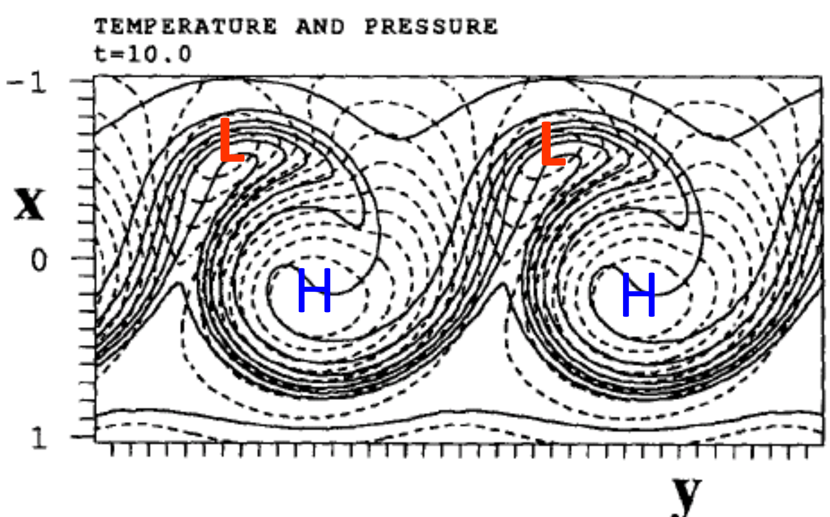
What Might Influence Cyclone Structure?

Source: Shapiro and Keyser (1990)

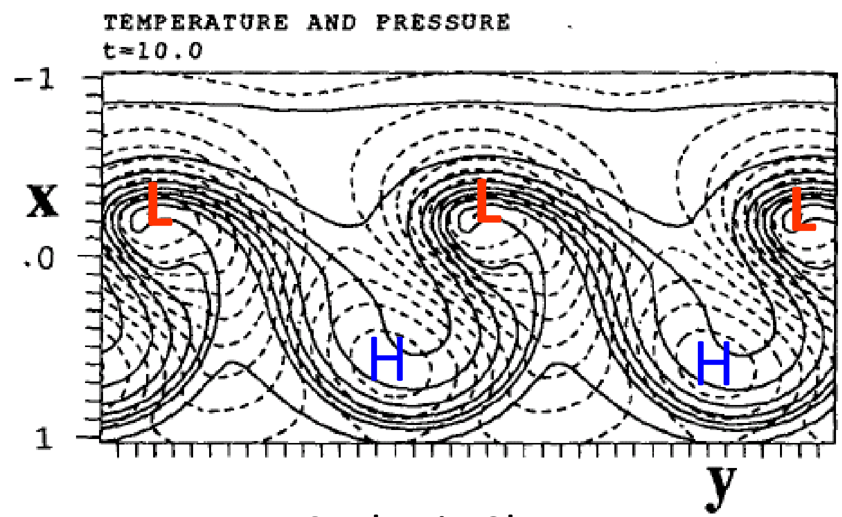
Large-Scale Flow (Idealized)

