

Atmospheric Conveyor Belts

Fronts Aloft

National Weather Service, Louisville, KY

System-Relative Flow: Conveyor Belts

- System-relative (S-R) wind analysis reveals the existence of sharply-defined boundaries, which separate air streams of vastly differing moisture contents. Air streams tend to contain relatively narrow ranges of potential temperature (θ) and wet-bulb potential temperature (θ_w) peculiar to the air stream's origins.
- S-R isentropic analyses for synoptic-scale weather systems tend to show well-defined air streams, which are identified by names – warm conveyor belt and cold conveyor belt.
- Thus, a conveyor belt consists of an ensemble of air parcels having nearly the same θ_w (or equivalent potential temperature/ θ_e) value, starting from a common initial location, which travel over synoptic-scale time periods (greater than 12 hrs).

On the following slides:

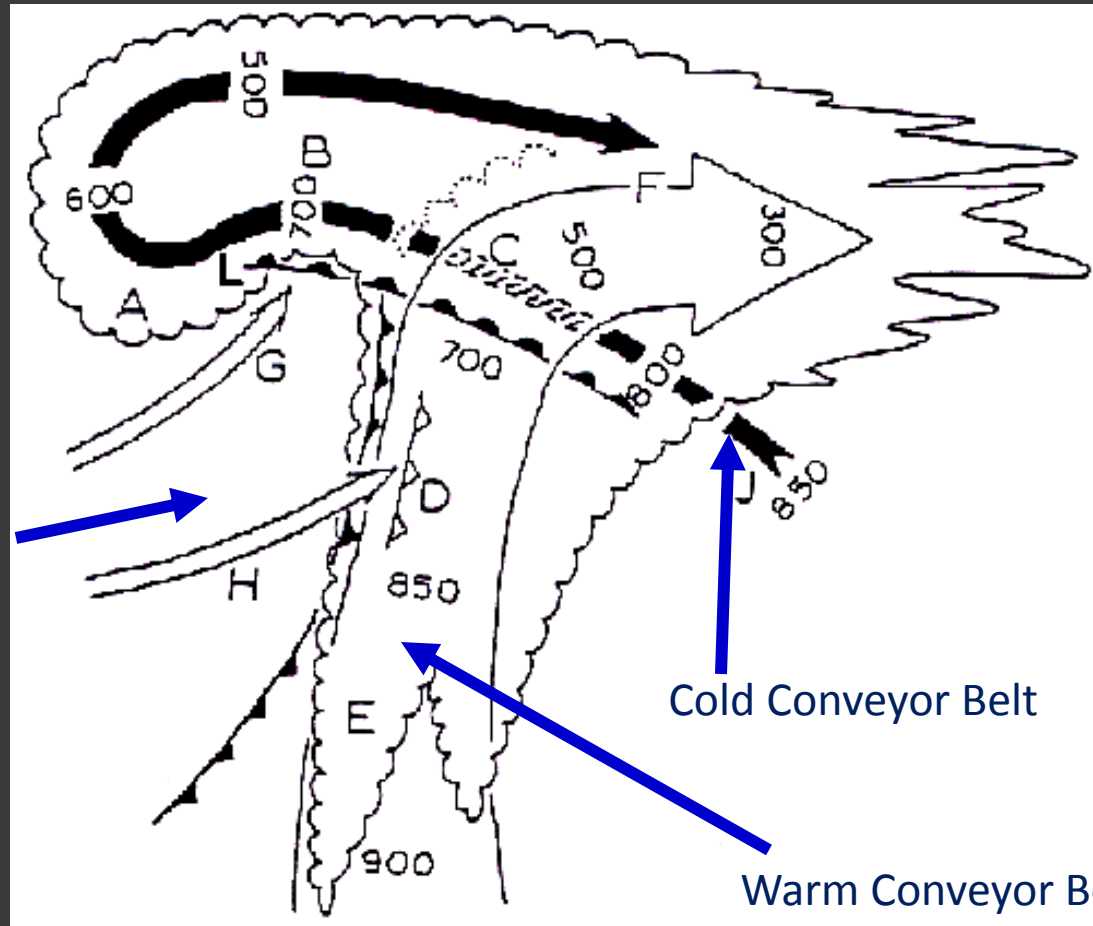
WCB = Warm Conveyor Belt

CCB = Cold Conveyor Belt

DCB = Dry Conveyor Belt

TROWAL = Trough of Warm Air Aloft

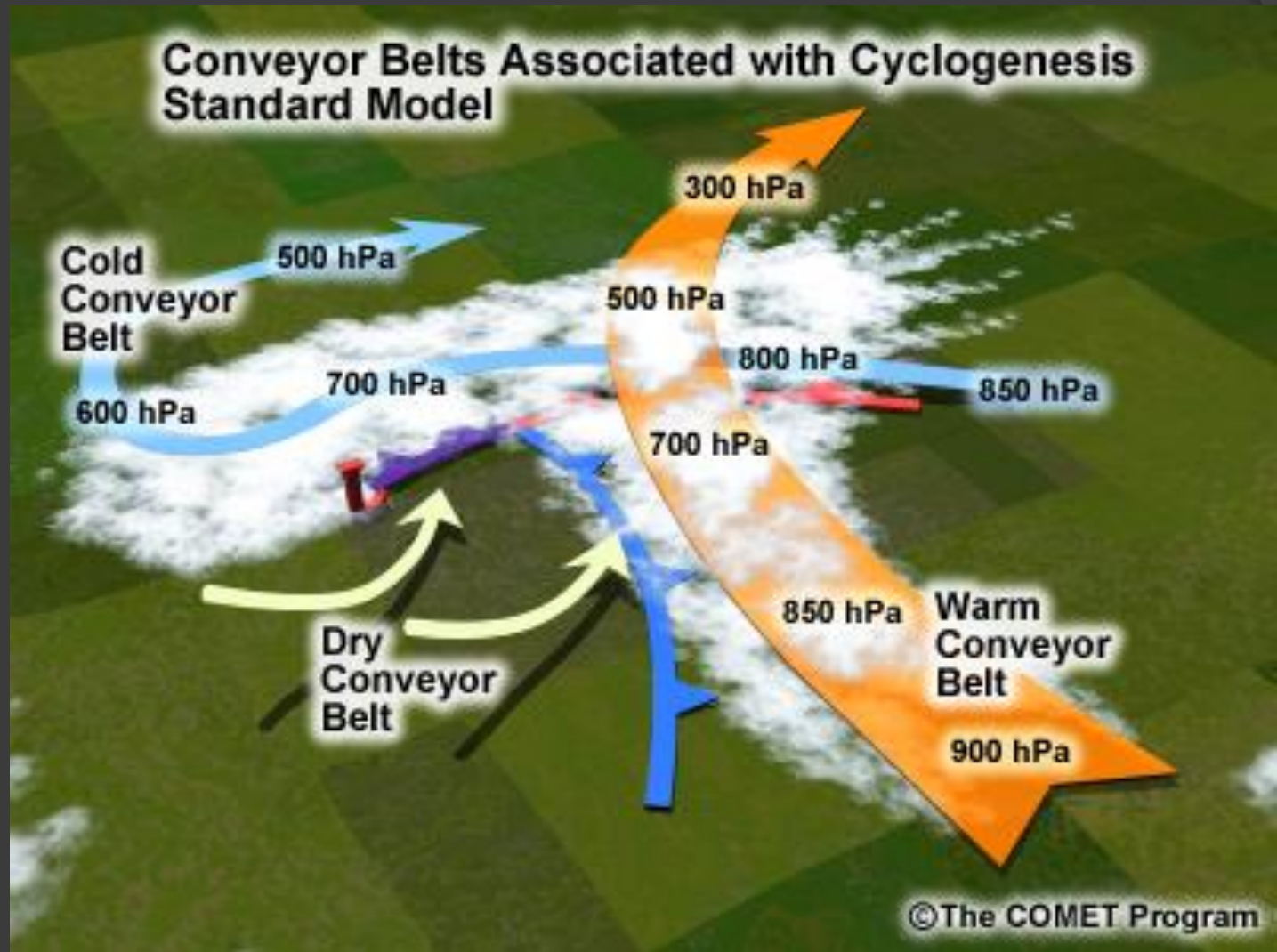
Conveyor Belts Associated with Cyclogenesis: Standard Model



From: Dusan Djuric
(1994) "Weather
Analysis", Chap. 10

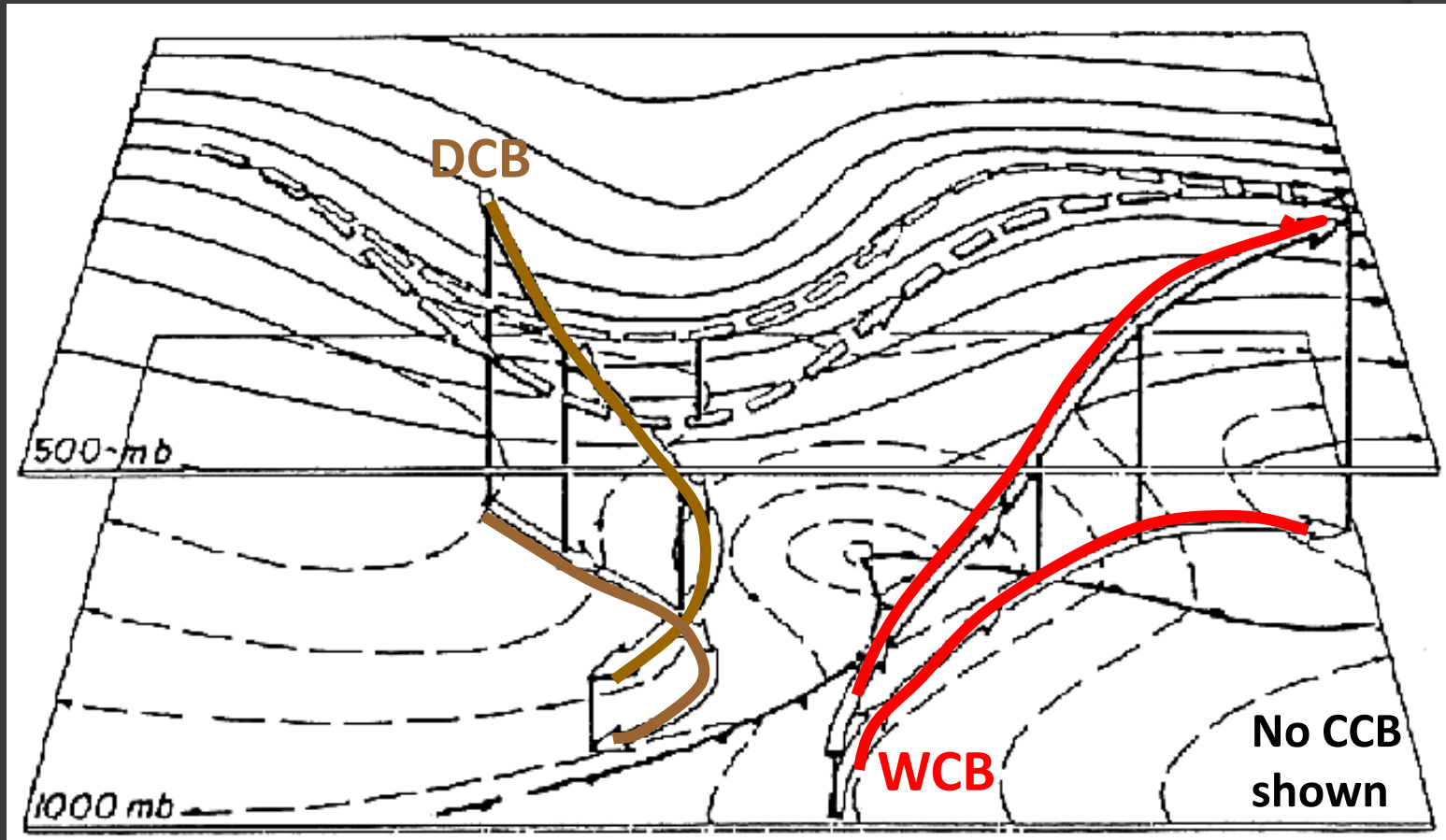
Air within the WCB rises quasi-isentropically as it flows from south to north, starting at low-levels and rising up to jet level as it turns anticyclonically downstream. A portion of the WCB also often turns cyclonically to the west overtop the CCB, forming the TROWAL (trough of warm air aloft) and comma head structure. The CCB also tends to rise as it flows from east to west, or northeast to southwest under the WCB.

