Quasi-Geostrophic Theory
Chapter 5

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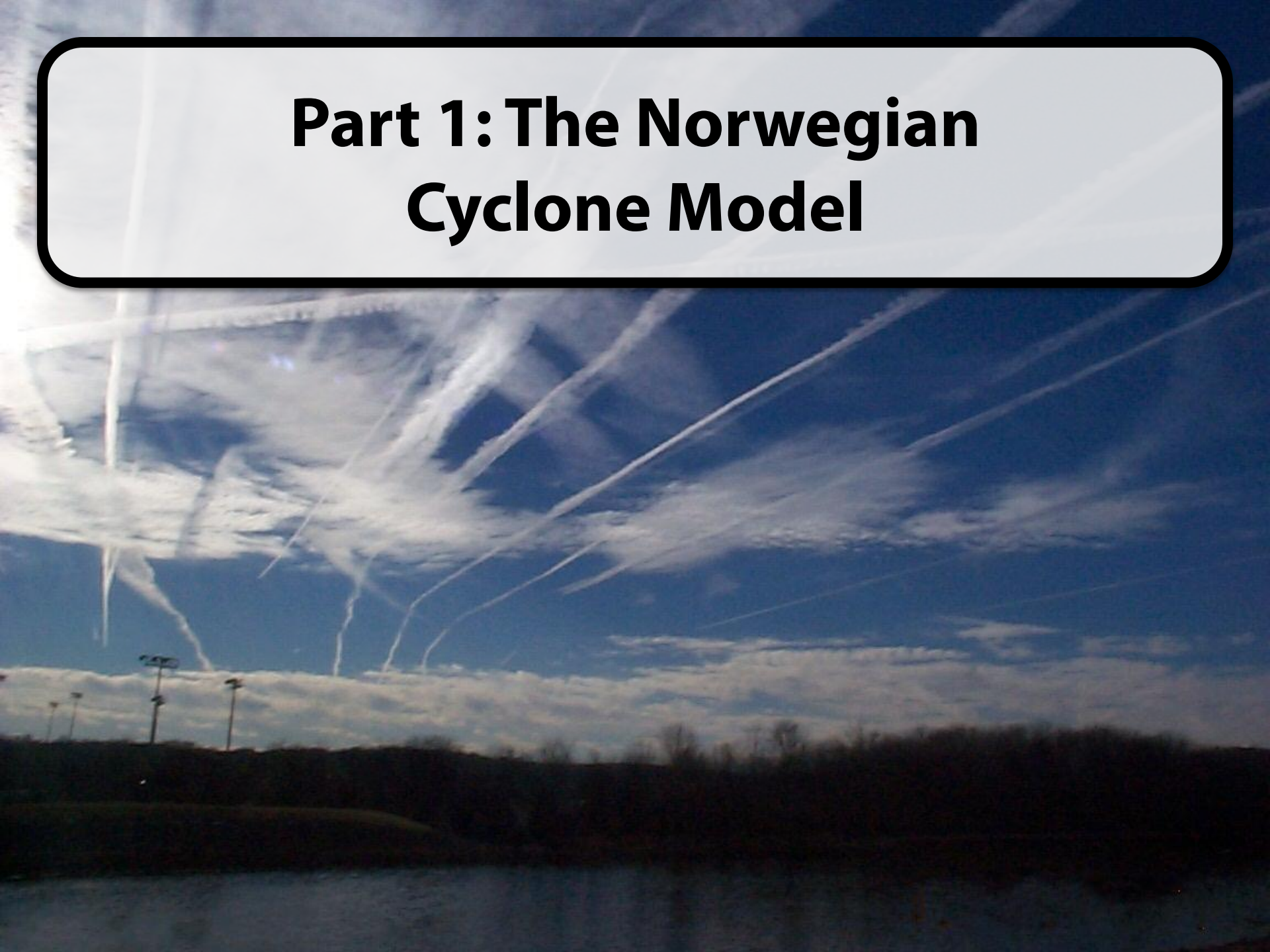


Part 1: The Norwegian Cyclone Model

Extratropical Cyclones

Extratropical Cylones are important for driving weather in the mid-latitudes. They are closely related to weather fronts.

Particularly strong extratropical systems are responsible for large-scale storm systems.