Unsheared





Anticyclonic Shear

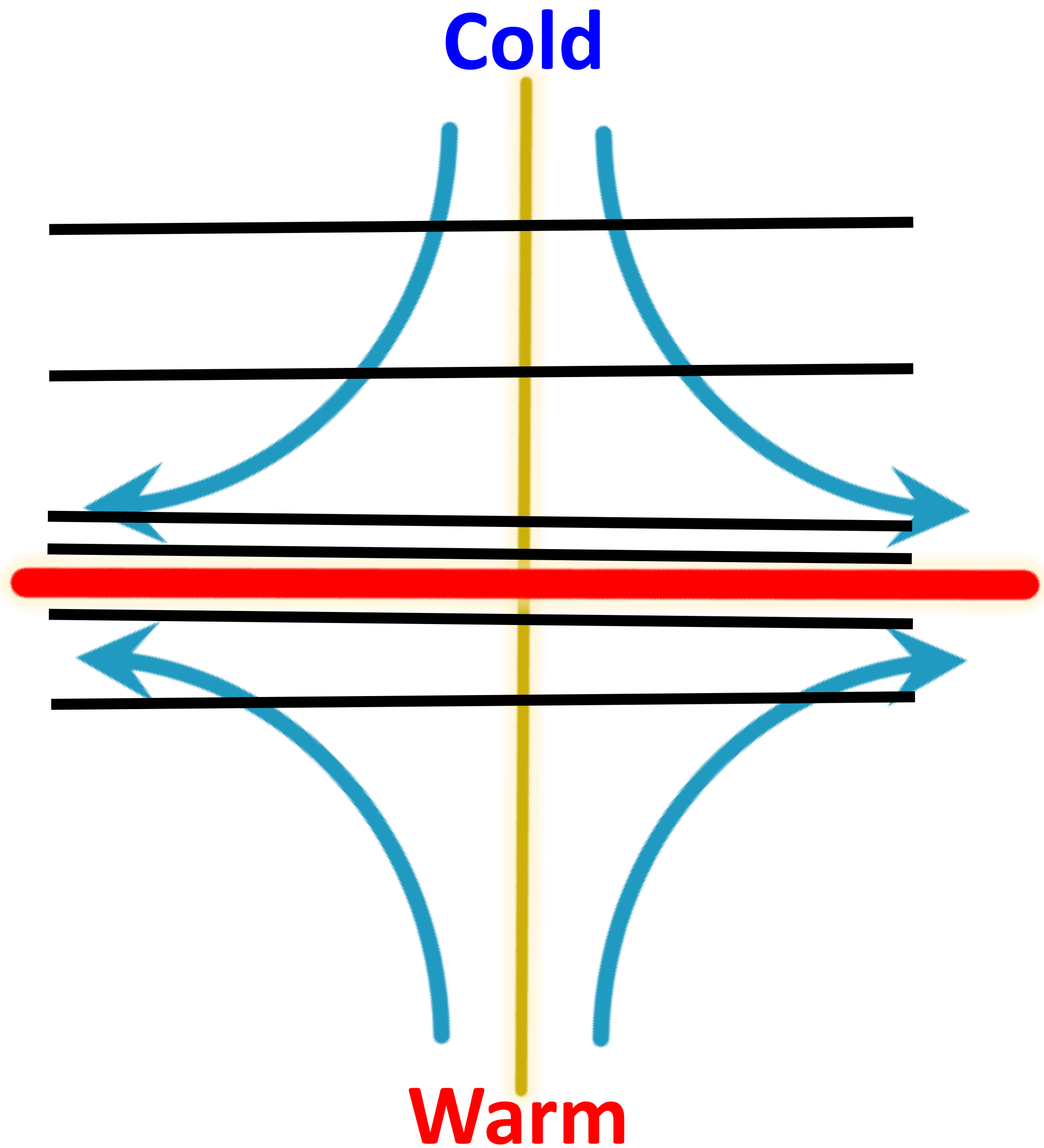


Cyclonic Shear

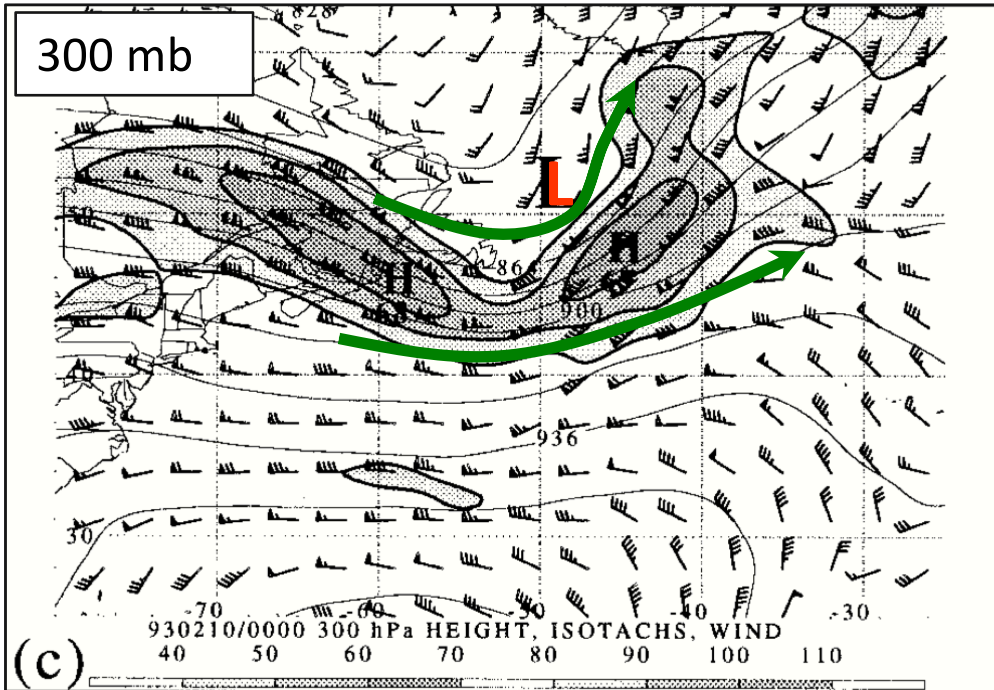
Source: Davies et al. (1991)

