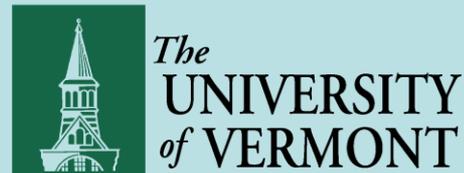
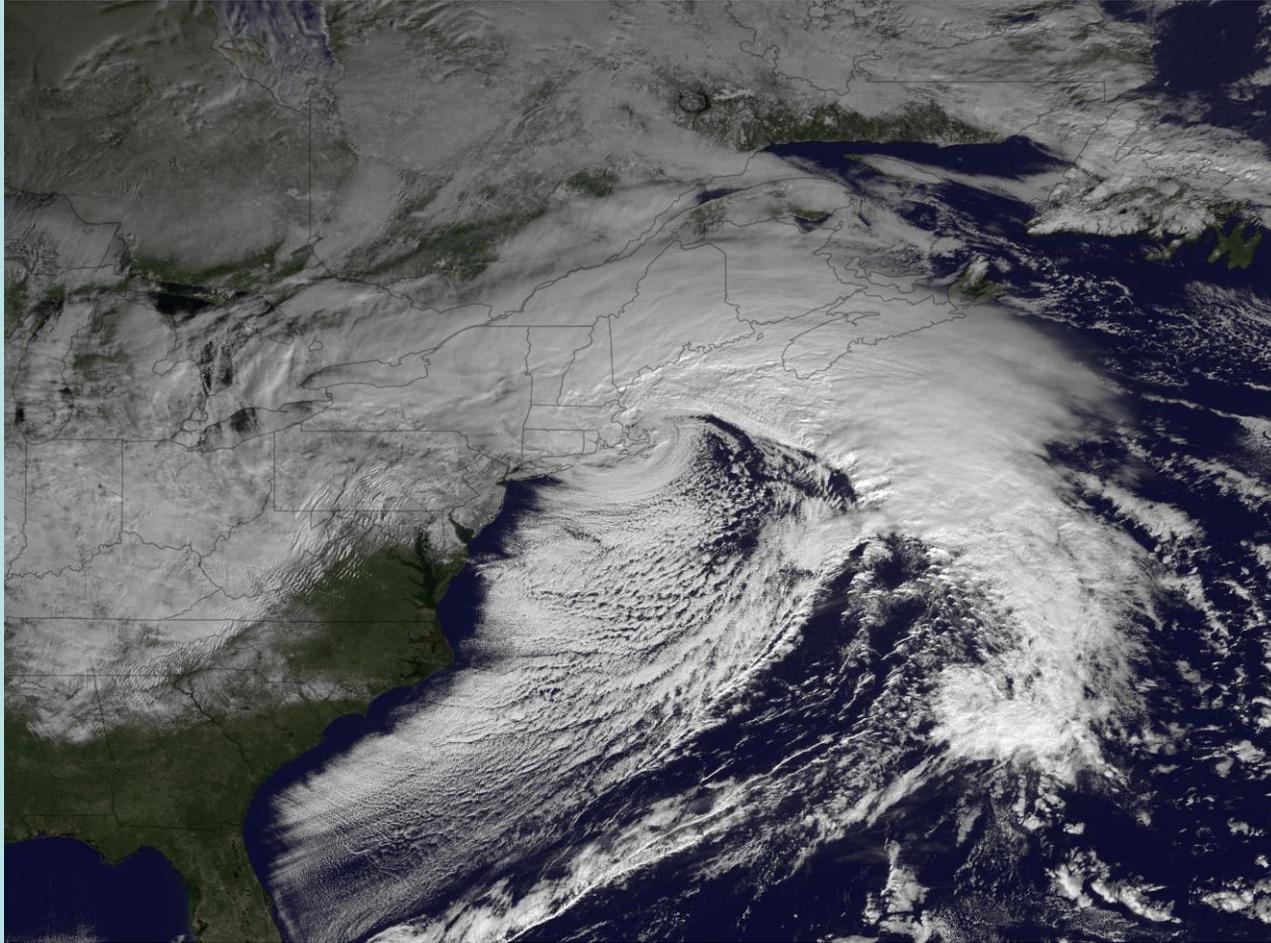


Satellites, Weather and Climate Module 9: *Air/sea interactions – winter cyclogenesis*



Winter storms – things to consider

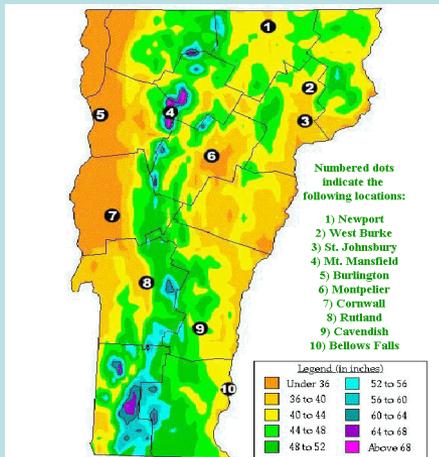
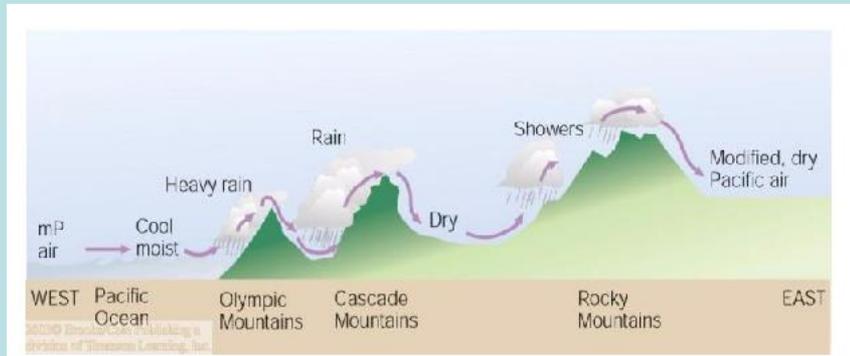
- Deep moisture
- Thermal discontinuity
- Favorable surface and upper level features
- Geographical features
- Climatology of event



Winter storm structure

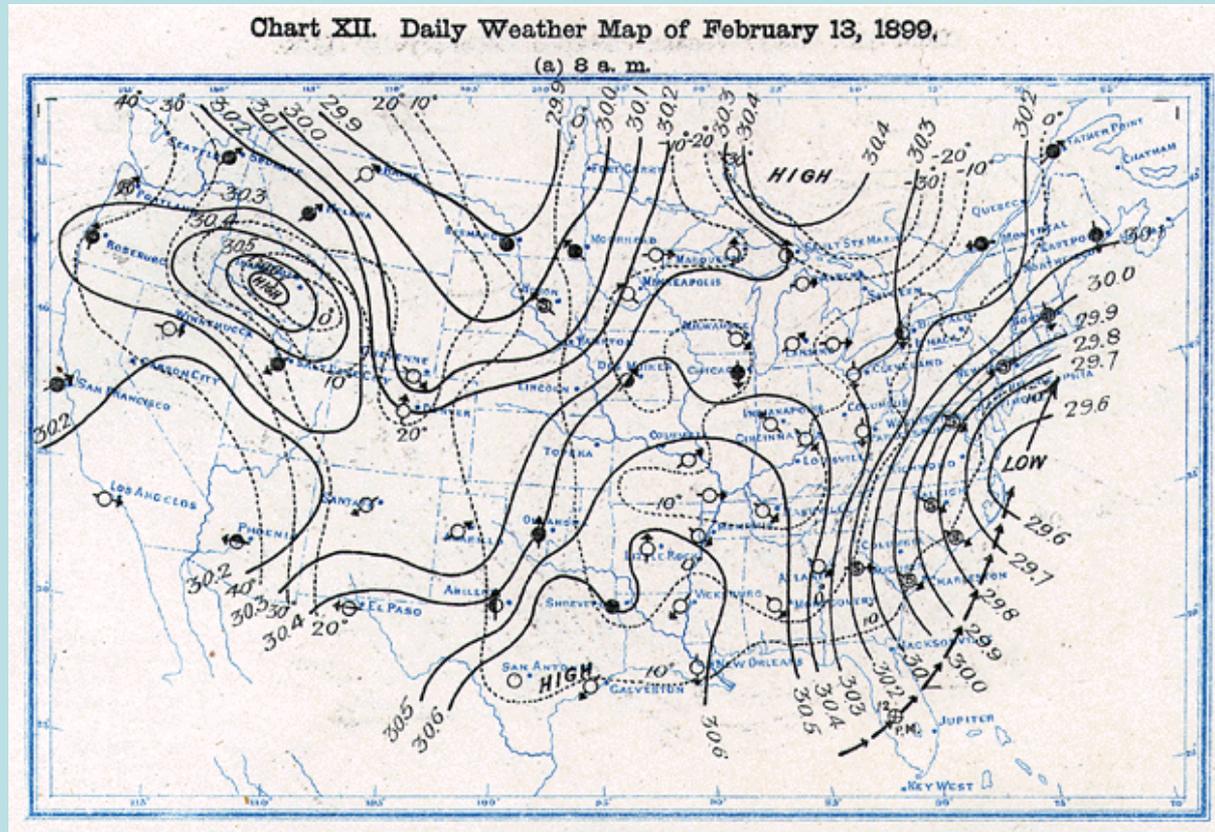
- Warm frontal processes leads to widespread steady precipitation
- Cold front explains convective type precipitation
- Conveyor belt theory combines and expands upon these

Role of local and regional geographical features



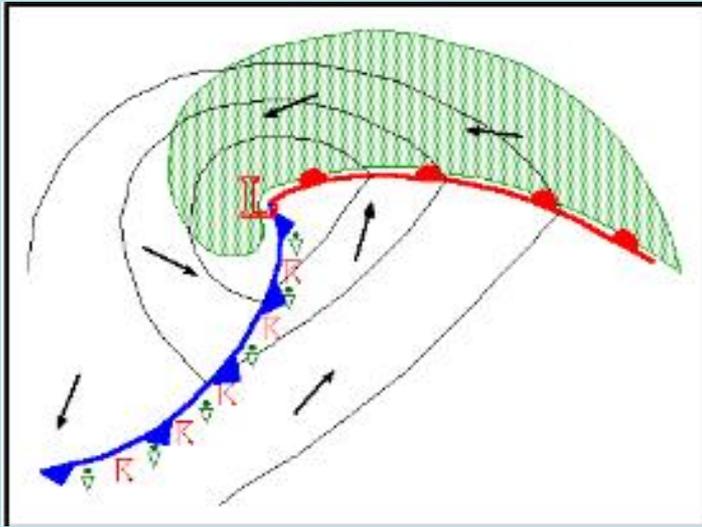
- Upslope areas receive more precipitation with drying in downslope areas.
- Green Mtns as opposed to Champlain Valley
- Sheffield Heights as opposed to Connecticut Valley