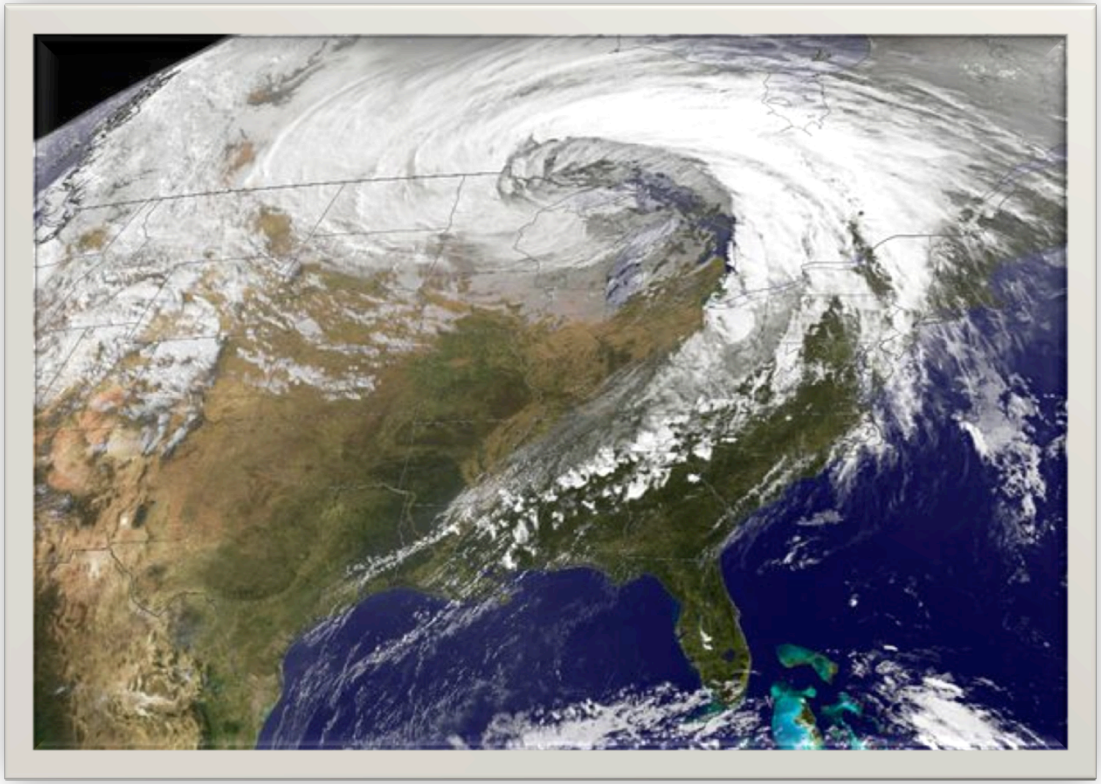


Figure: Extratropical Cyclones are associated with severe winter storm systems, and are particularly relevant for the US Northwest and Northern Europe.

Extratropical Cyclones

Extratropical cyclones…

- … are low pressure systems
- … form through spinup of low-level positive vorticity
- … are closely related to divergence/convergence
- … are closely associated with fronts
- … sometimes develop rapidly, and sometimes not at all

Question: Why do extratropic cyclones exhibit these characteristics?

Warm Fronts

- … are broader in shape than cold fronts
- … tend to move more slowly than cold fronts
- … have precipitation spread out over a larger distance

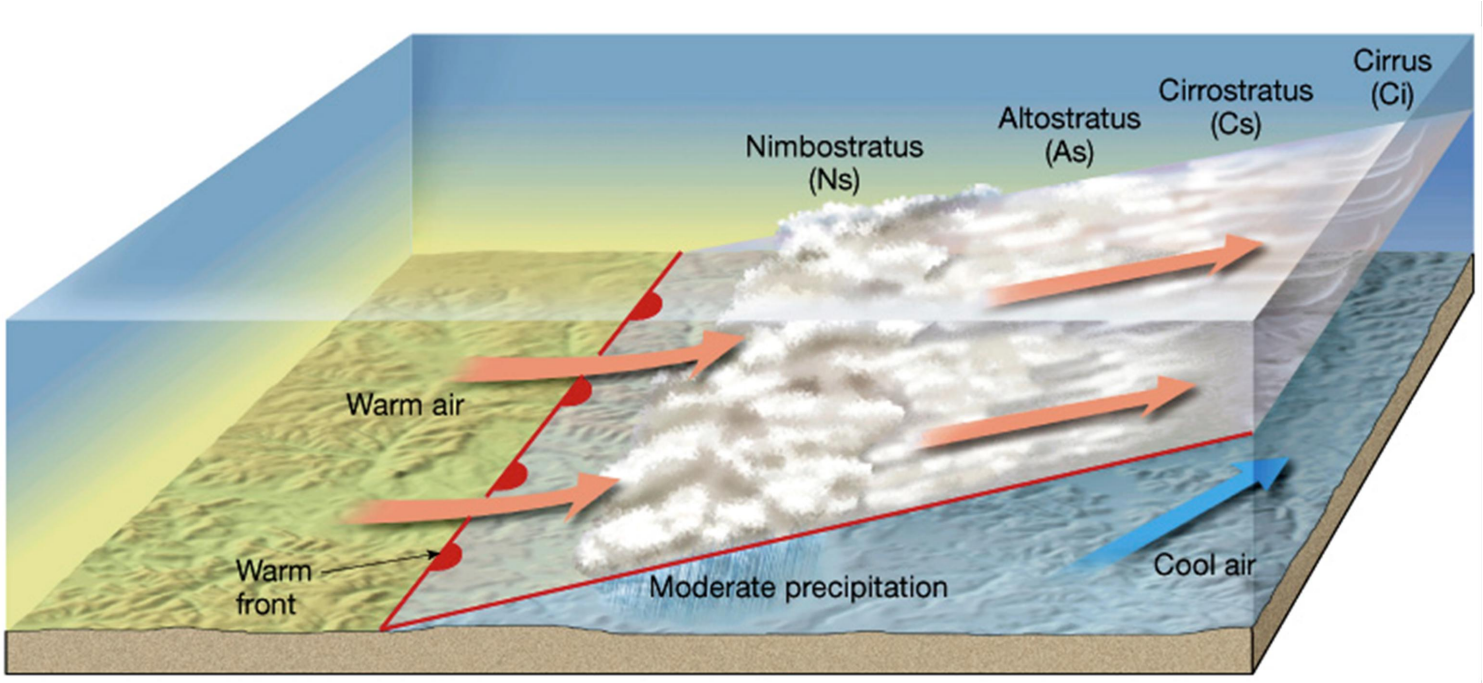


Figure 9.6 in *The Atmosphere, 8th edition*, Lutgens and Tarbuck, 8th edition, 2001.