Effects of Deformation

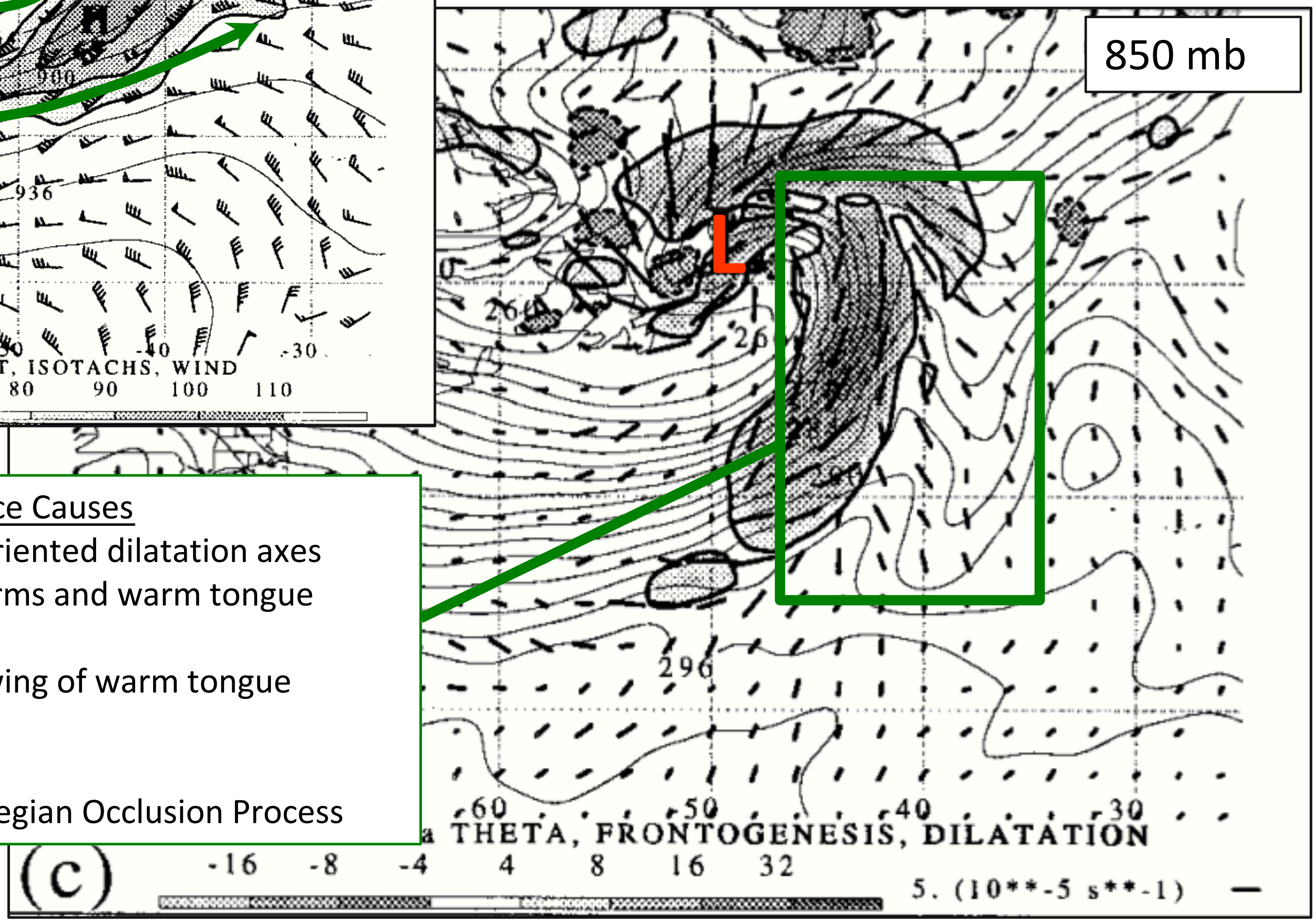
- The axis of dilatation is a collector of isotherms and the locus for frontogenesis