Conveyor Belts Associated with Cyclogenesis: Standard Model



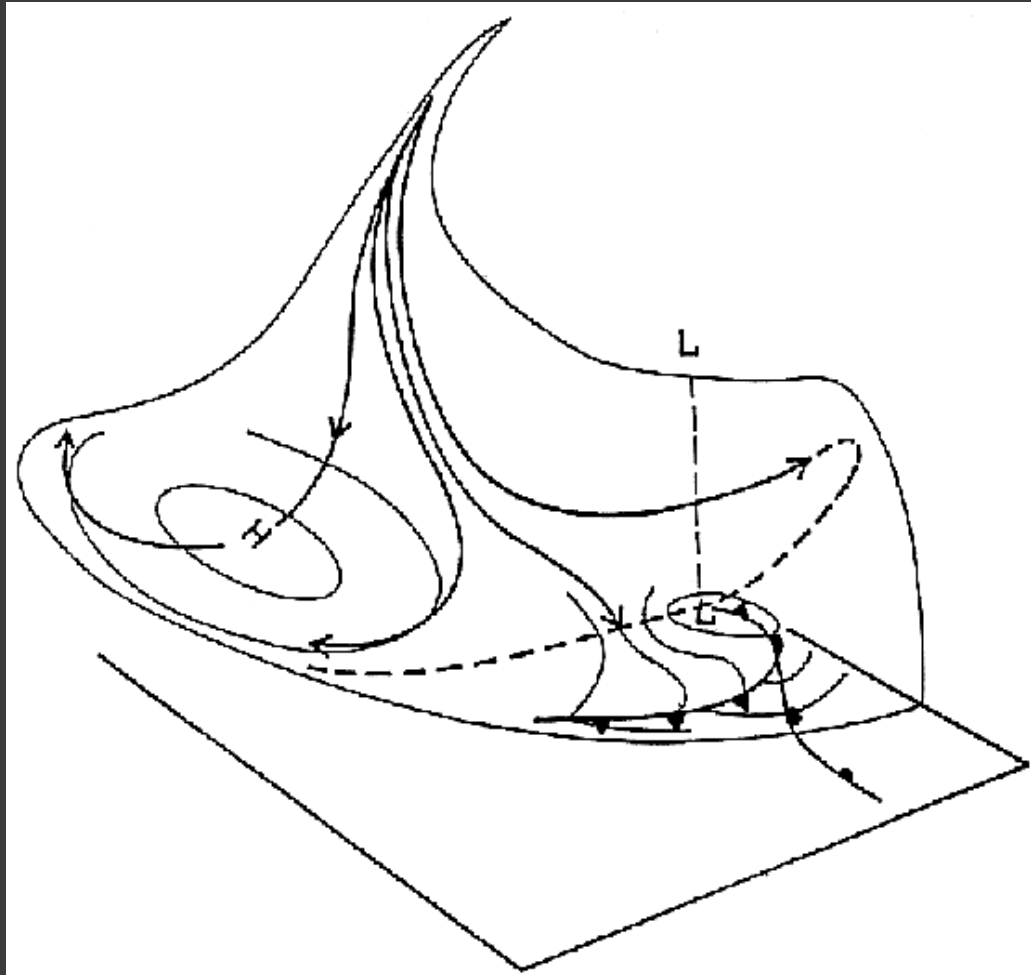
Adapted from Dusan Djuric (1994) "Weather Analysis", Chap. 10

Three-Dimensional View of Conveyor Belts: Standard View



3-D representation of airflow in a developing mid-latitude cyclone
(Palmen and Newton 1969)