Cold Fronts

- … are vertically steep
- … tend to travel faster than warm fronts
- … are associated with strong storms at boundary

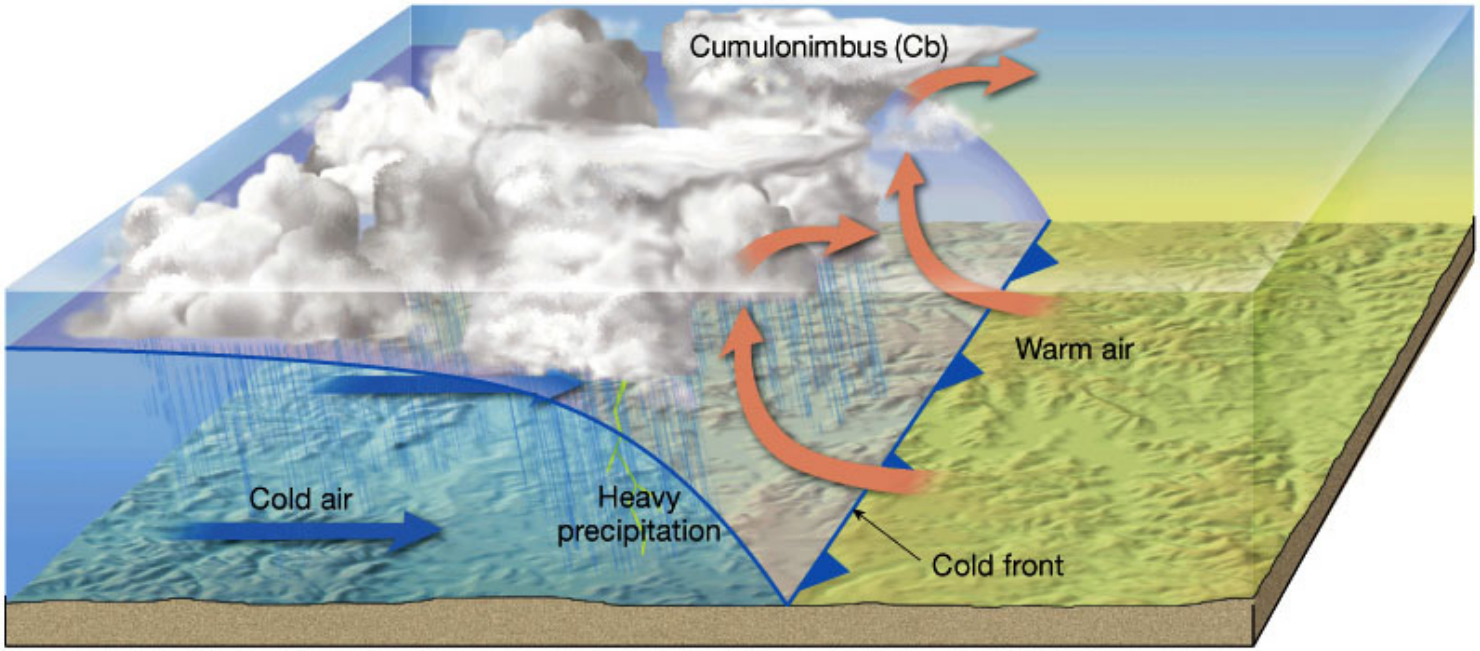
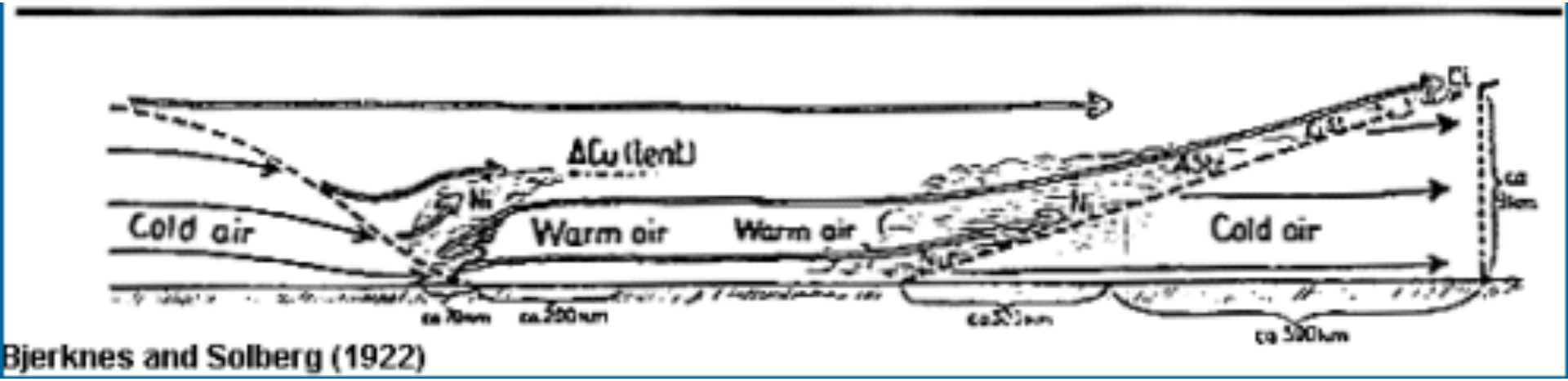


Figure 9.6 in *The Atmosphere, 8th edition*, Lutgens and Tarbuck, 8th edition, 2001.