Large-Scale Flow (Observed)



Downstream Diffluence =
Norwegian-like occlusion



<u>Downstream Diffluence Causes</u>

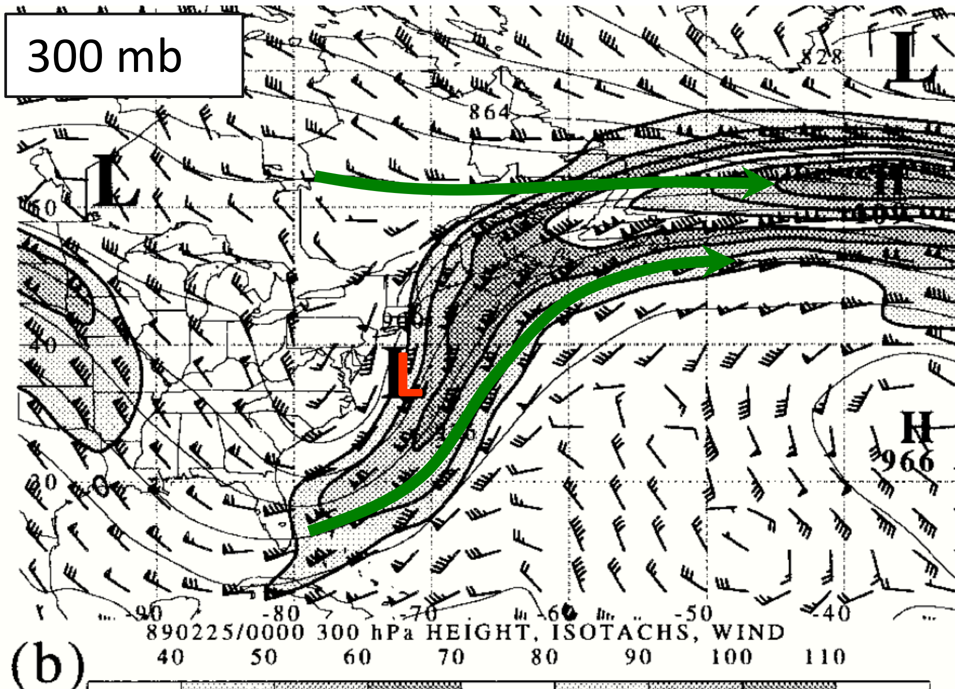
Strong meridionally oriented dilatation axes oriented along isotherms and warm tongue