Surface map – Blizzard of 1899



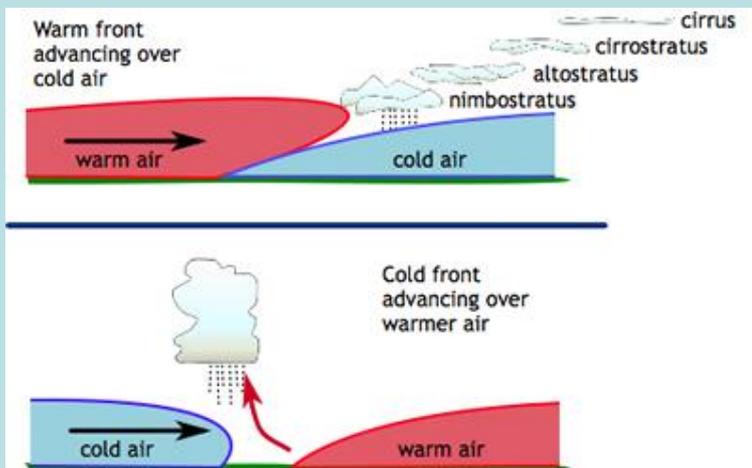
Prior to the 1920's we did not analyze for fronts. This concept was developed by Bjerknes in 1919 and evolved through the 1920's.

Norwegian cyclone model – 1920's (Bjerknes)



- o Based on concept of air masses
- o Norwegian cyclone or Polar frontal theory provided large scale conceptual model of extratropical Cyclones
- o introduced role of frontal processes

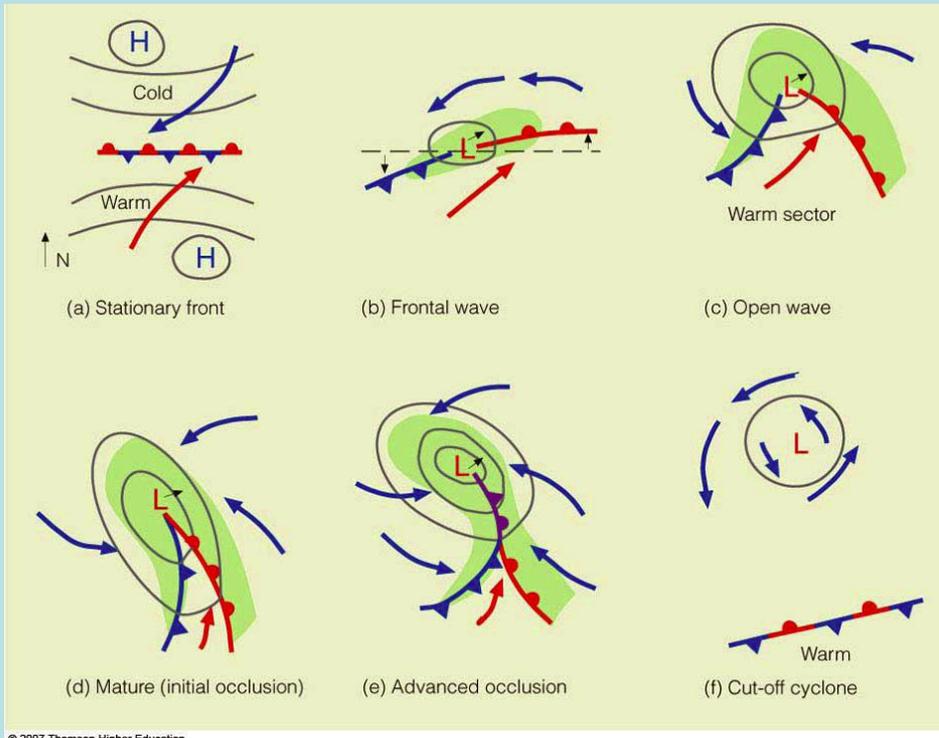
Stood the test of time, although over the years we have added details.



Sources of lift

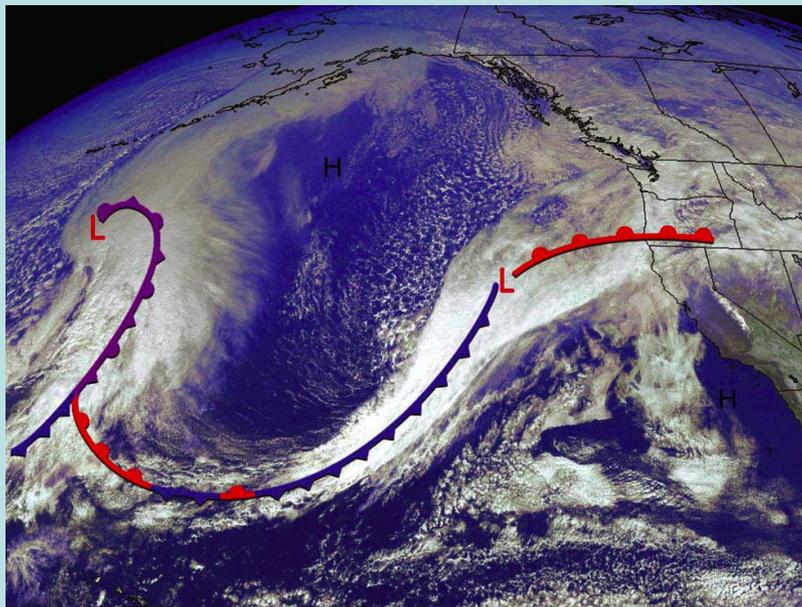
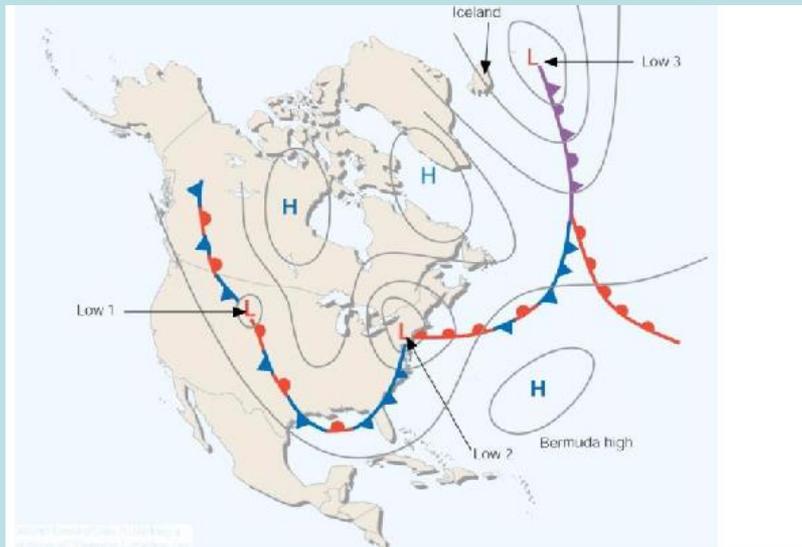
- Convergence
- Frontal
- Convection

Norwegian model ~ 1920



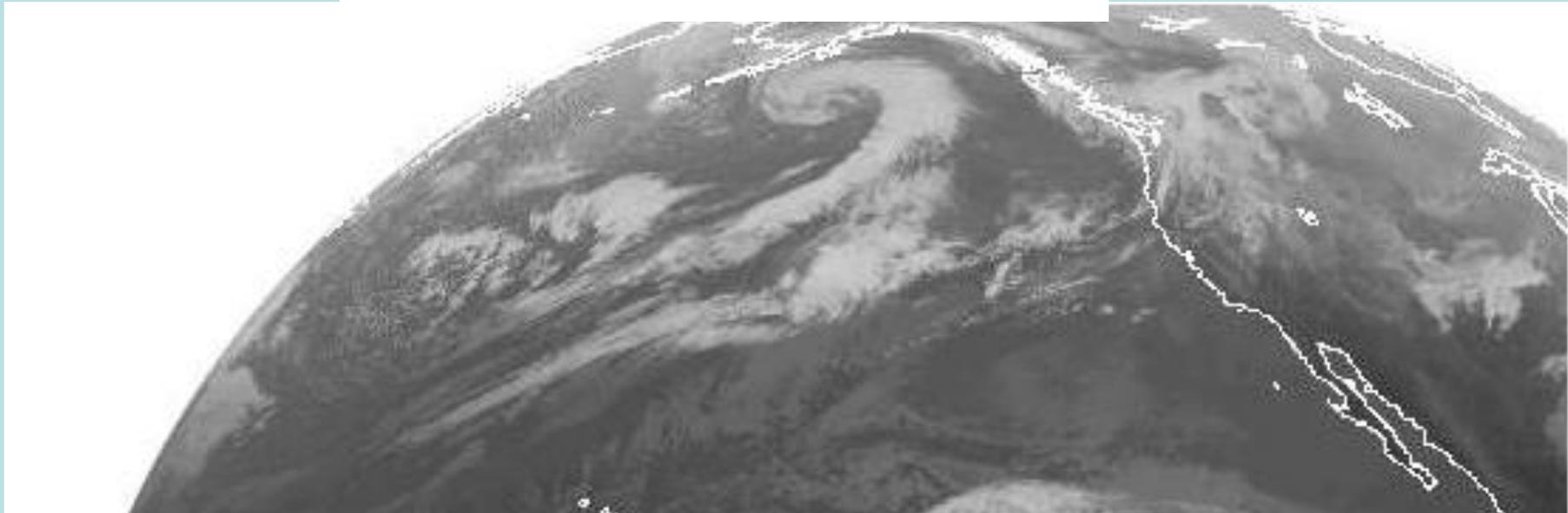
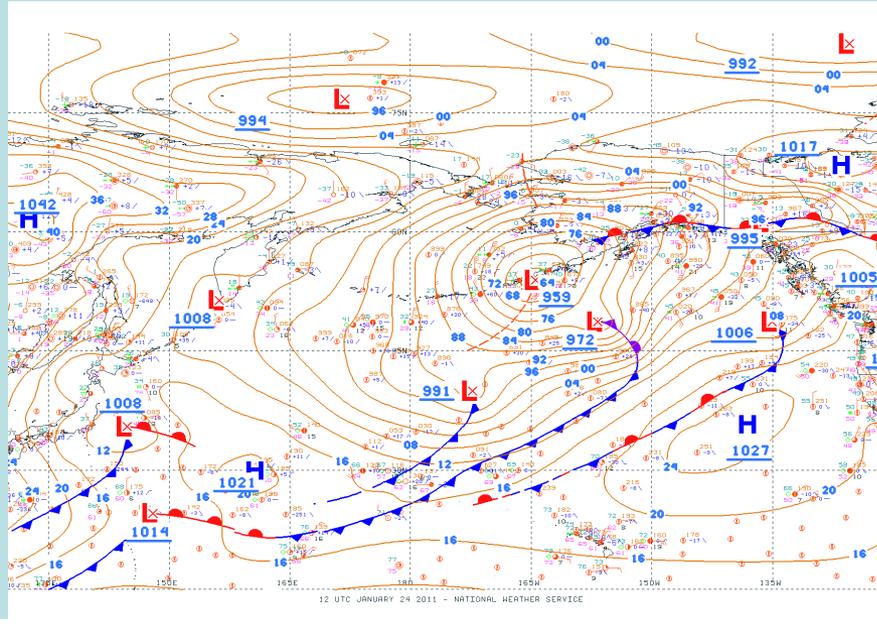
- a... Boundary between two air masses – a front
- b... Spin of earth along with wind shear results in cyclonic flow
- c & d... System moves in direction of warm sector winds as wave develops
- Cold front eventually cuts off or over-runs warm front forcing warm air aloft - Occlusion