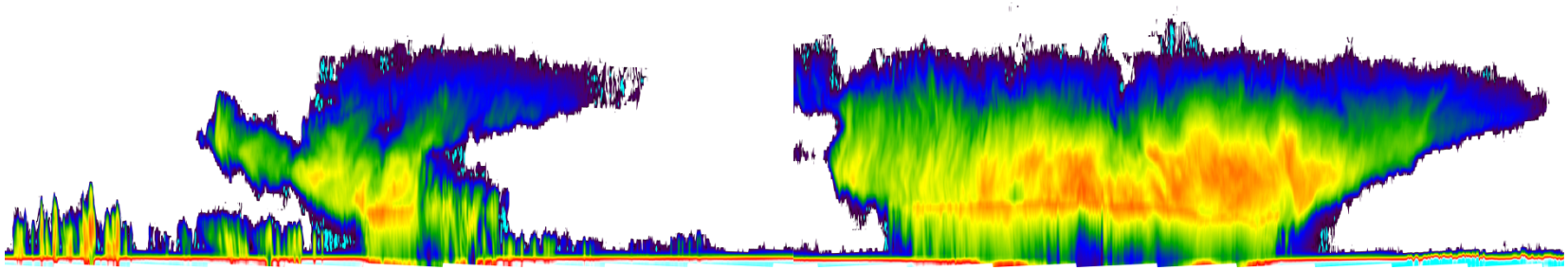
Fronts and Precipitation

Norwegian Cyclone Model

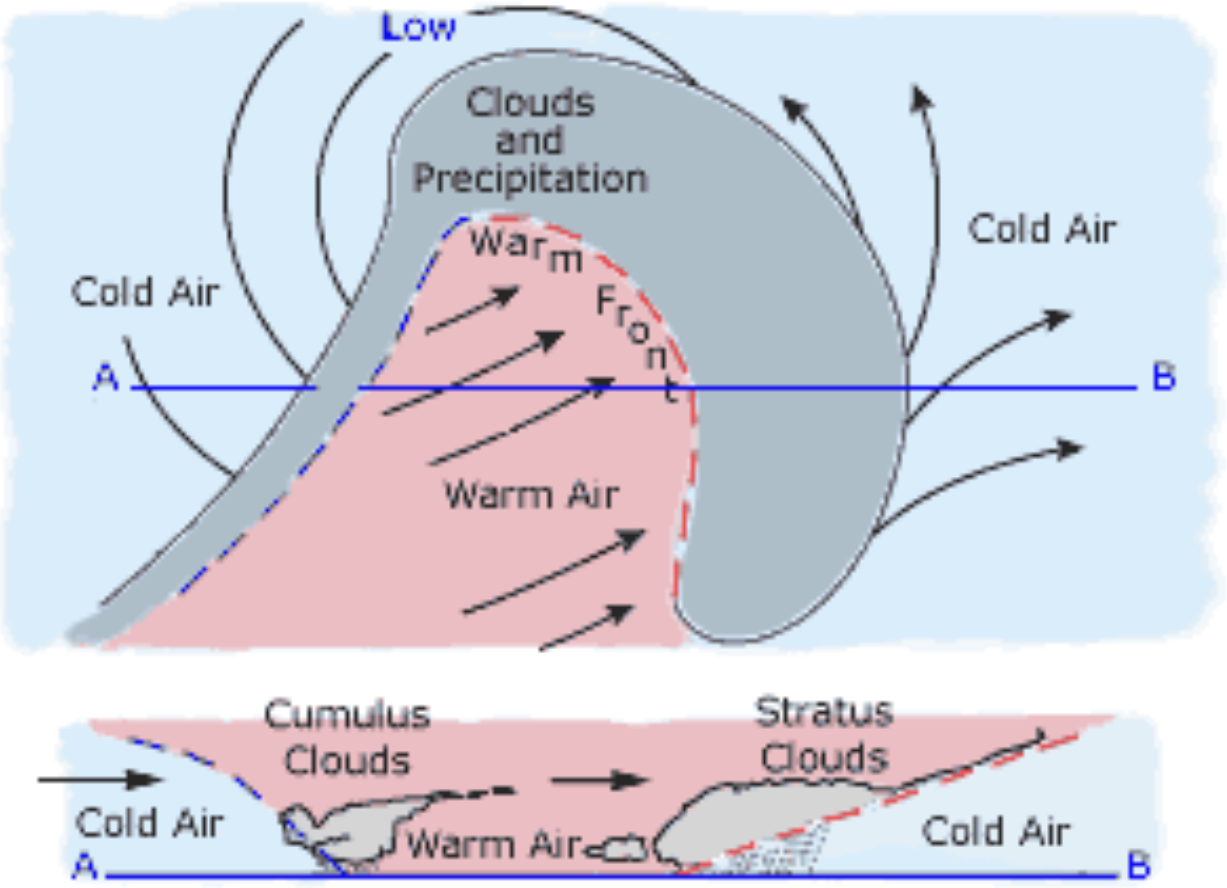


Bjerknes and Solberg (1922)