Stretching and narrowing of warm tongue and warm sector

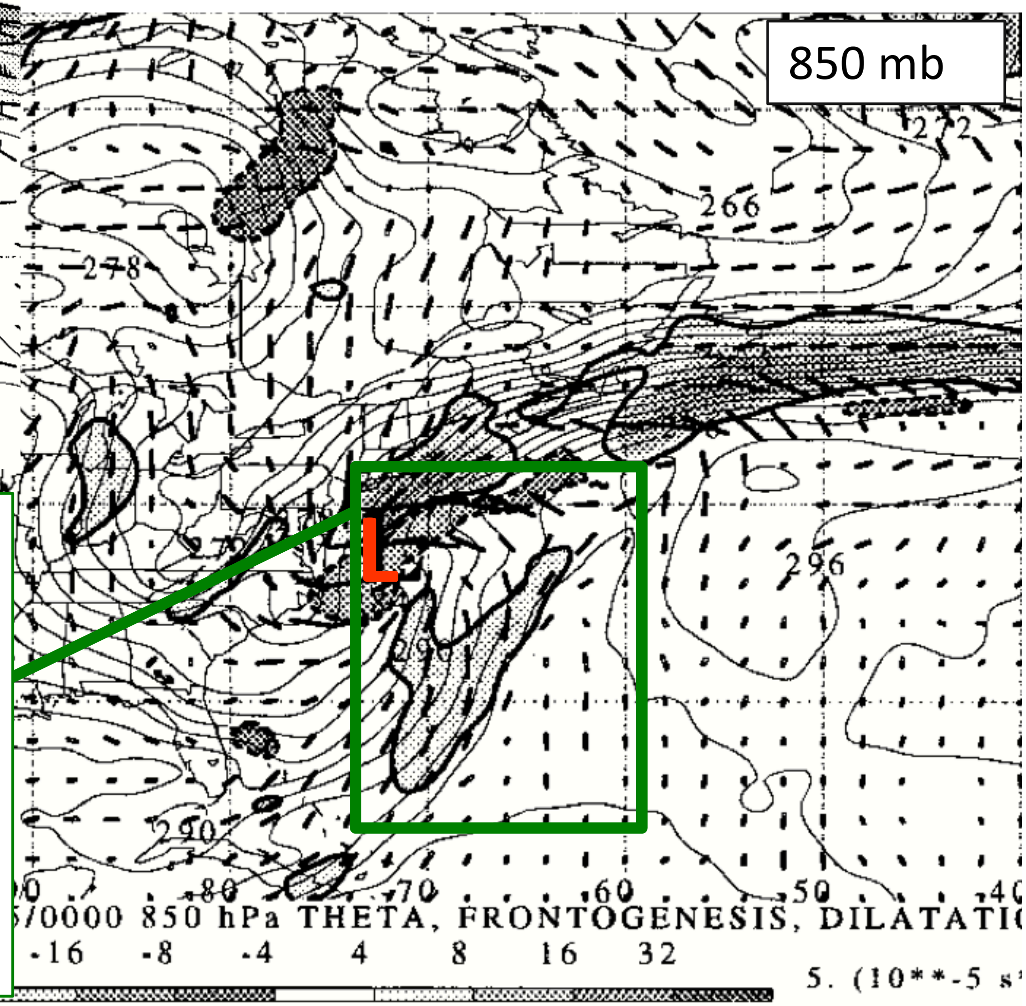
Consistent with Norwegian Occlusion Process

Source: Schultz et al. (1998)

Large-Scale Flow (Observed)



Downstream Confluence =
Frontal T-Bone and Fracture



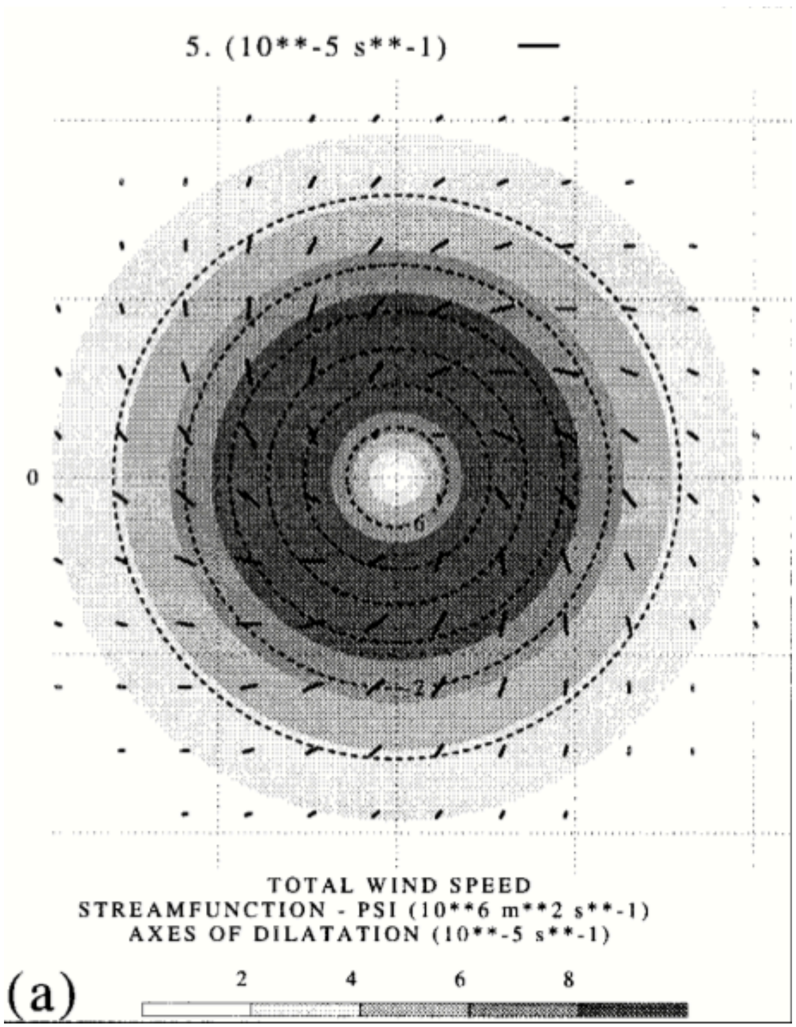
<u>Downstream Confluence Causes</u>
Weak meridionally oriented dilatation along cold front