Norwegian cyclone family – Conceptual model

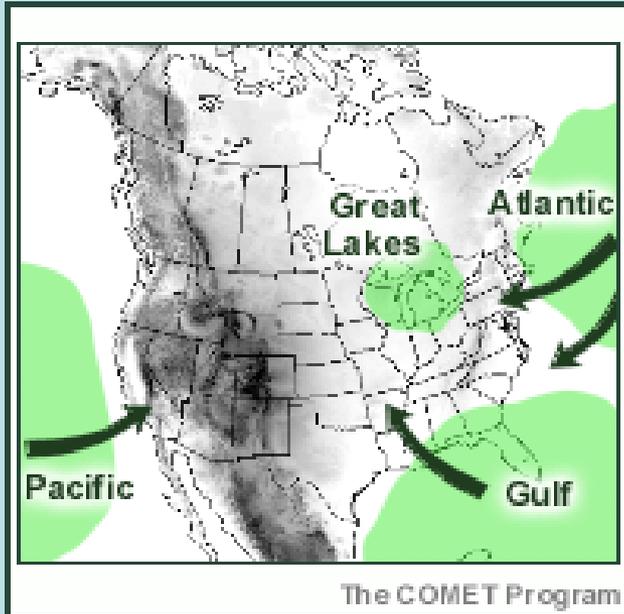
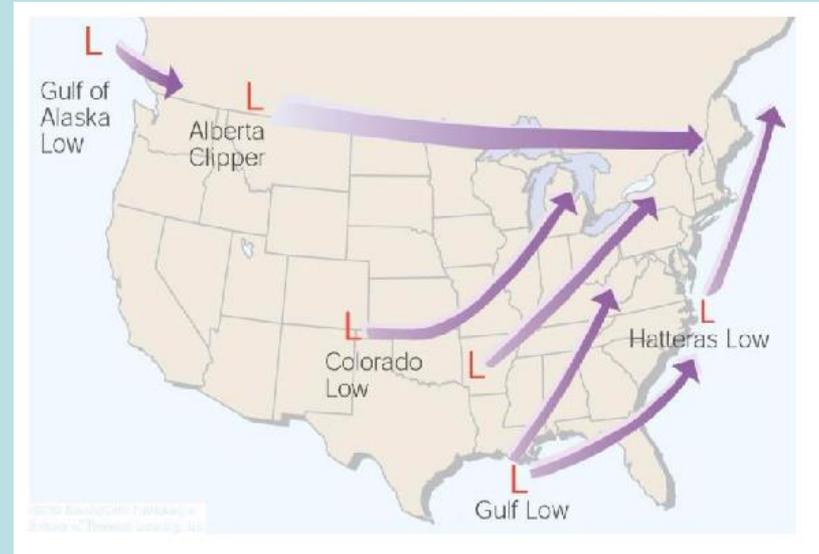
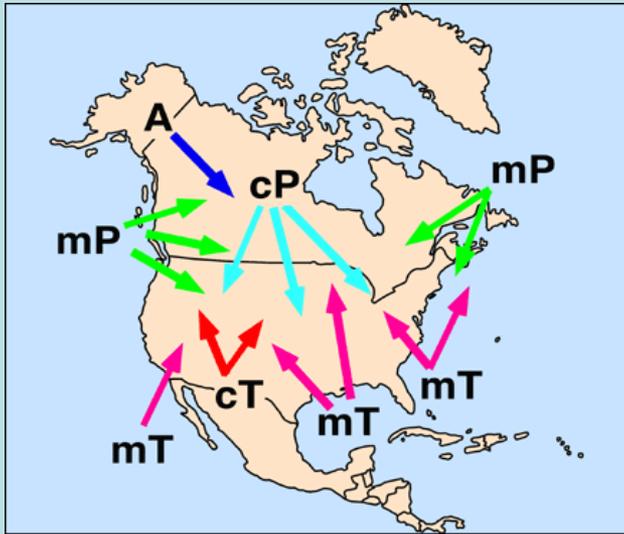


- Not a continuous global band
- **???Cyclone families prevalent over ocean areas...less so over land. WHY ???**
- There are breaks or weak areas in the cloud bands
- **Cyclones represent warm moist air moving poleward** while anticyclones represent cold air moving south – striving for thermal balance

Jan 24 2011 12z



Air mass and moisture sources and favored storm tracks



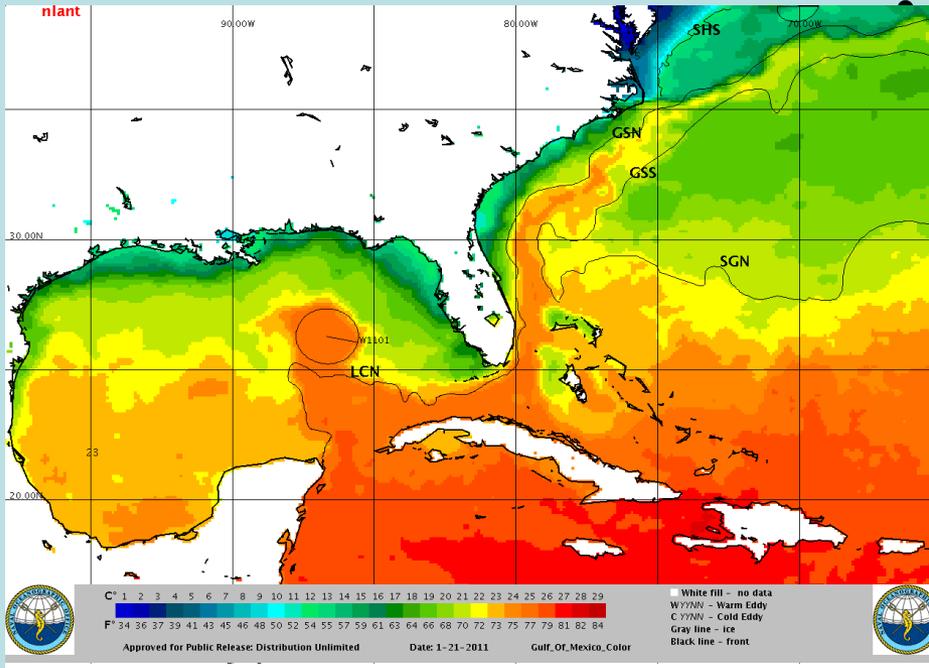
Class question...

Explain the reasons for Gulf of Mexico and Cape Hatteras area for storm development or cyclogenesis