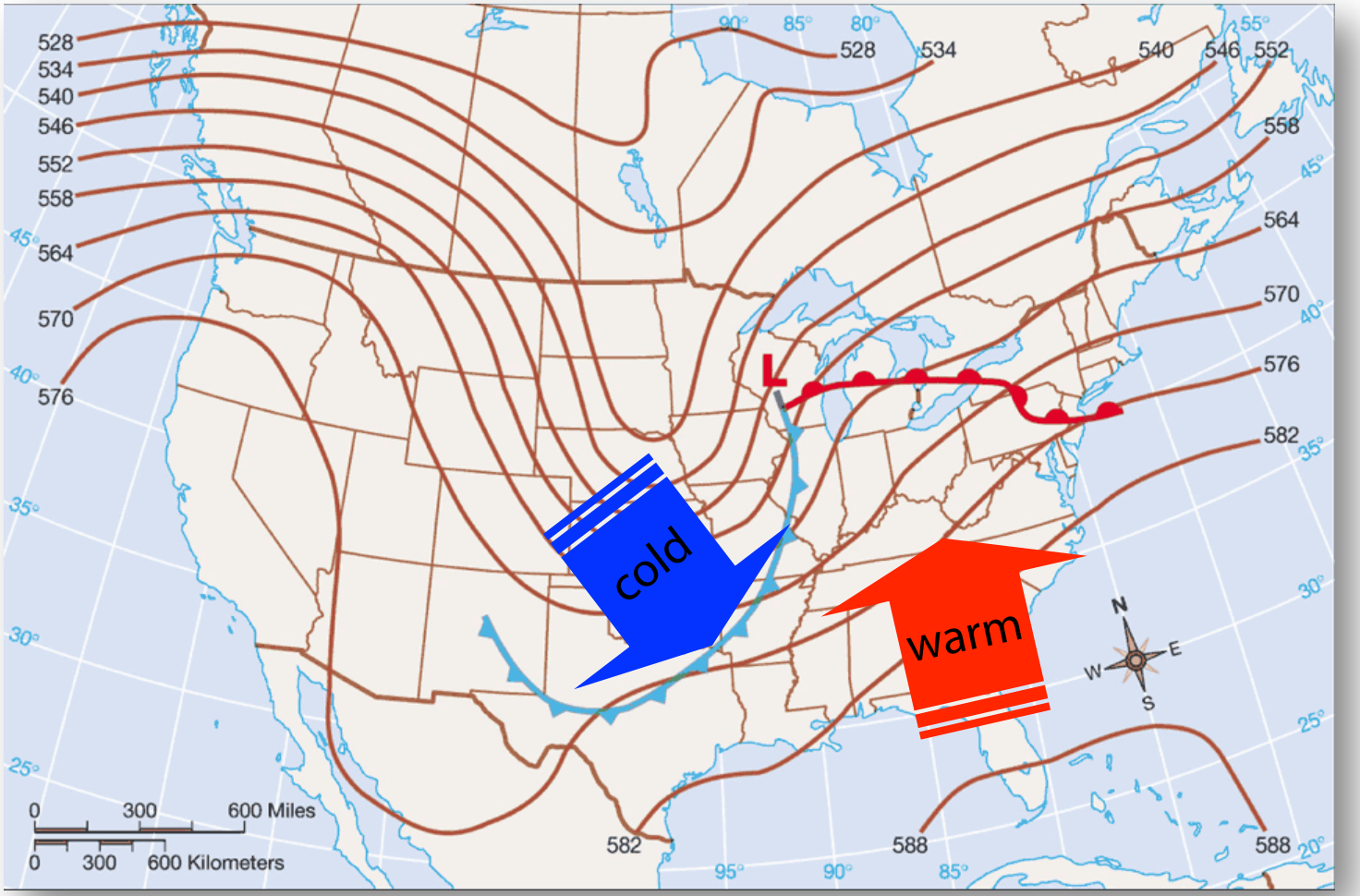
CloudSat Radar



Norwegian Cyclone Model



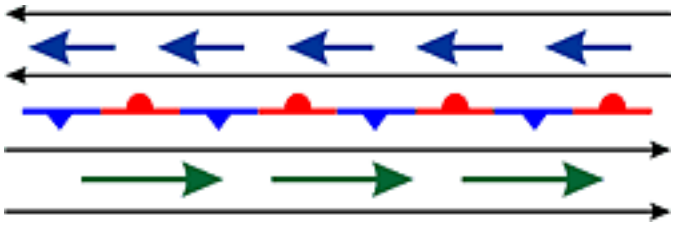
Cold and Warm Advection

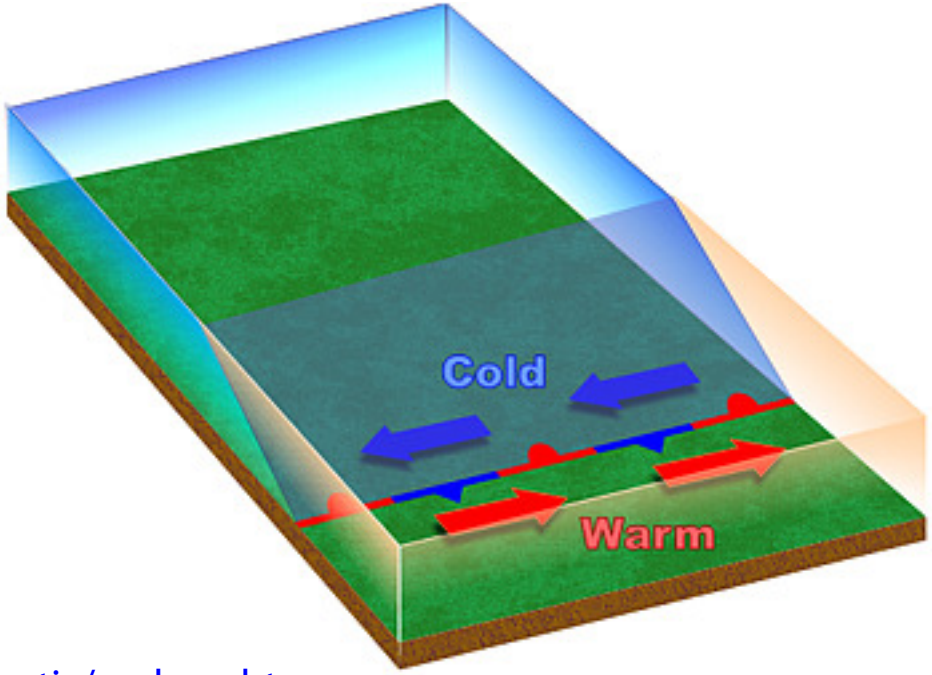


Norwegian Cyclone Model

In this model, there will initially be a boundary, or front, separating warm air to the south from cold air to the north. The front is often stationary.