Dry Conveyor Belt

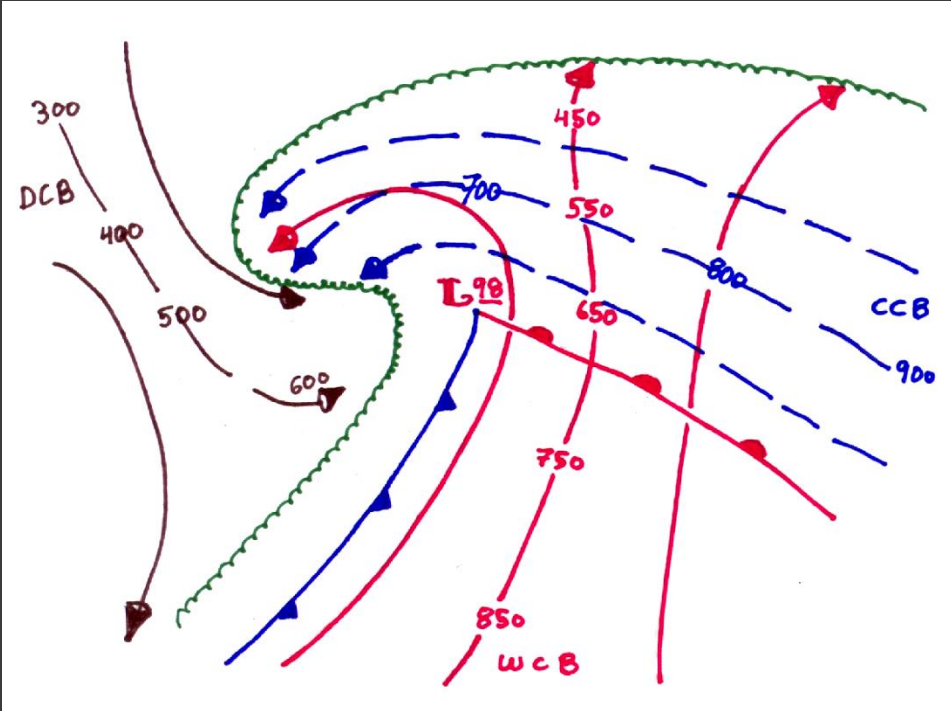


Relative trajectories of extruded stratospheric air during tropopause folding; descending dry conveyor belt (streamlines) is within plane of isentropic surfaces (from Danielsen 1964). Note the sinking air behind low system.

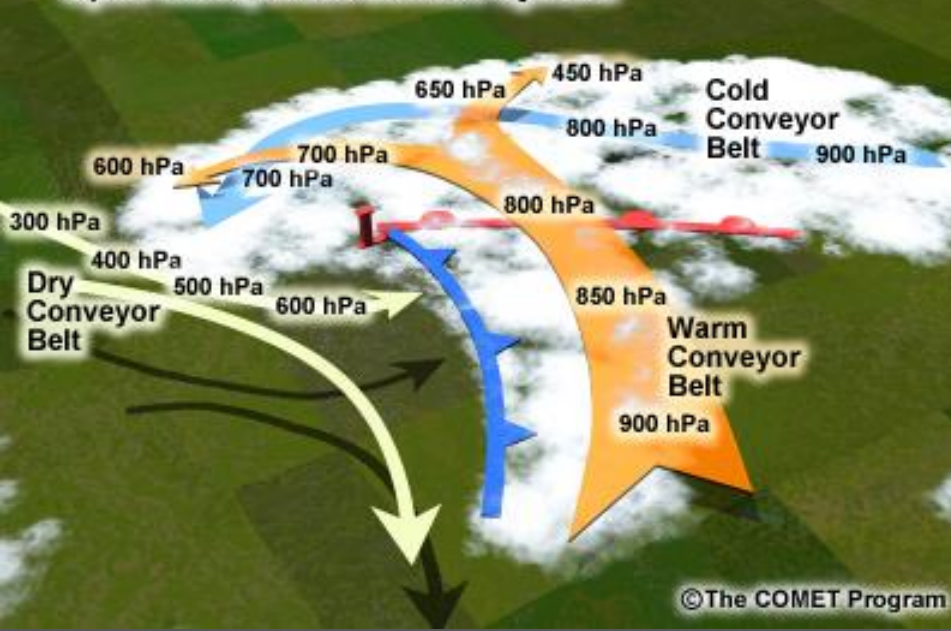
Some Thoughts on the Conveyor Belts Associated with Cyclogenesis

- Schultz (2001, MWR) challenged the notion of an anticyclonically-ascending cold conveyor belt (CCB) popularized by Carlson (1980, MWR)
- He found that, at least in one case, the anticyclonic path of the CCB represented a **transition** between the warm conveyor belt and cold conveyor belt. The transition zone begins in the lower troposphere where the circulation around the cyclone is closed and widens with height to the point where the cyclone becomes an open wave aloft. Above this point, the anticyclonic path becomes the dominant air stream.
- From this viewpoint, comma heads that are relatively shallow are likely the result of a **cyclonically turning CCB**, but comma heads with deeper clouds and heavier precipitation rates (perhaps associated with CSI) are the result of “wraparound” (west or northwest moving) moisture from the **cyclonic path of the warm conveyor belt (WCB)** – this is essentially how the TROWAL (trough of warm air aloft) develops.

Conveyor Belts Associated with a Mid-Tropospheric Open-Wave, Weak Surface System

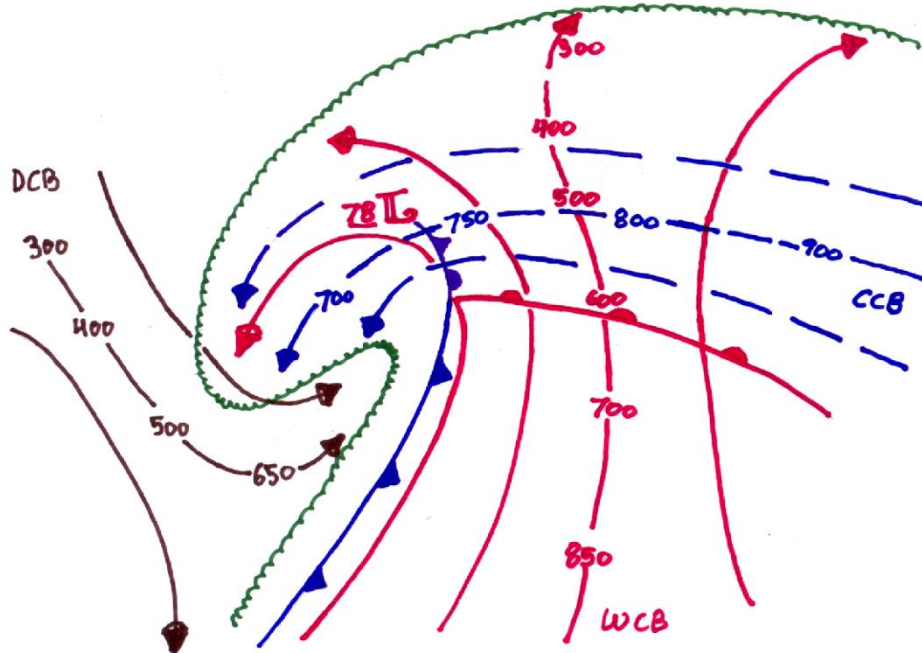


Conveyor Belts Associated with an Mid-Tropospheric, Open-Wave, Weak Surface System