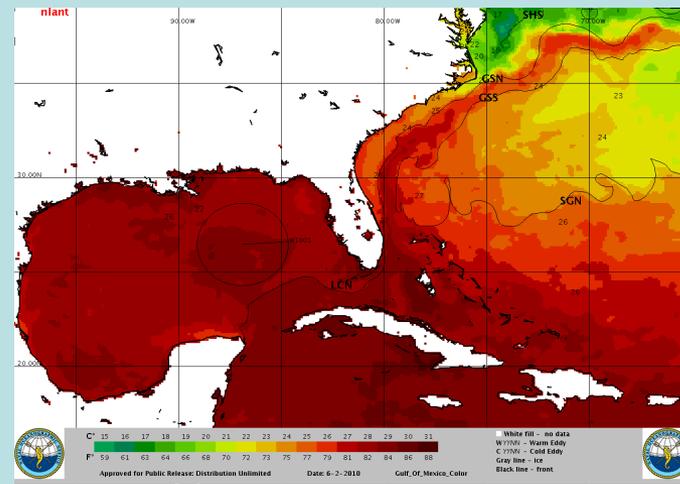
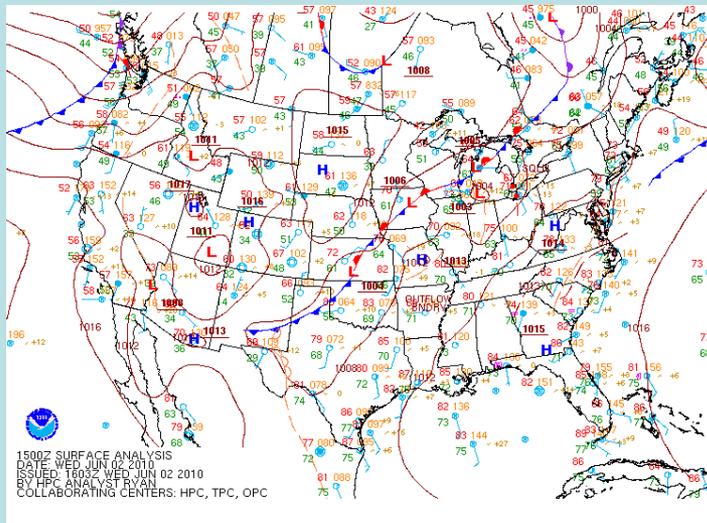
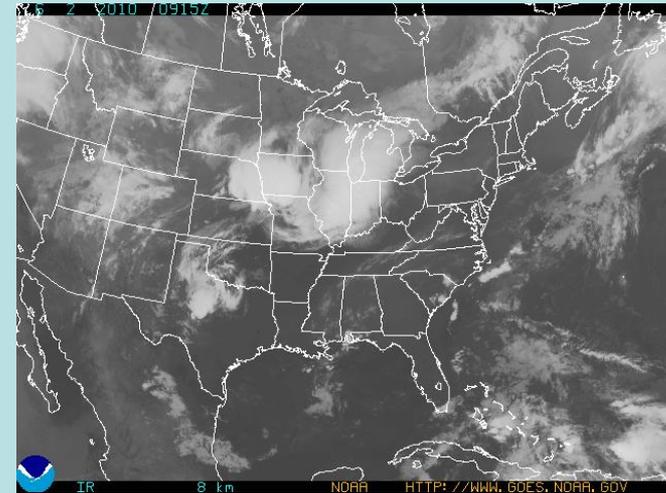
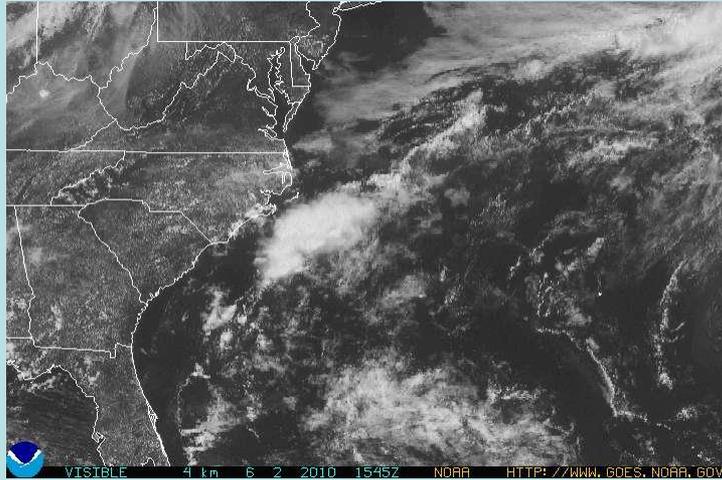
Gulf Stream and Hatteras storms

Gulf Stream provides low warmth and moisture (instability) for winter storm development

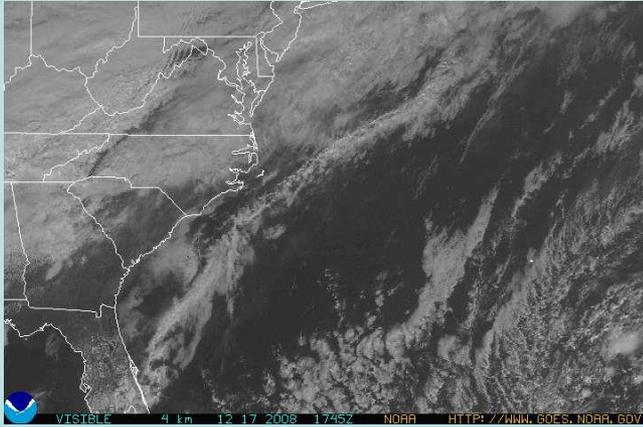
Doubt the thermodynamic effect...it's a favored area for nocturnal thunderstorms



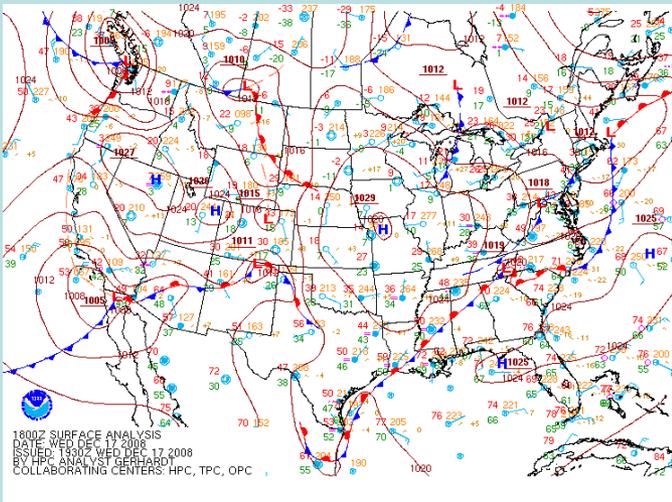
Thunderstorms in predawn hours over the Gulf Stream with no surface weather features



Dec 17 2008 18z



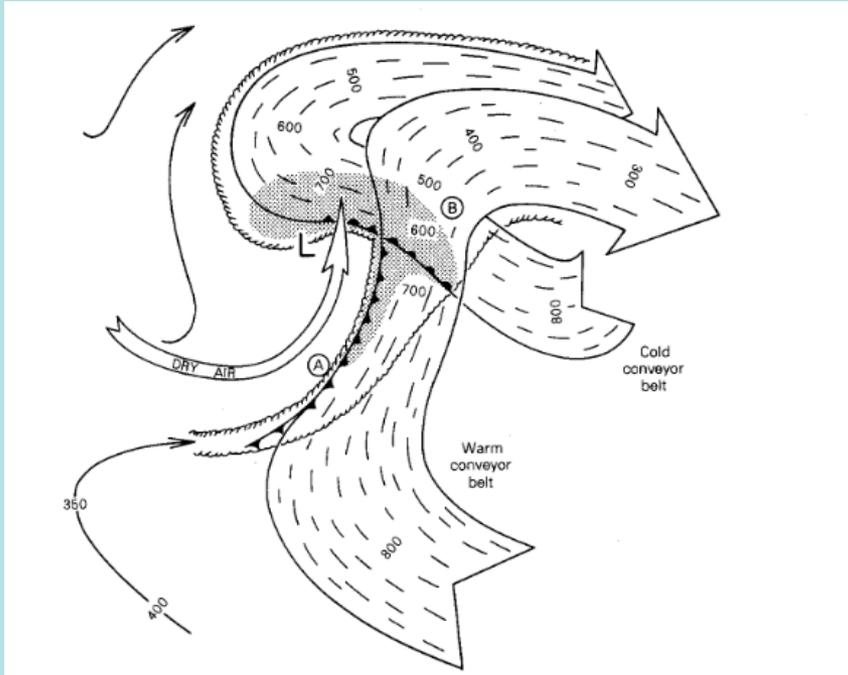
- Example of low level instability of Gulf Stream before cyclogenesis



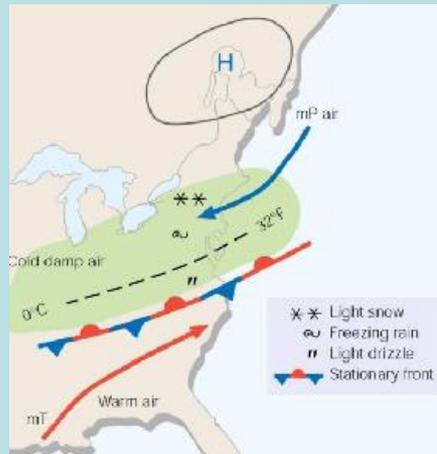
- True frontal boundary lags to the west

Conveyor Belts

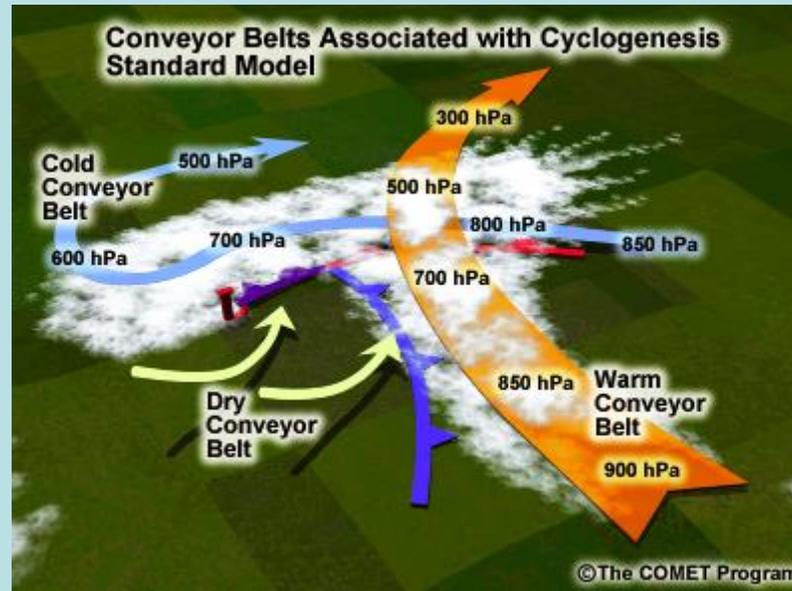
Adding to the Norwegian model...