Overhead view



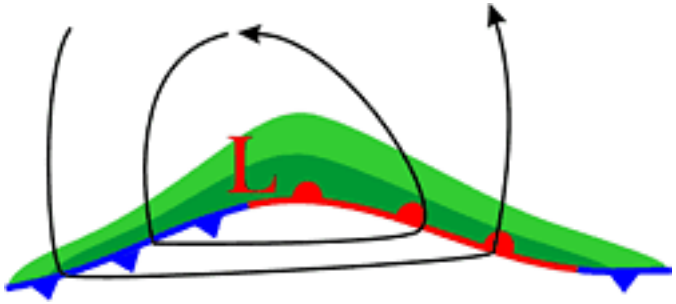


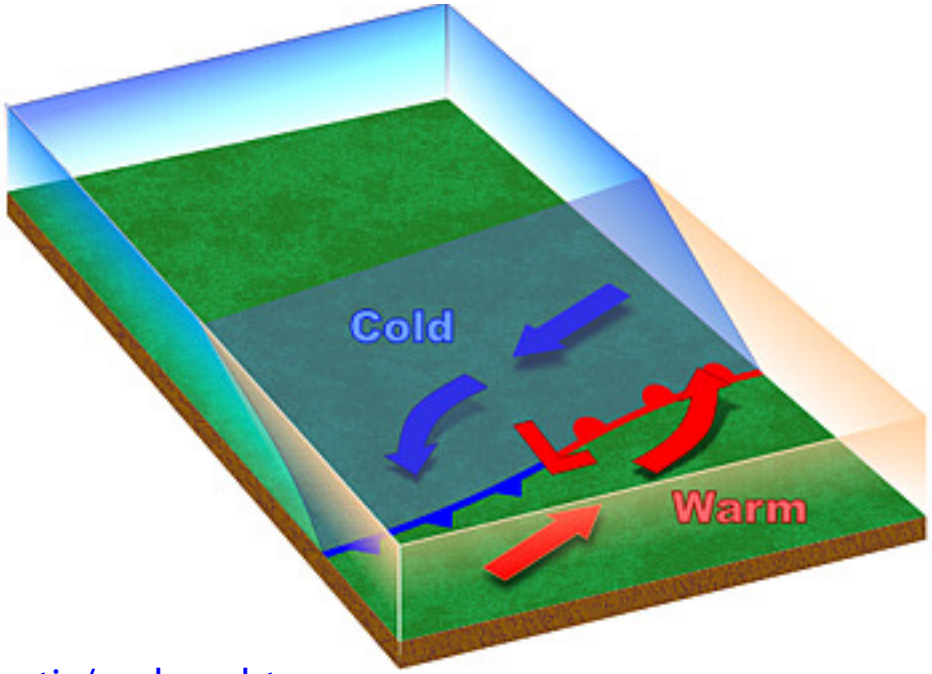
http://www.srh.weather.gov/jetstream/synoptic/cyclone.htm

Norwegian Cyclone Model

A wave on the front will form as an upper level disturbance embedded in the jet stream moves over the front. The front develops a "kink" where the wave is developing. Precipitation will begin to develop with the heaviest occurrence along the front (dark green).

Overhead view





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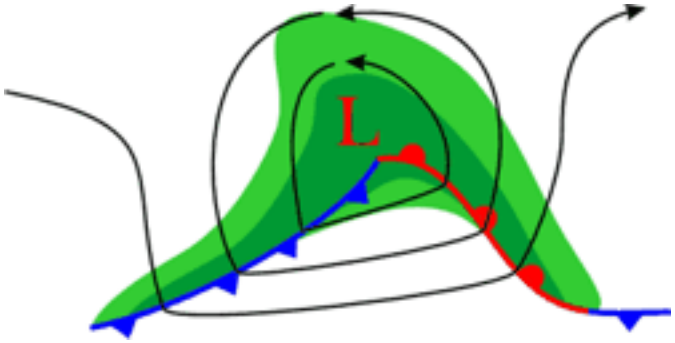
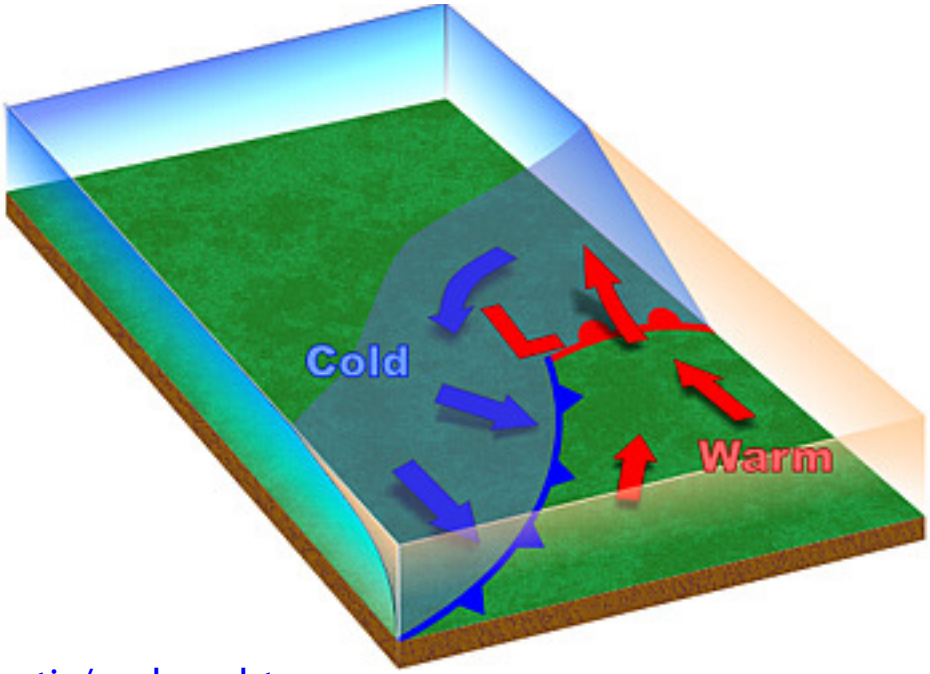
Norwegian Cyclone Model