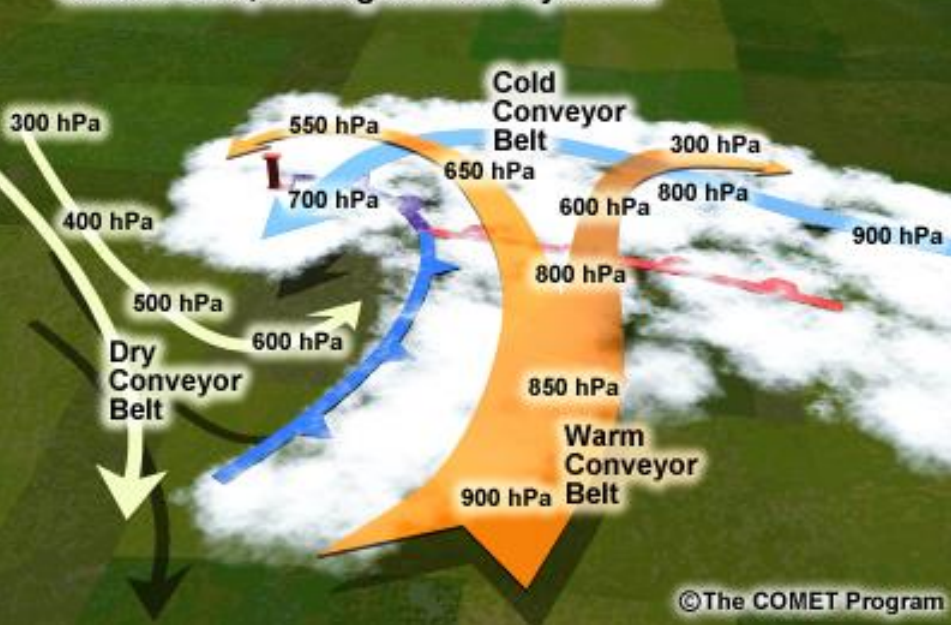


- Progressive shortwave trough
- Short time scale (< 12 hrs) for precipitation
- Modest westward extension of comma head, often disconnected from main precipitation shield
- Weak east-to-west flow in CCB, compensated for by eastward motion of system (*thus storm motion increases system-relative flow (speed) of low-level CCB*)
- Often a non-occluded system (low) with inverted trough north or northwest of low

Conveyor Belts Associated with a Mid-Tropospheric Closed Low, Strong Surface System



Conveyor Belts Associated with an Mid-Tropospheric, Closed Low, Strong Surface Systems



- Slow-moving upper-level system
- Long-lasting event (> 12 h)
- Extensive comma head
- Cyclonic extension of WCB flows north and west into comma head, resulting in TROWAL
- Strong east-to-west flow in CCB, north of warm front
- Surface system is typically occluded
- North and northwest of cyclone, WCB overrides and is nearly parallel to CCB

Conveyor Belts Associated with an Mid-Tropospheric, Closed Low, Strong Surface Systems

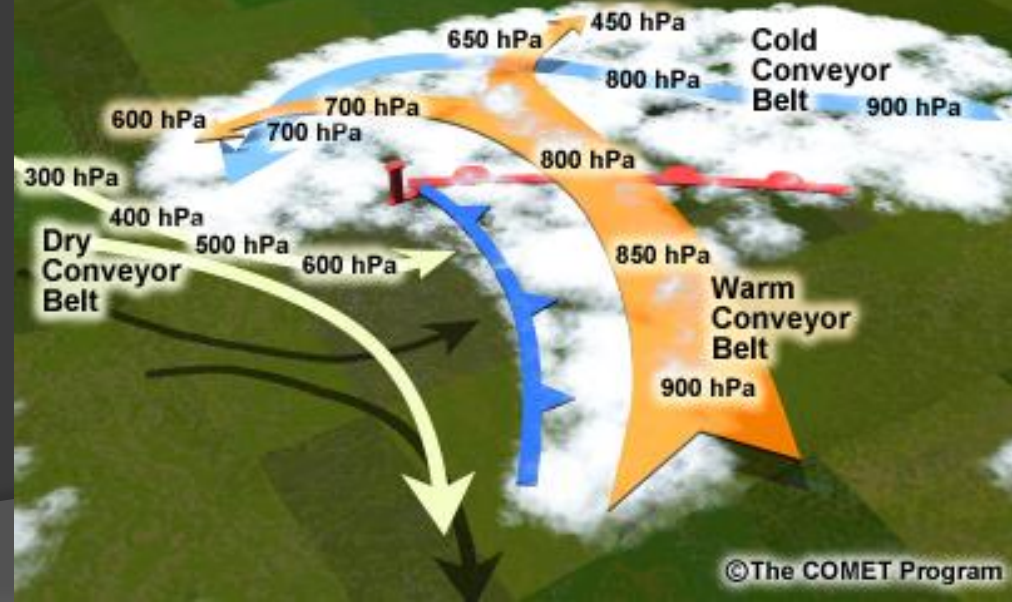


- Slow-moving upper system (*above*)
- Long-lasting snow event
- Extensive comma head
- Strong E/NE flow in CCB, north of warm front
- WCB precip along/ahead of cold front