- Conveyor belts represent trajectories relative to the moving storm...not air masses.
- Warm Conveyor Belt (WCB) moves warm moist air south to north
- Greatest ascent over the warm front before curving anticyclonically with upper level winds
- Cold Conveyor Belt originates in low levels along/north of warm front and moves westward before curving anticyclonically
- WCB major supply of moisture while CCB extends precipitation area westward forming comma head



Combined Norwegian and Conveyor Belt models



Warm Conveyor Belt (WCB)

- Originates well south of storm near surface in warm air mass and flows north
- Rises over warm front and surface cold air before joining upper level westerly flow
- WCB responsible for much of storm's precipitation

Cold Conveyor Belt (CCB)

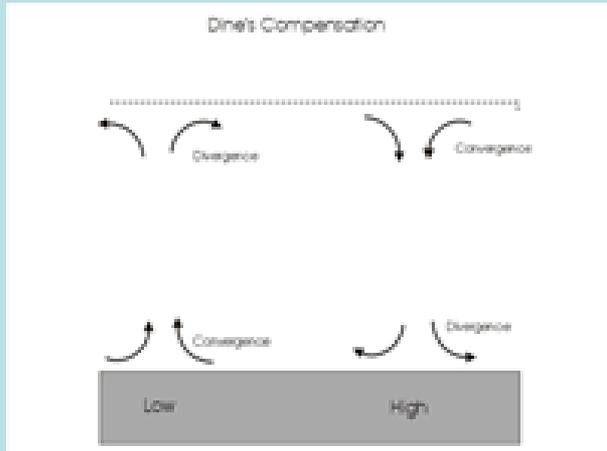
- Originates along or north of warm front in cold relatively dry air
- Moves WESTWARD under WCB and becomes saturated as it rises
- CCB spreads precipitation and comma head cloud west before curving anticyclonically

Dry slot or Dry Conveyor Belt (DCB)

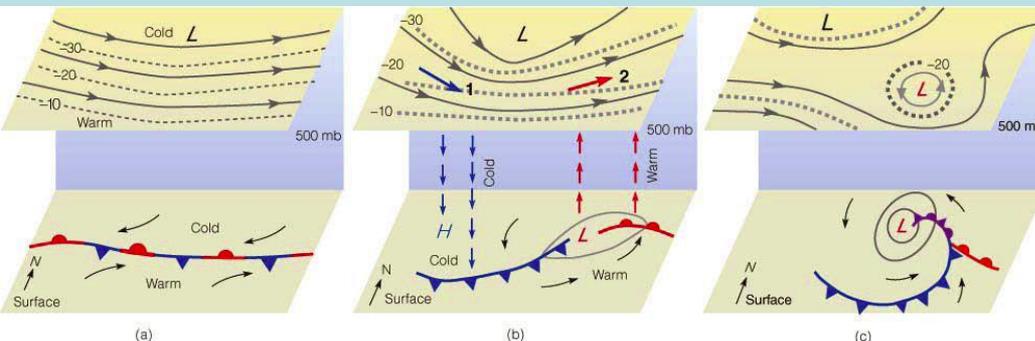
- Originates in mid and high levels of cold air mass west of storm
- Sinks and curves in spiral fashion into storm
- Results in DRY slot with dissipating clouds between CCB and WCB

Storm Development

Linkage between winds aloft and winter storms



Upper level flow linked to surface development through Divergence – Convergence (Dines compensation)



Mass continuity states:

$$du/dx + dv/dy + dw/dz = 0$$

Or

$$du/dx + dv/dy = - dw/dz$$

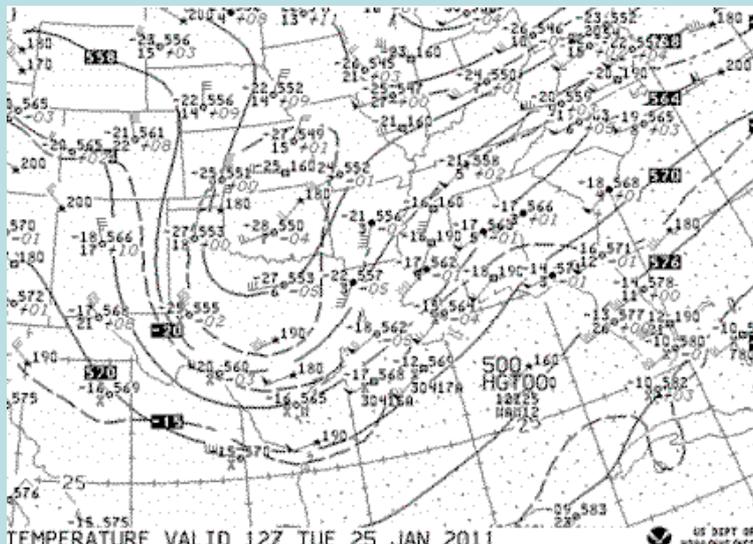
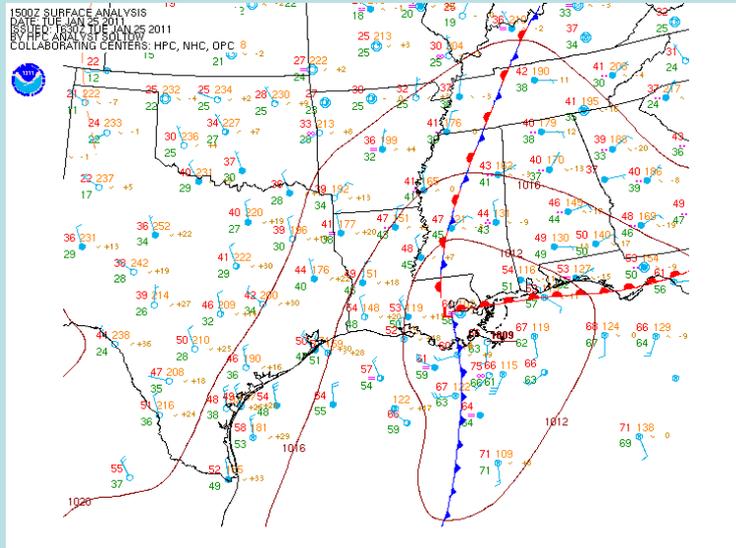
Real world example of Dines Compensation concept

-Upper level directional divergence over Louisiana with low level convergence

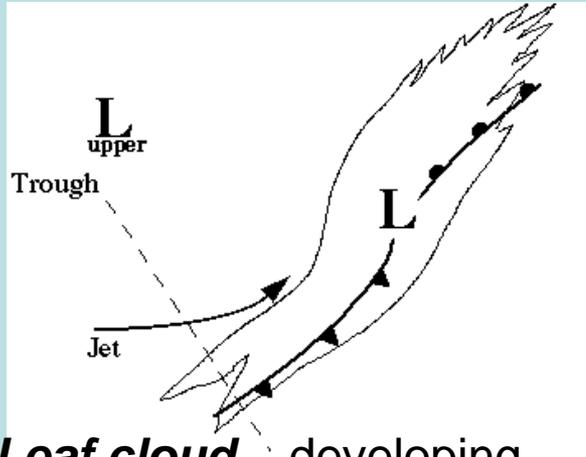
Speed Divergence Southeast Tx into La

This enhances vertical motion and storm development with cloud system evolving into comma type cloud

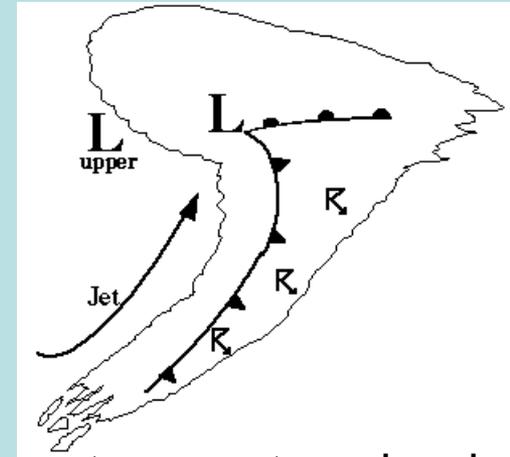
Note developing conveyor belt systems inferred from low level flow



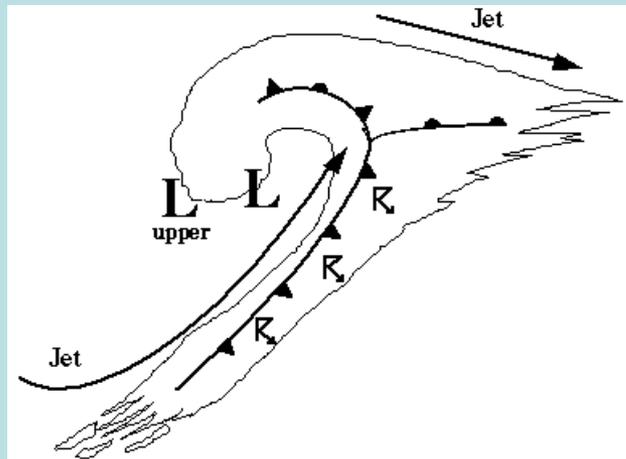
Satellite signatures of developing cyclogenesis to mature storm



