The Process of Occlusion

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Supplemental Reading: Schultz and Mass (1993), Schultz and Vaughan (2011)

Objections to the NCM Occlusion

- Structures resembling an occlusion can be present without a pre-existing warm sector
- The so-called "occluded front" is often drawn from the peak of the warm sector to the low center *without evidence that the process of occlusion occurred*
  - "The occlusion is added as an accretion"
- There is often little or no temperature gradient across an occlusion at the surface
  - The largest gradients are often aloft

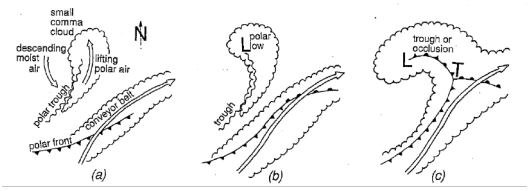
Source: Schultz and Mass (1993)

Objections to the NCM Occlusion

- There are few if any well documented cases of cold fronts overtaking warm fronts to form occlusions
- Occluded fronts often appear to form when the low center separates from the peak of the warm sector and deepens back into the cold air
  - The occluded front is essentially a new front
- Satellite imagery suggests that occluded-like structures form in non-classical ways

Source: Schultz and Mass (1993)

The Instant Occlusion



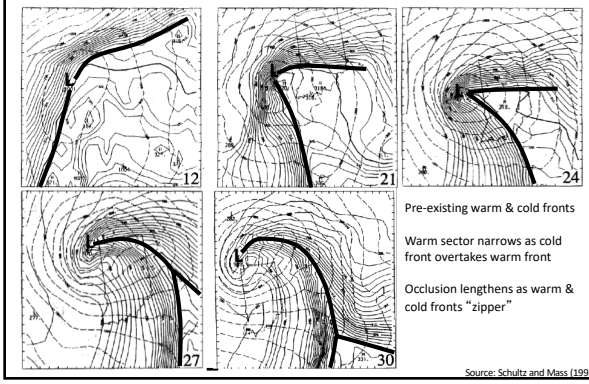
- Occurs when a comma cloud/PVA aloft approaches and merges with a frontal wave
- Structure that forms looks like an occlusion, but without the history of catch up

Source: Reed (1979), Schultz and Mass (1993), Djuric (1994)

Outstanding Questions

- Do cyclones ever occlude in a classical manner in which the cold front catches up to the warm front?
  - A: Yes!
- Can occlude structures form from non-classical mechanisms
  - A: Yes!
- Might there be a better way to conceptualize the occlusion process
  - A: Yes!

Evolution of Ideal Occlusion



Pre-existing warm & cold fronts

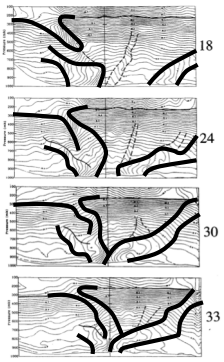
Warm sector narrows as cold front overtakes warm front

Occlusion lengthens as warm & cold fronts "zipper"

Source: Schultz and Mass (1993)

Vertical Structure

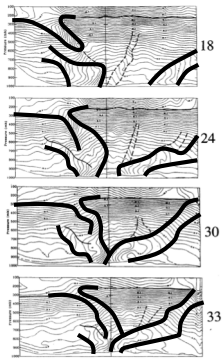
- HR 18
  - Distinct warm and cold fronts
  - Intervening warm sector
  - Cold & upper level fronts somewhat distinct
- HR 24
  - Warm sector narrows
  - Cold & upper-level fronts merge



Source: Schultz and Mass (1993)

Vertical Structure

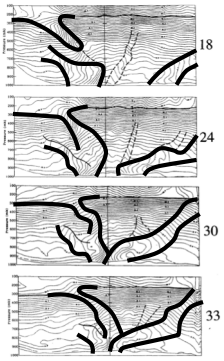
- HR 30
  - Cold & warm fronts meet, forming warm-type occlusion
- HR 33
  - Upper-level cold front continues to move downstream, forming elevated cold front of the occlusion



Source: Schultz and Mass (1993)