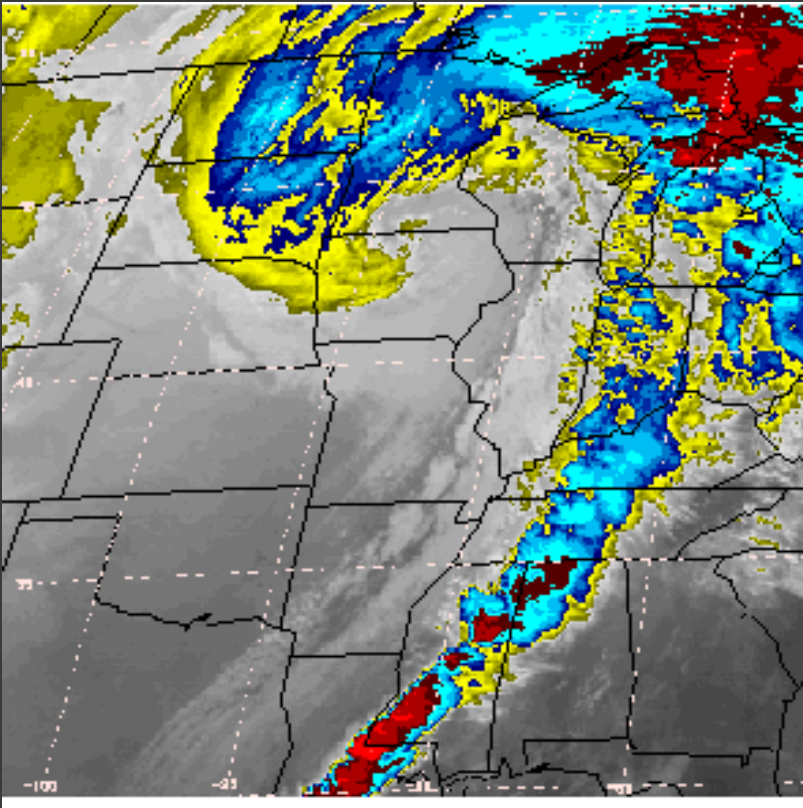
Conveyor Belts

- Progressive system/shortwave (*below*)
- Short time scale for precip
- Westward extension of comma often disconnected from main precip shield
- Weak E/NE flow in CCB, enhanced by eastward motion of system
- WCB precip often ahead of surface front (cold front/frontogenesis aloft)

Conveyor Belts Associated with an Mid-Tropospheric, Open-Wave, Weak Surface System

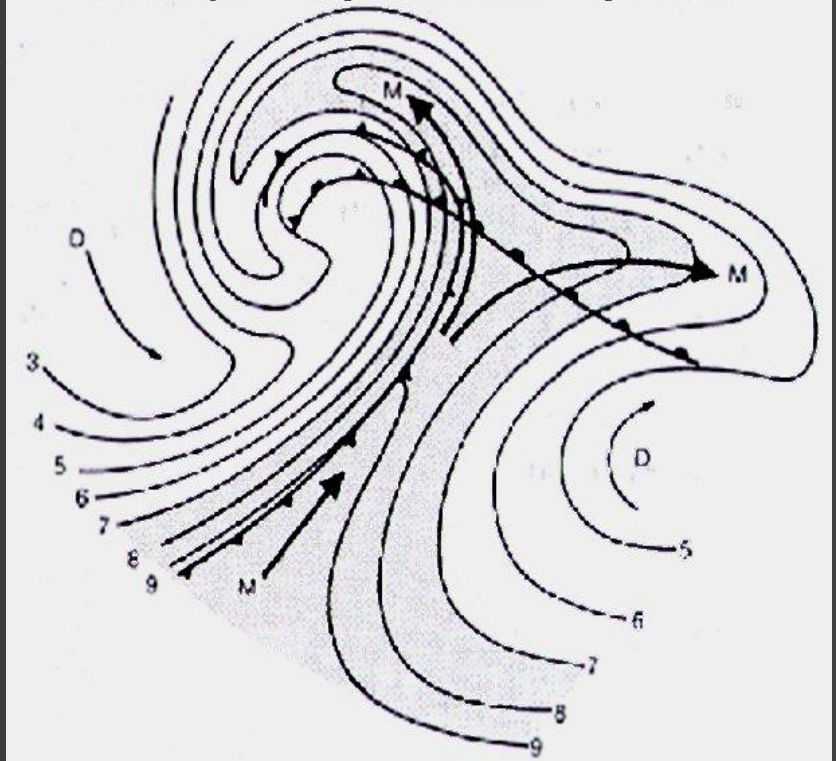


Conveyor Belts



- WCB coincident with convection
- Cold front aloft (back edge of convection) ahead of surface front (back edge of low/mid clouds from nrn IL to srn MO to NE TX)
- Surface cold front less active, still showers
- WCB wraps NW overtop CCB in Northern Plains; comma head along/north of TROWAL