Strong zonally oriented dilatation along warm front

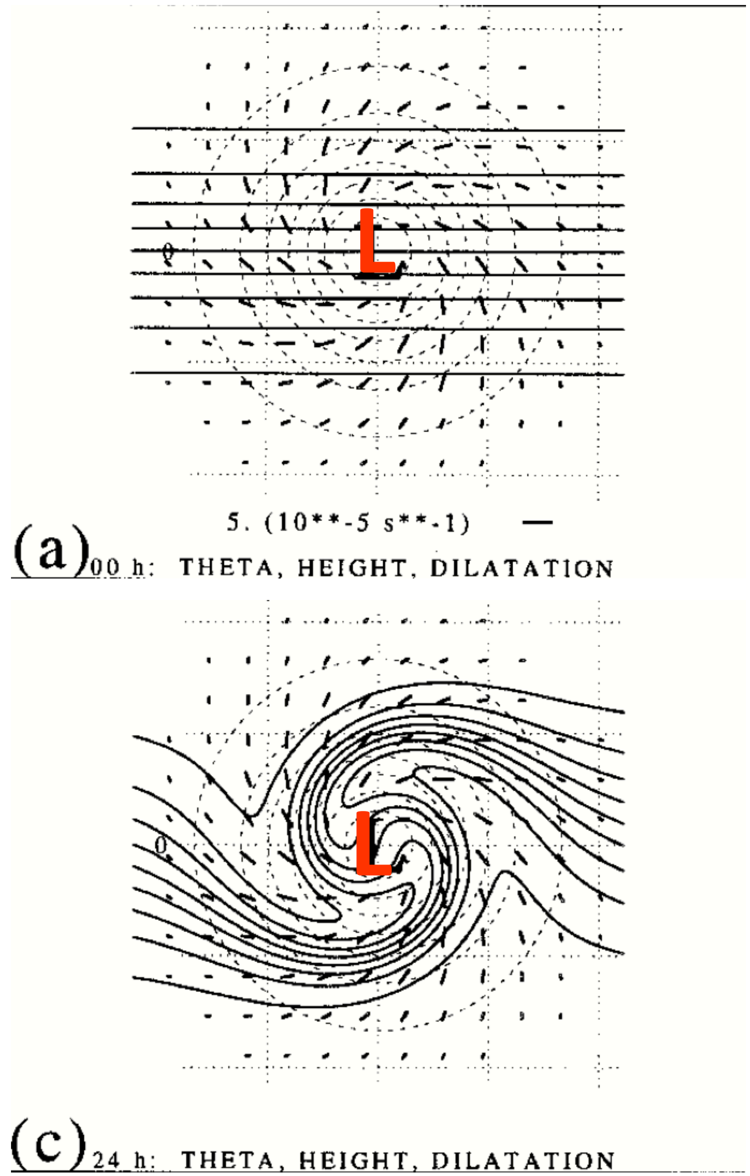
Frontal Fracture (weak frontogenesis) near juncture of cold & warm fronts where dilatation has more zonal component

Source: Schultz et al. (1998)