As the wave intensifies, both cold and warm fronts become better organized.

Overhead view





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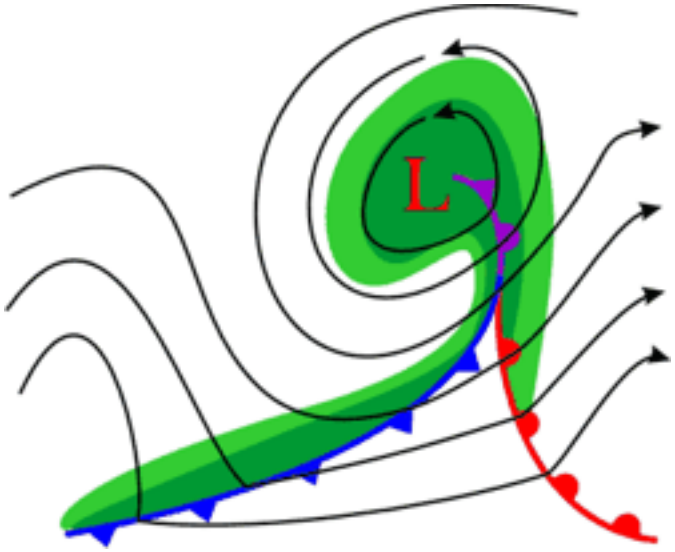
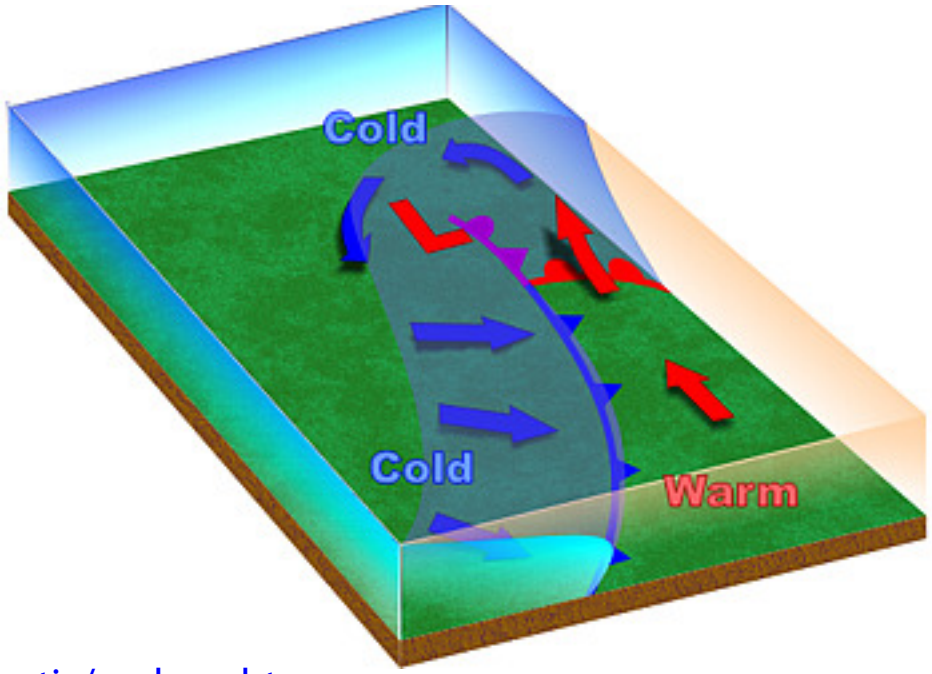
Norwegian Cyclone Model

The wave becomes a mature low pressure system, while the cold front, moving faster than the warm front, "catches up" with the warm front. As the cold front overtakes the warm front, an occluded front forms.