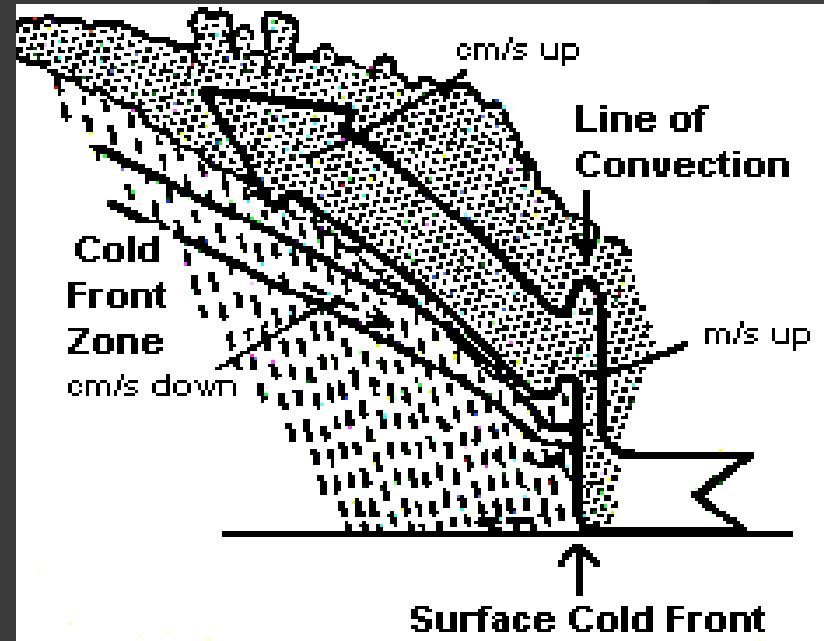
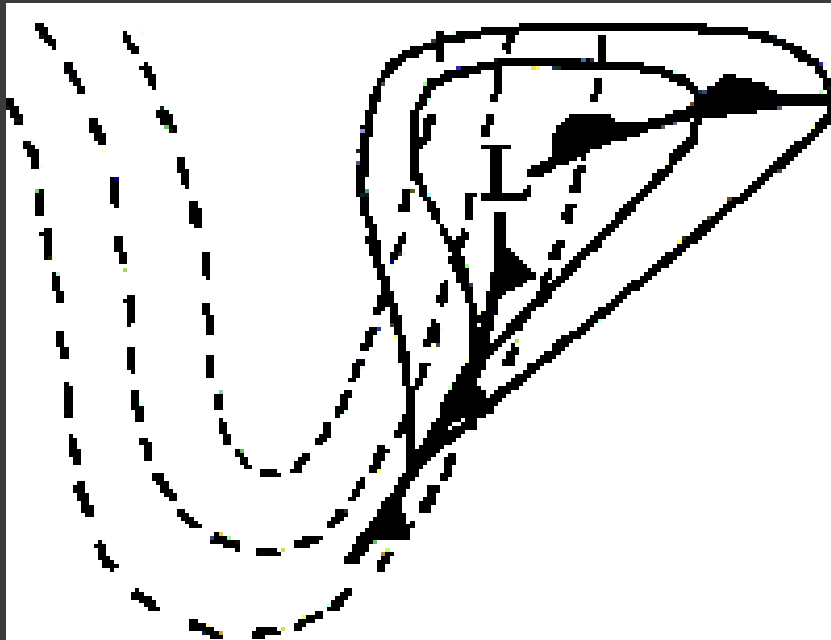
Isentropic Analysis of Moist/Dry Airflow



- Deep moisture associated with WCB
- CCB from east initially dry; saturates as precip falls into it from WCB moisture
- WCB/CCB combine in the comma head/deformation zone
- DCB sinks and dries south and west of surface low

Ana-Cold Front, Kata-Cold Front, Cold Front Aloft

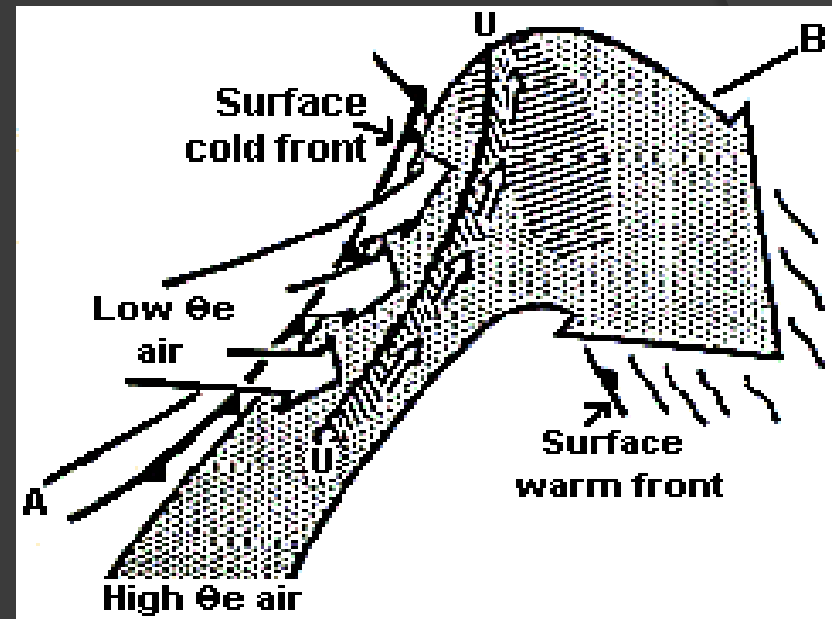
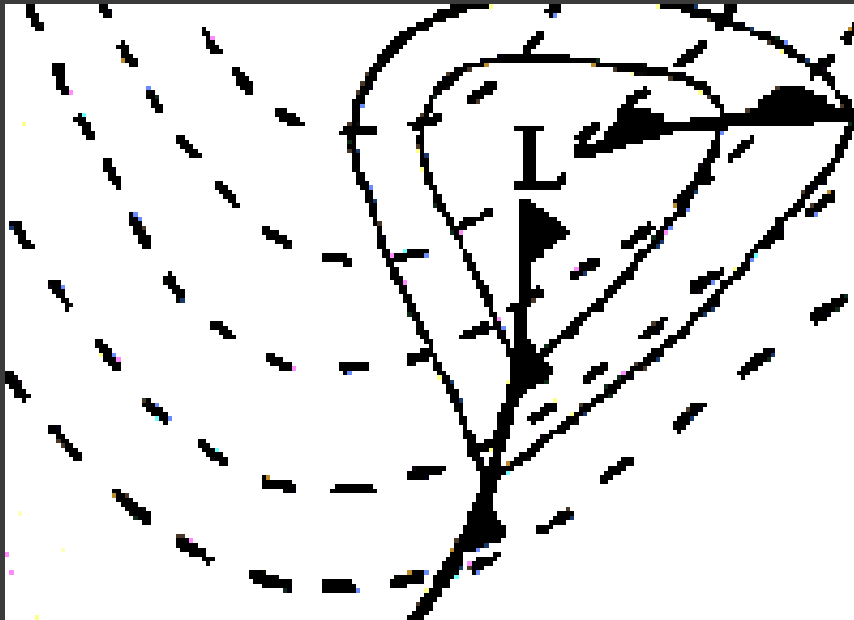
Ana-Cold Front