Vertical Structure

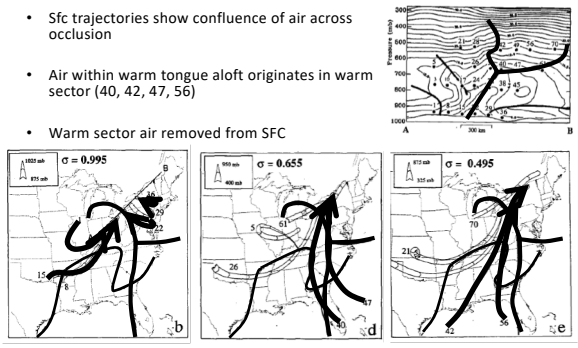
- Key points
  - Surface-based cold front catches warm front in classical manner
  - Cold front does not "ride up" over warm front
  - Upper-level frontal zone provides elevated cold-front of the occlusion



Source: Schultz and Mass (1993)

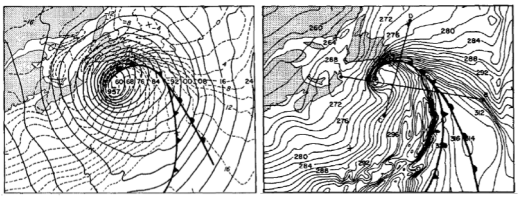
Airflow

- Sfc trajectories show confluence of air across occlusion
- Air within warm tongue aloft originates in warm sector (40, 42, 47, 56)
- Warm sector air removed from SFC



Source: Schultz and Mass (1993)

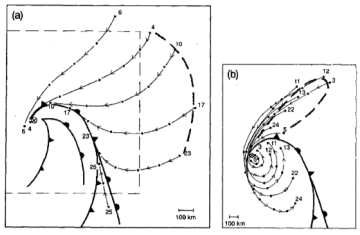
Non-Classical Occlusion



- Deeply occluded system with warm-core seclusion
- Front forms from "occludogenesis" rather than catch up
- Wind fields generate the warm tongue & seclusion

Source: Kuo et al. (1992)

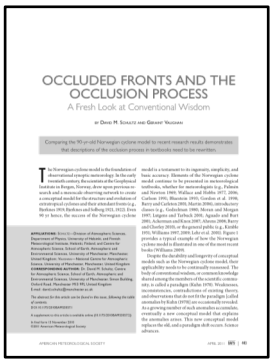
Non-Classical Occlusion



- Confluence of trajectories along occlusion
- "Crossing" of post-occlusion trajectories
  - #5 starts to south in warmer air than 13. #5 ends in seclusion.
- Seclusion forms from the "wrapping" of cold air originating in warm/occluded frontal zone

Source: Kuo et al. (1992)

A New Perspective



OCCLUDED FRONTS AND THE OCCLUSION PROCESS

A Fresh Look at Conventional Wisdom

Conventional Wisdom

- The occluded front forms and lengthens as the cold front overtakes the warm front
- The occlusion may be warm or cold type depending on the temperatures behind the cold front and ahead of the warm front
- The formation of an occlusion signifies an end to the cyclone deepening phase
- The occluded front features the pre-frontal weather of a warm front (widespread clouds and precipitaiton) and the post-frontal weather of a cold front (clear skies and drying)

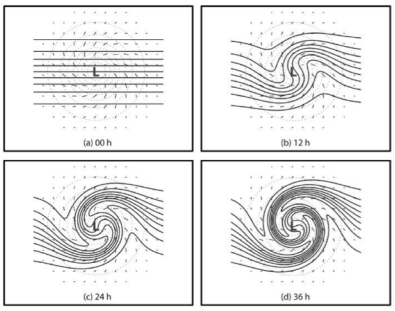
Source: Schultz and Vaughan (2011)

Catch-Up Process

- Question
  - Is the catch-up process an explanation of occlusion formation or a consequence of the underlying physical process?
- Alternative Answer
  - Lengthening and narrowing of warm tongue, and catch-up of cold and warm fronts better explained by differential deformation and rotation around low center

Source: Schultz and Vaughan (2011)

Deformation and Rotation



Advantage: Explains "occludogenesis", strengthening of instant occlusion, lengthening of occlusion as low deepens into cold air, catchup process, etc.