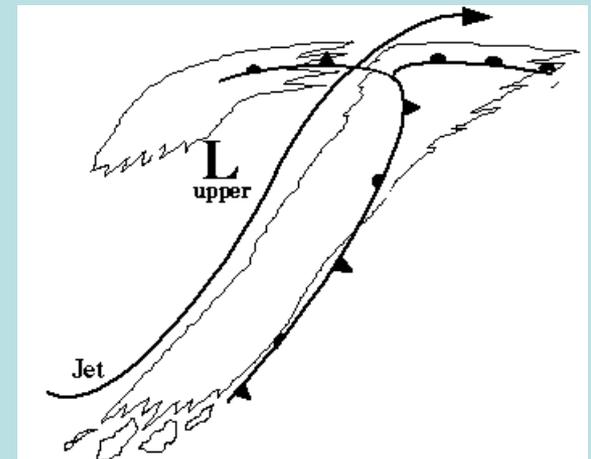
Leaf cloud – developing frontal wave



Cyclogenesis – storm system developing

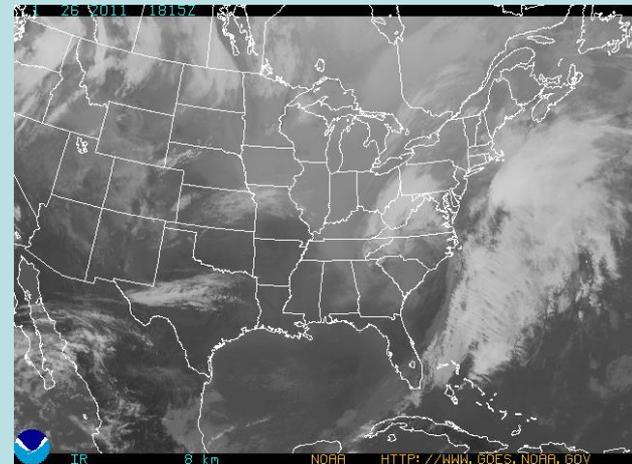
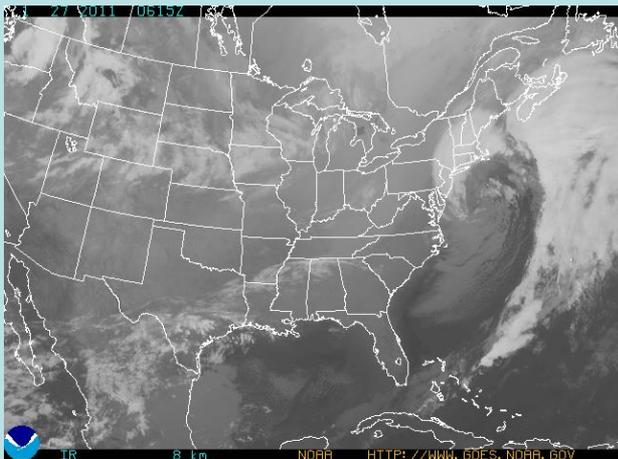
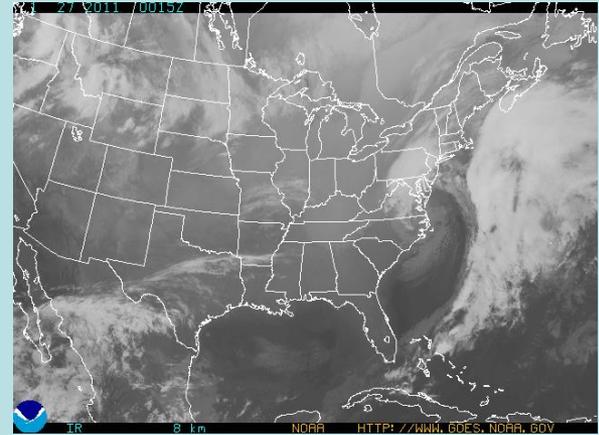
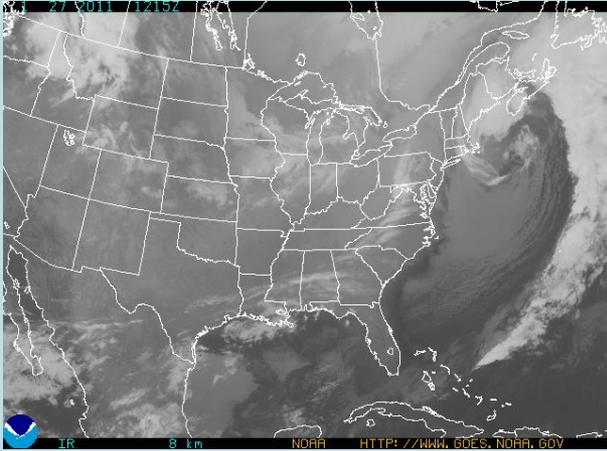


Mature storm



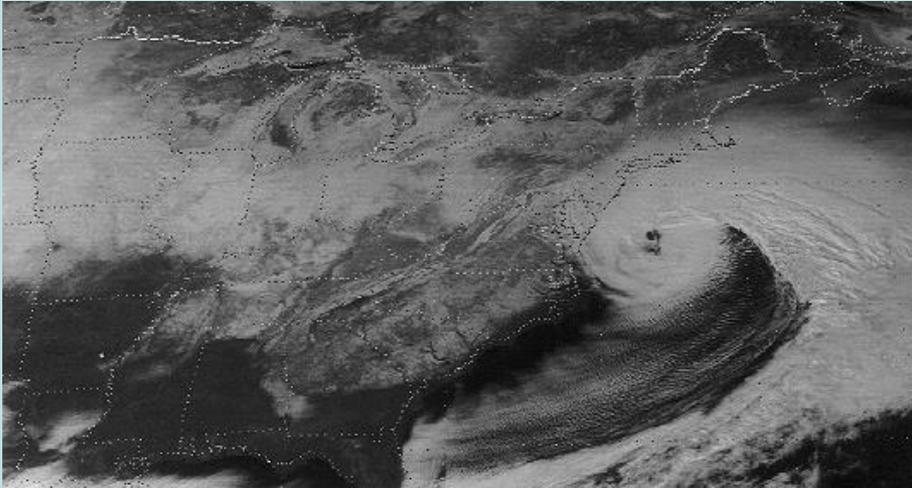
Storm will soon begin to dissipate or move away

Can you relate this to general satellite signature of cyclogenesis??