Really Idealized

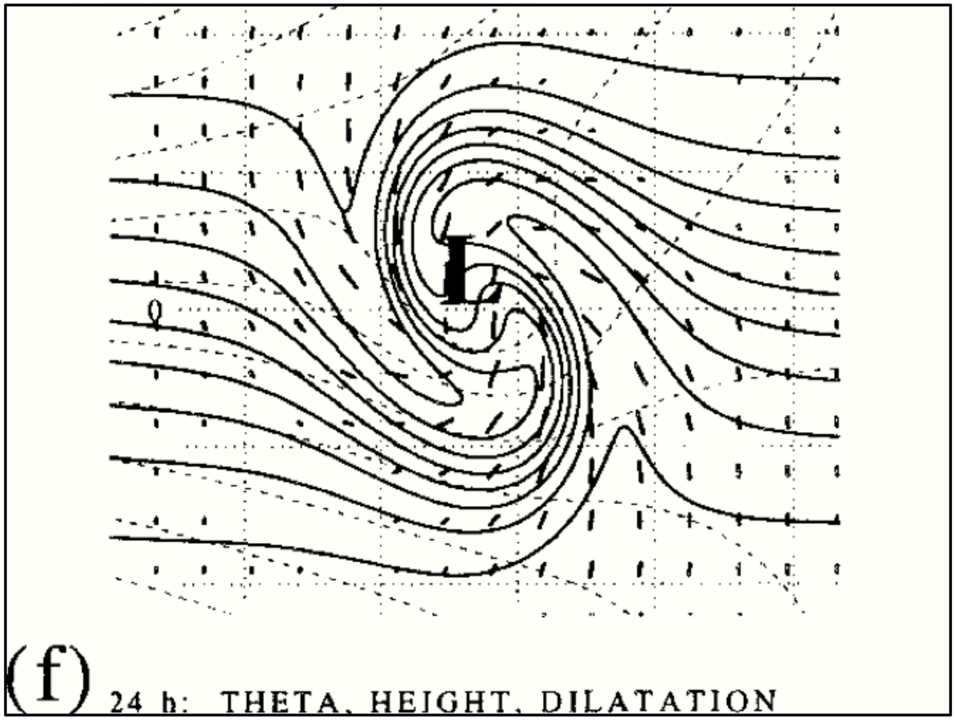


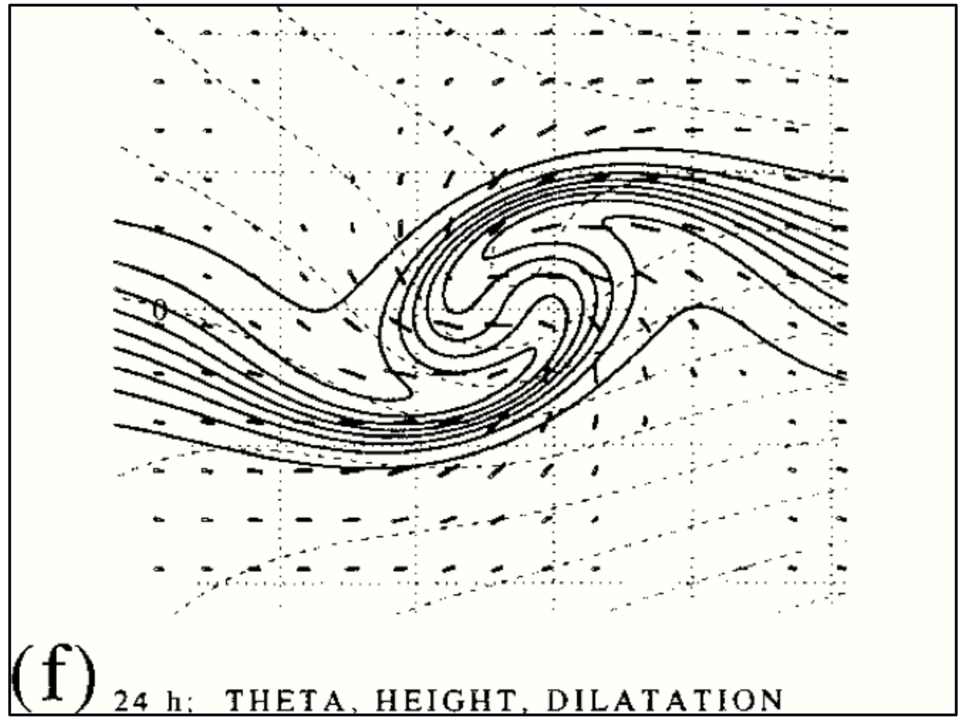
"Doswell Vortex"



Source: Schultz et al. (1998)