Overhead view





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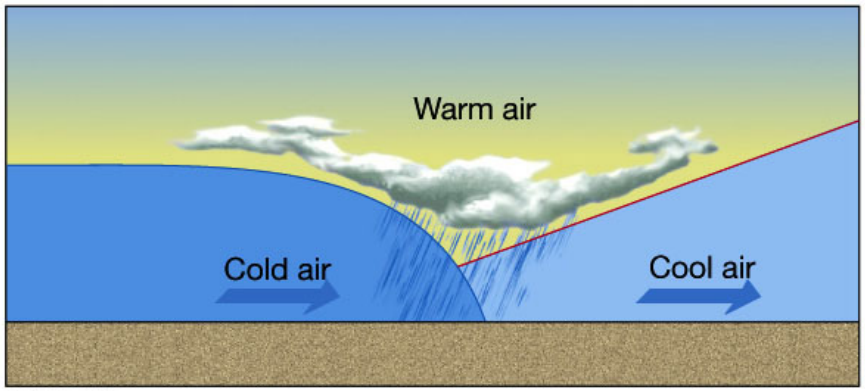
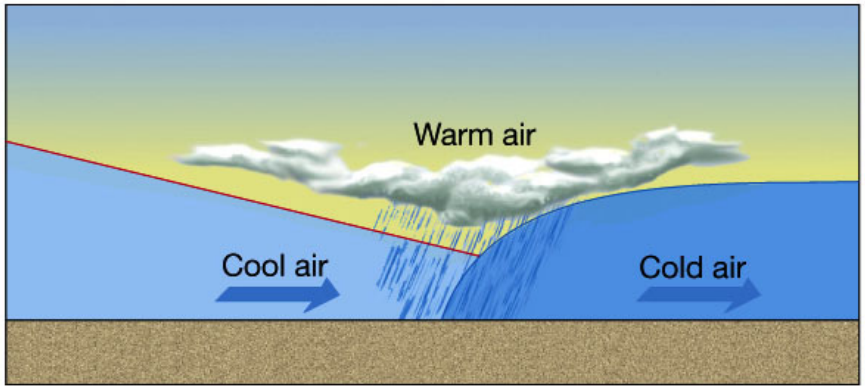
Occluded Front



(a) Cold-type



(b) Warm-type

Definition: A **Cold Occlusion** occurs when the occluding air mass is colder than the cool air ahead of the warm front and so moves under both air masses.

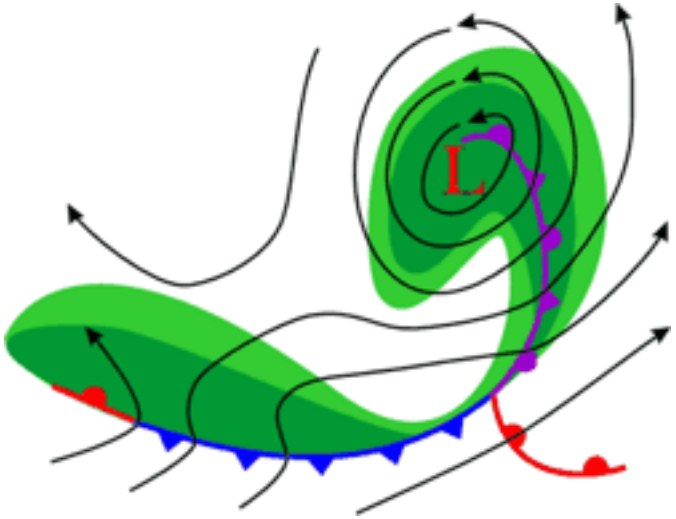
Definition: A **Warm Occlusion** occurs when the occluding air mass is warmer than the cold air ahead of the warm front and so moves between the warm and cold air layers.

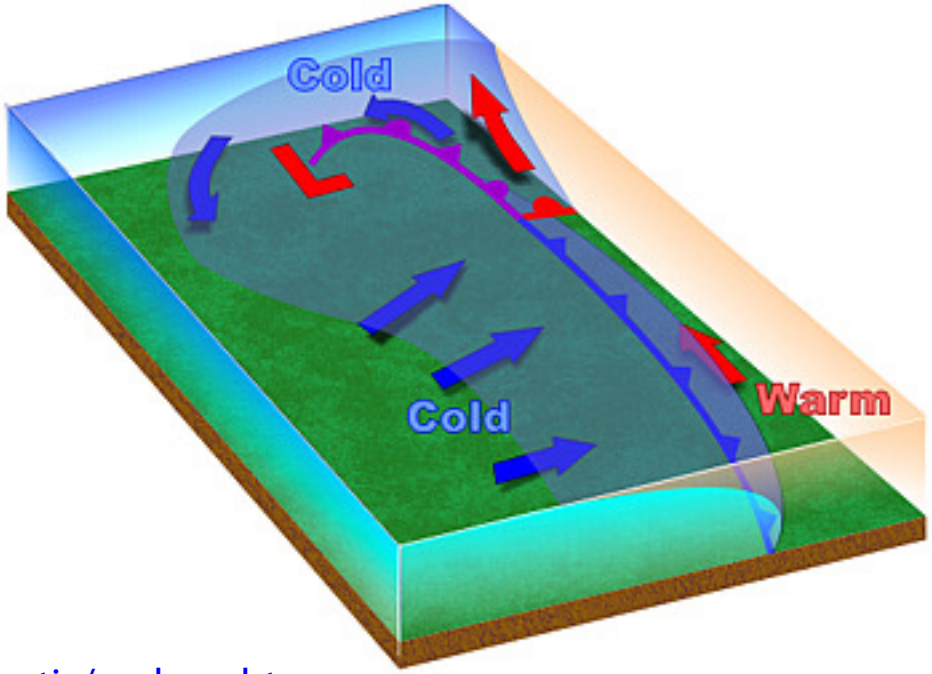
Figure 9.9 in *The Atmosphere, 8th edition*, Lutgens and Tarbuck, 8th edition, 2001.

Norwegian Cyclone Model

As the cold front continues advancing on the warm front, the occlusion increases and eventually cuts off the supply of warm moist air, causing the low pressure system to gradually dissipate.

Overhead view





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