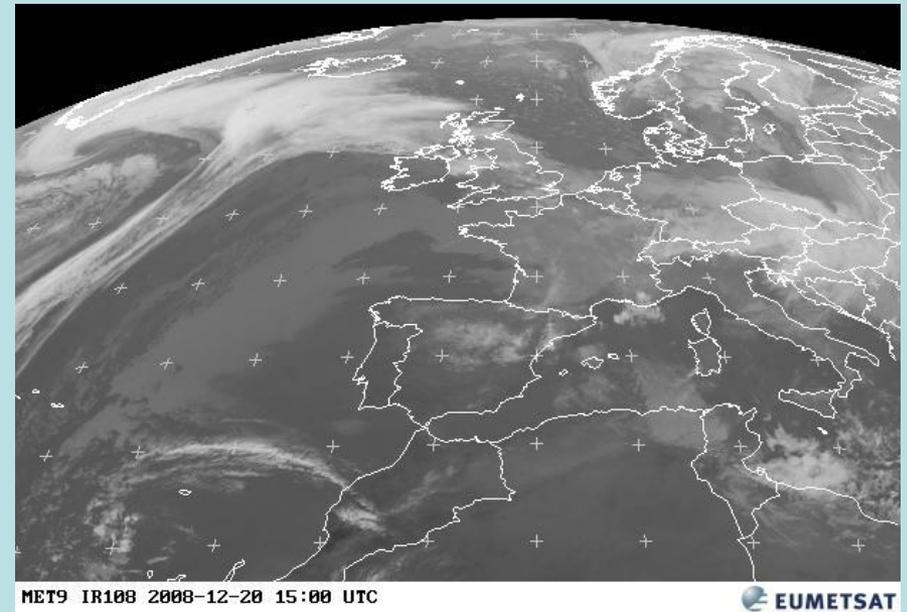


Satellite signatures

Mature winter storms about to shear off

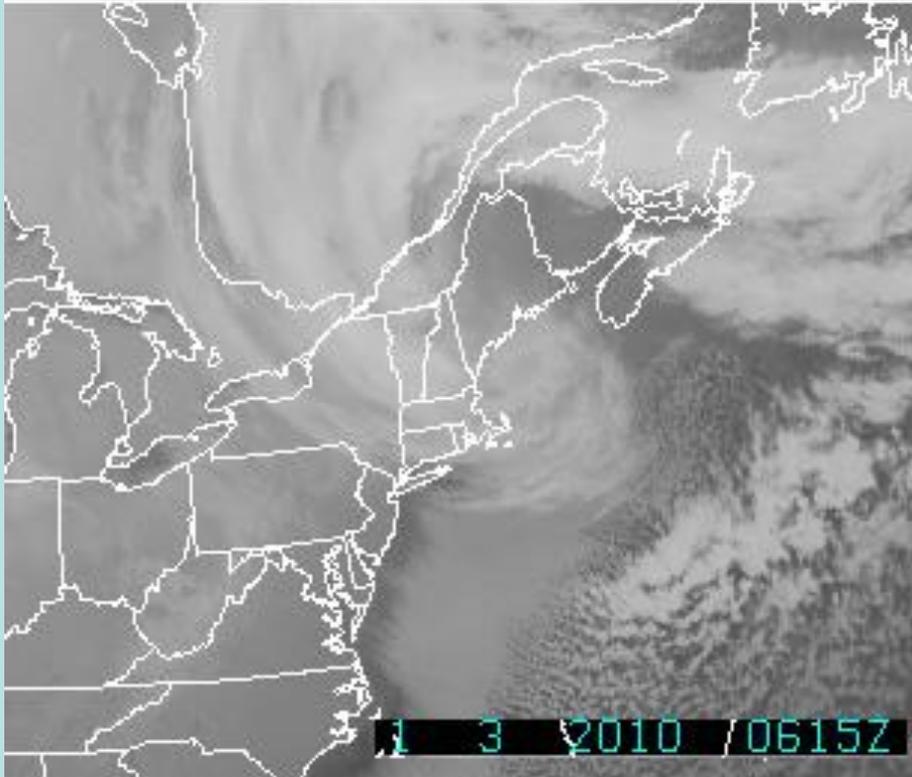


- Blizzard 1979



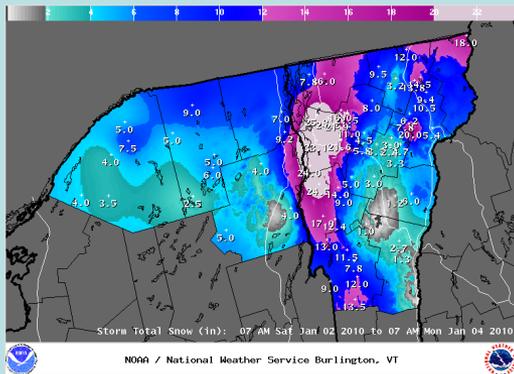
December 20, 2008 Atlantic Ocean

Winter storm - Jan 2-3, 2010

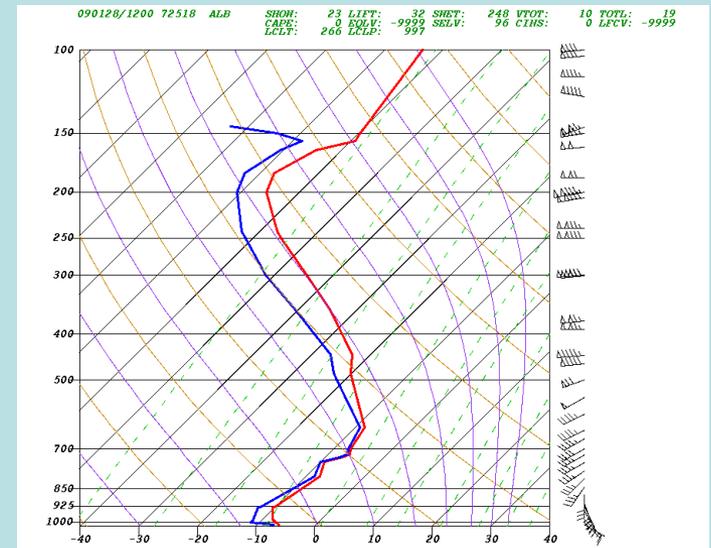
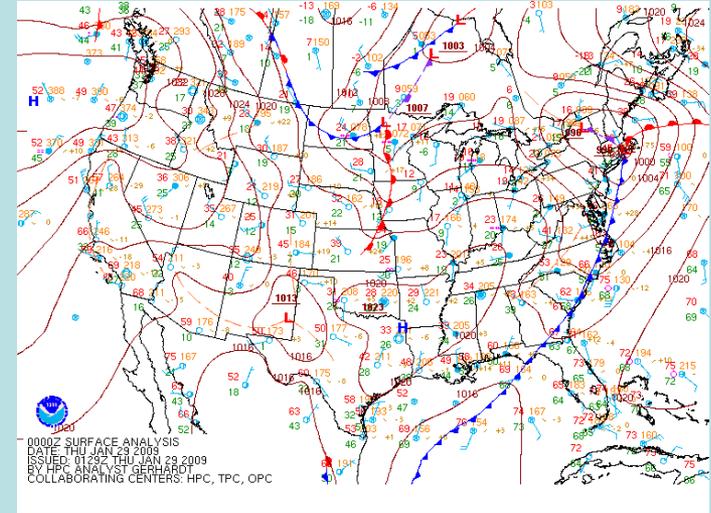
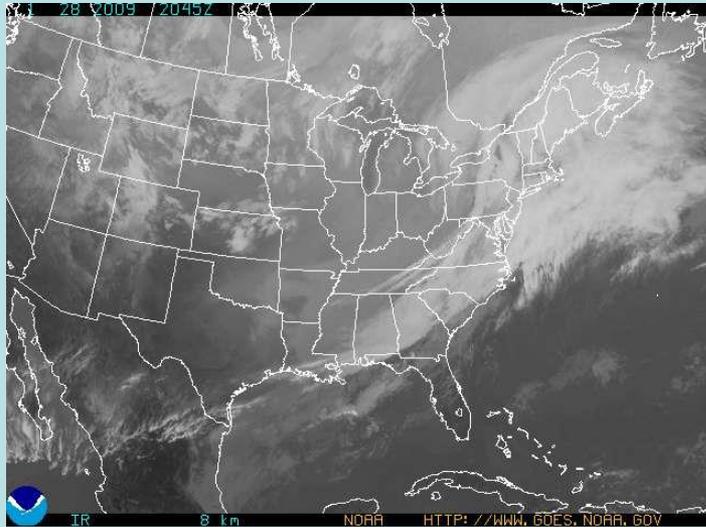


1. Can you pick out the:
WCB
CCB
DCB

2. Can you explain why so much snow fell in Champlain Valley???

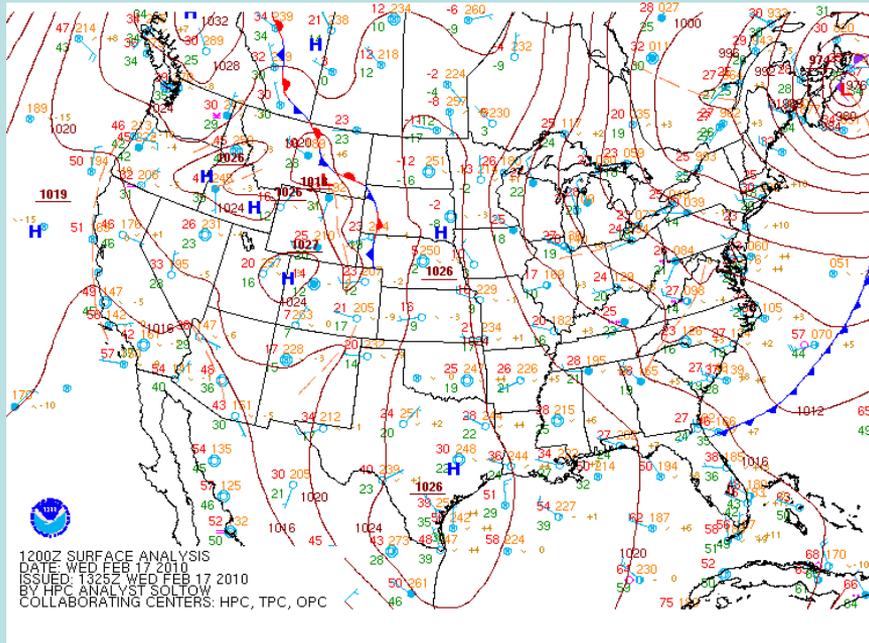


Jan 29 2009 00z

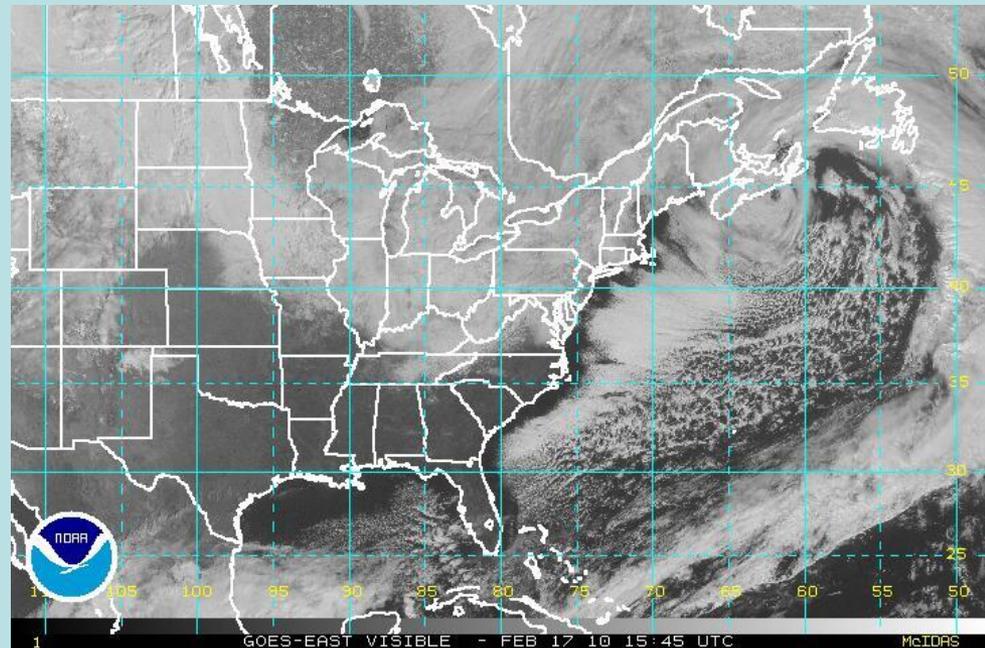


- Developing comma cloud
- Air mass contrast and conveyor belts
- Deep moist layer
- Warm advection noted above surface

Feb 17 2010 12z/15z

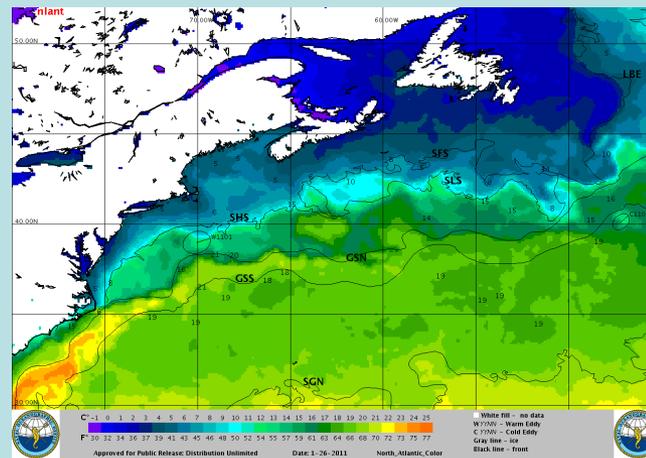
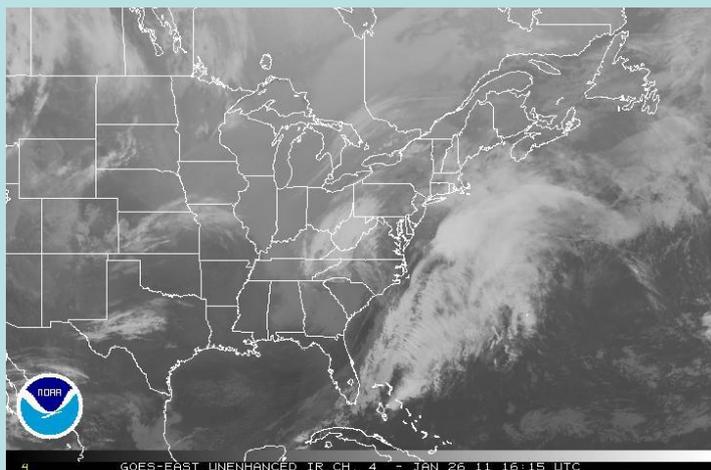
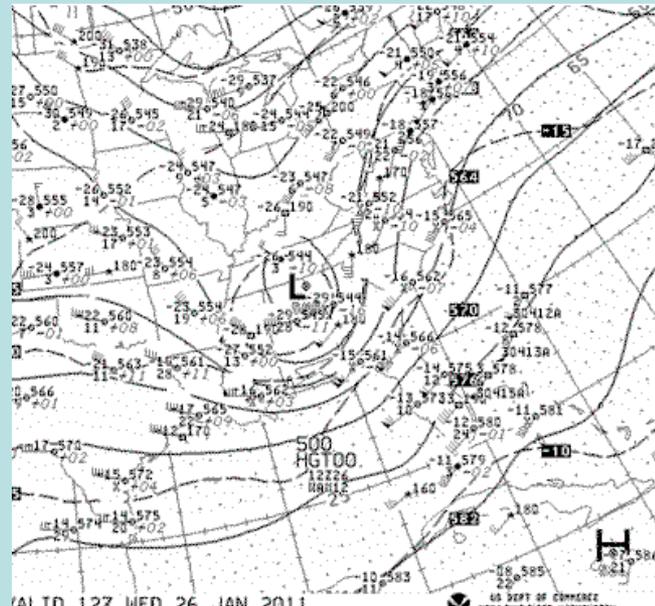
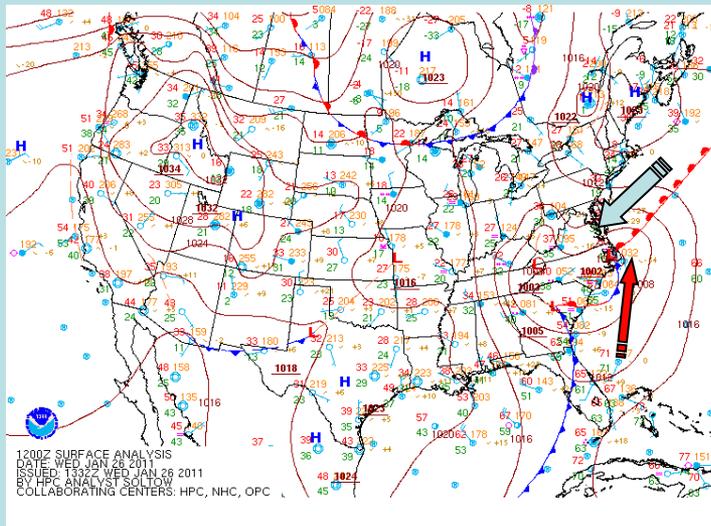


