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


Real-Data Simulations QEII Storm

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

• 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)

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

Source: Shapiro and Keyser (1990)

• Warm-core seclusion

Source: Shapiro and Keyser (1990)

• 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)

• 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)

Source: Davies et al. (1991)

Effects of Deformation

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

Source: Shapiro and Keyser (1990)

Source: Schultz et al. (1998)

Large-Scale Flow (Observed)

Source: Schultz et al. (1998)
Really Idealized

Source: Schultz et al. (1998)

Background Diffluence
- More meridionally oriented dilatation axes and fronts
- Narrowing warm sector and tongue

Background Confluence
- More zonally oriented dilatation axes and fronts
- Frontal 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)

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)

Class Activity

Analyze the cyclones below using the Godsk et al. (1957) and Shapiro-Keyser Models. Discuss the key features and differences in each model for the storms.

HR 06
HR 09
HR 12

Godsk et al. (1957)

HR 06
HR 09
HR 12

Shapiro-Keyser