Really Idealized





<u>Background Diffluence</u>

More meridionally oriented dilatation axes and fronts

Narrowing warm sector and tongue

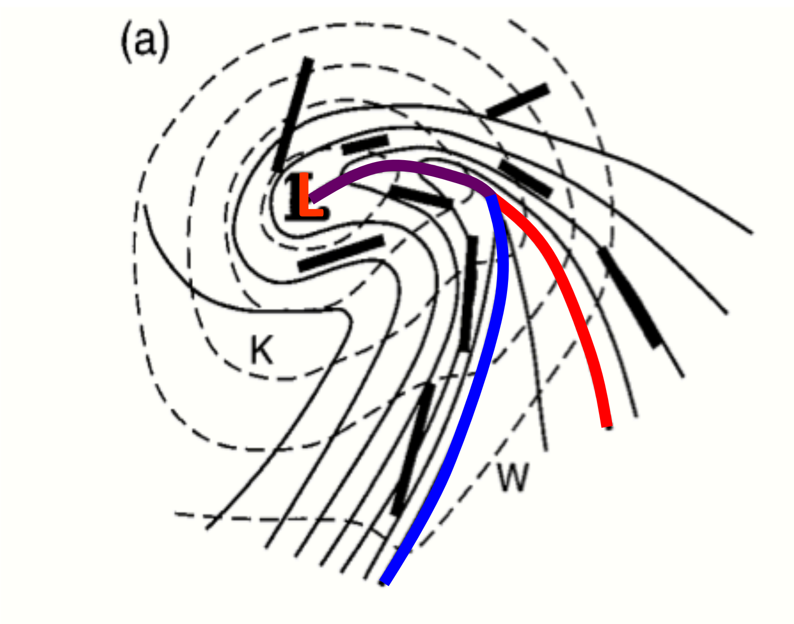
<u>Background Confluence</u>

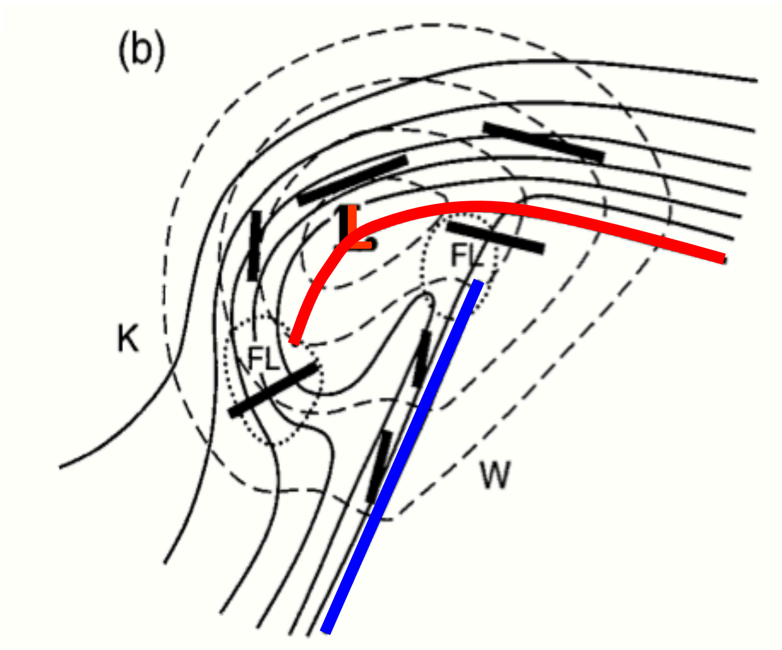
More zonally oriented dilatation axes and fronts

Frontal T-Bone

Source: Schultz et al. (1998)

Norwegian vs. S–K





Deformation acts to stretch warm tongue and narrow warm sector

Norwegian-like occlusion process

Deformation strengthens warm front

Causes frontolysis/frontal fracture of cold front near warm front

S-K like T-bone

Source: Schultz et al. (1998)

Summary

- Key features of Shapiro-Keyser model influence
  - Frontal fracture, frontal T-bone, warm-core seclusion, bent-back warm front

- Works well for some intense marine cyclones, but Godske et al. (1957) also effective and may be better for others

- Downstream confluence favors a strong warm front and frontal T-bone

- Downstream diffluence favors a narrowing warm sector and warm tongue (i.e., occluded like)

Class Activity

Analyze the cyclone below using the Godske et al. (1957) and Shapiro-Keyser Models
Discuss the strengths and weakenesses of each model for this storm

Godske et al. (1957)

Shapiro-Keyser