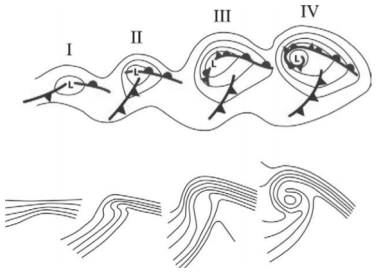
Source: Schultz et al. (1998), Schultz and Vaughan (2011)

Reconciling conceptual models

- Key physical process operating in traditional occlusion and Shapiro-Keyser model is "wrap-up" of the thermal wave by differential rotation and deformation
- In the NCM, the narrowing of the warm sector and "catch-up" of the cold front to the warm front is a consequence of this process
- In the S-K model, the separation of the low center from the warm sector, development of the intervening warm front, and formation of bent-back front are a consequence of this process

Source: Schultz and Vaughan (2011)

Alternative S-K Model



Eliminates pesky use of "warm front" and "bent-back warm front"

Source: Schultz and Vaughan (2011)

Warm and Cold Type Occlusion

- Temperature "rule" for occlusion formation doesn't work because fronts are not zero order discontinuities in temperature
- Static stability is a better discriminator for occlusion type (low static stability goes over high)
  - Explains why warm-type is more common
    - Cold front is usually less stable
  - Suggests that cold-type occlusions may be more common in areas where warm fronts tend to be weak (e.g., California)

Source: Stoelinga et al. (2002), Schultz and Vaughan (2011)

Occlusion Ends Cyclone Deepening

- Norwegian Model
  - Occlusion indicates end of deepening phase because cyclone no longer has access to potential energy stored in warm sector
    - "After the occlusion, the cyclone soon begins to fill up" (Bjerknes and Solberg 1922)
- Reality
  - Cyclones often deepen after occlusion formation
  - Cyclogenesis better viewed from QG or PV perspective

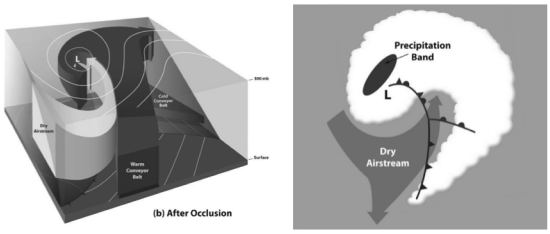
Source: Schultz and Vaughan (2011)

Occlusion Weather and Precip

- Norwegian Model/CW
  - Occlusions are associated with widespread clouds/precip followed by clearing after surface frontal passage
- Reality
  - Occlusions are associated with a variety of cloud/precip patterns, including dry slots and banded precipitation

Source: Schultz and Vaughan (2011)

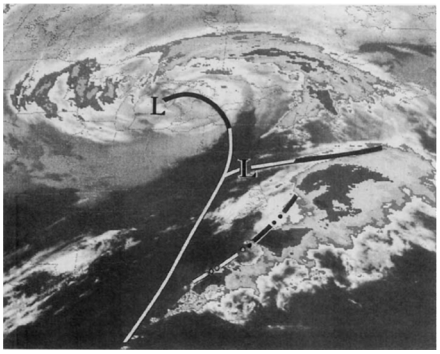
Occlusion Weather and Precip



The Dry Airstream
Gradients in "weather" not necessarily collocated with surface front
Don't use back edge of cirrostratus to locate surface front!

Source: Schultz and Vaughan (2011)

Occlusion Weather and Precip



Source: Mass and Schultz (1993), Schultz and Vaughan (2011)

Summary

- Occlusions form as described by Norwegian Cyclone Model (i.e., Catch up)
- The also form through non-classical processes
- Formation and lengthening of warm tongue and catch-up process better explained by the wrap-up of the baroclinic zone by differential deformation and rotation
- Paradigm can also explain "occludogenesis" and S-K model
- Move into the 21st century
  - Warm/cold type determined by static stability
  - Think QG/PV to understand cyclone development
  - Recognize cloud/precip patterns with occlusions are varied

Class Activity

- Use the Real-Time-Wx -> Analyses -> Global-10day bundle and find a NCM and a S-K model cyclone
- Evaluate the applicability of differential rotation and deformation as a paradigm for explaining the thermal wave wrapup in each cyclone
- Analyze the S-K cyclone using the alternative model presented herein