- Front: sharp temperature gradient and wind shift, and significant vertical motion
- Deep/sharp trough aloft; flow aloft roughly parallel to surface front
- *System-relative* airflow exhibits sloping rearward ascent of warm, moist air which can result in line of showers or storms along front and extensive post-frontal precip (e.g., leading line-trailing stratiform quasi-linear convective system/QLCS)
- Watch for precip type change (rain to sleet to snow) on backside of precip shield if cold enough

Ana-Cold Front, Kata-Cold Front, Cold Front Aloft

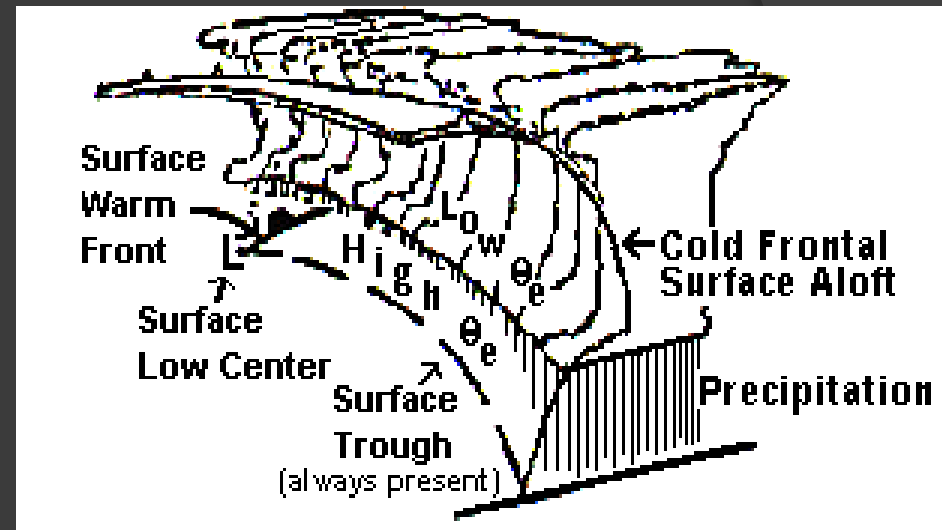
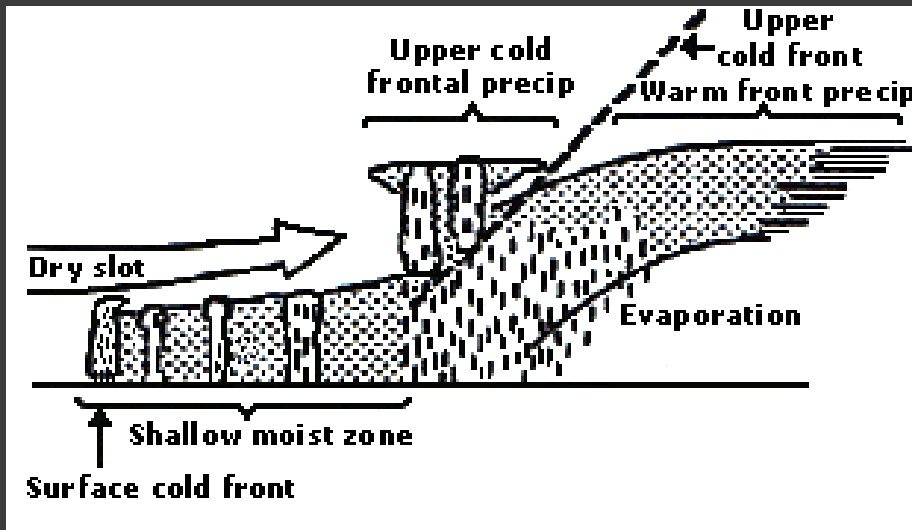
Kata-Cold Front



- Front: usually less defined than ana-front, with weak-to-moderate temperature gradient
- Less amplified pattern aloft (more westerly momentum)
- Scattered showery precip along surface front
- *System-relative* forward sloping ascent and band or area of more significant precipitation ahead of surface front (may be associated with cold front aloft)

Ana-Cold Front, Kata-Cold Front, Cold Front Aloft

Cold Front Aloft



- Associated with the leading edge of CAA aloft and frontogenesis/convergence between warm, moist air ahead of CFA (WCB) and cooler, drier air behind it (DCB)
- Often significant lift/precipitation along/ahead of CFA within warm sector (e.g., pre-frontal QLCS)
- Surface front/trough less active behind CFA, especially in cool season due to limited instability
- Monitor satellite images, leading edge of 700/500 mb CAA, and subtle shortwaves/RH in models
- Precipitation can move out faster than models and forecasts suggest due to CFAs