Identify cloud types and conveyor belts



Evolving coastal cyclogenesis

12z Jan 26, 2011

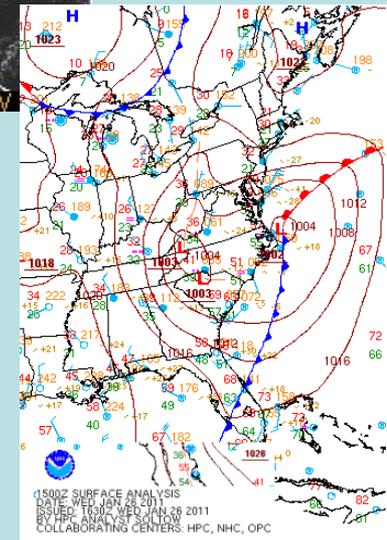
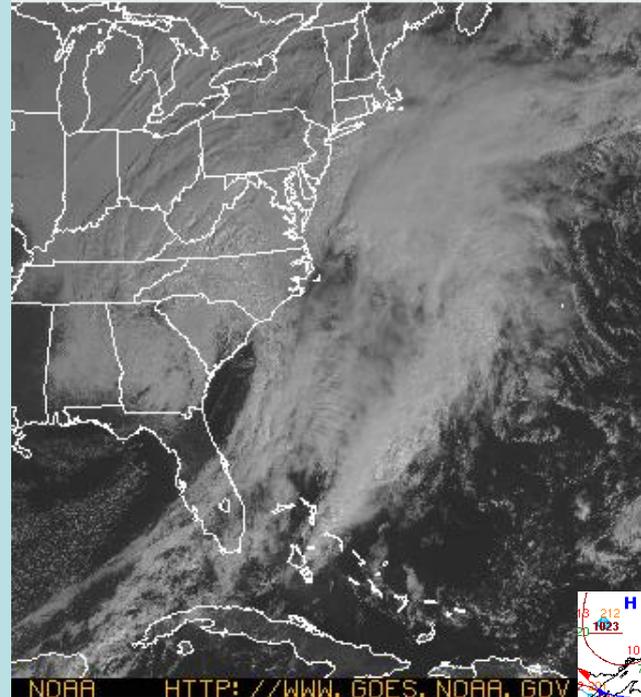


Jan 25-26 2011 storm system

Cyclogenesis

15z Jan 26, 2011

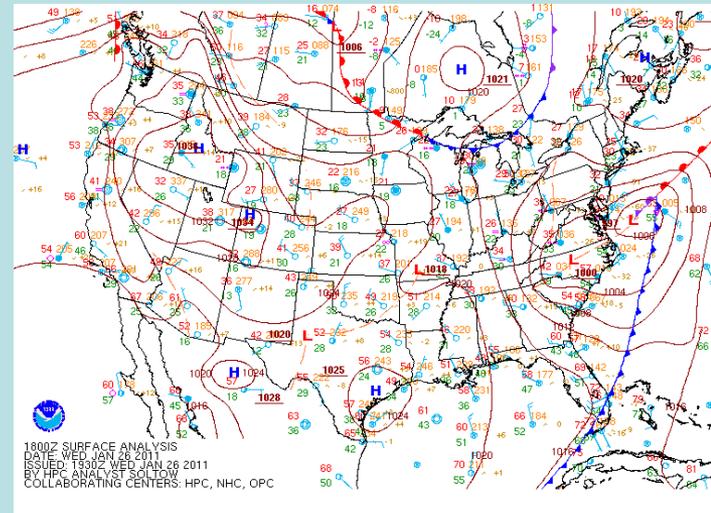
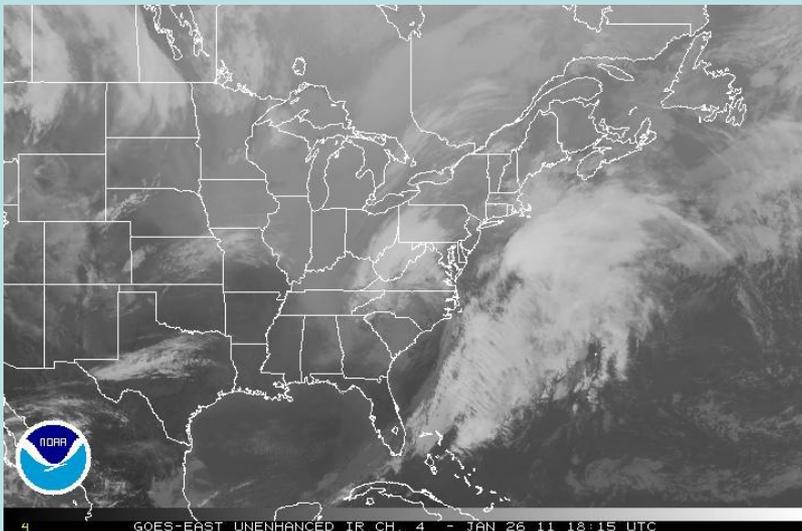
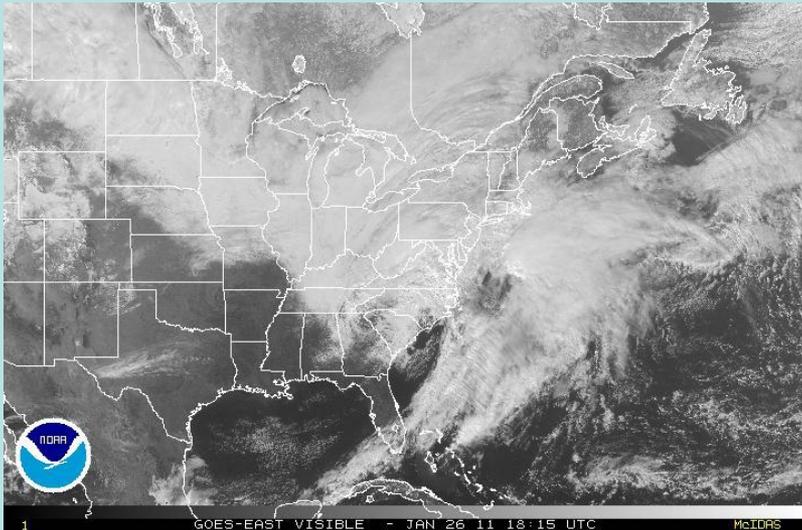
- Do shadows help you pick out the CCB??
- Can you pick out 2 or 3 circulation centers in the satellite imagery?



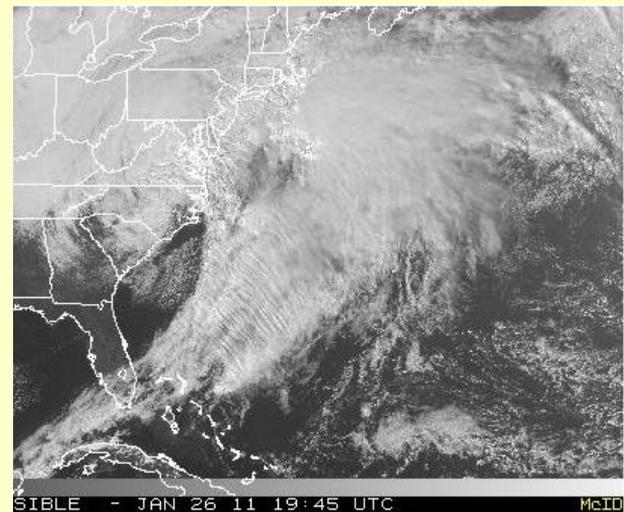
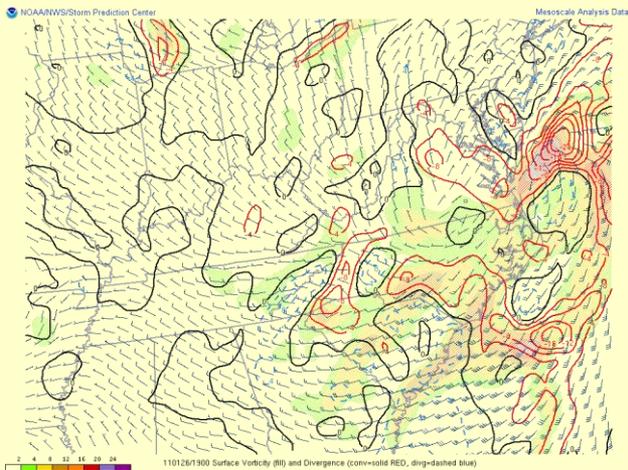
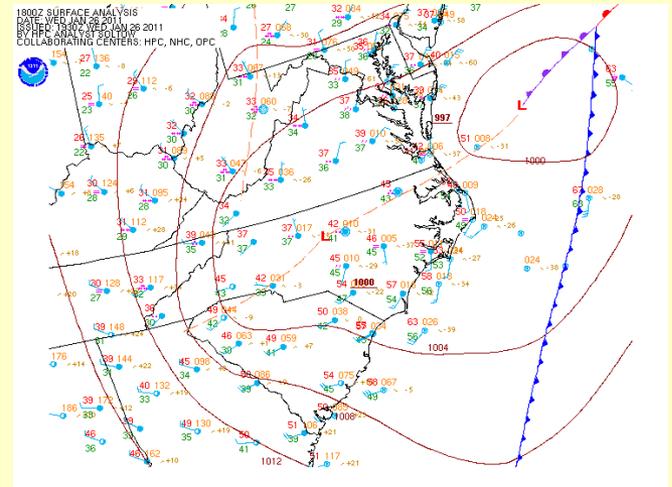
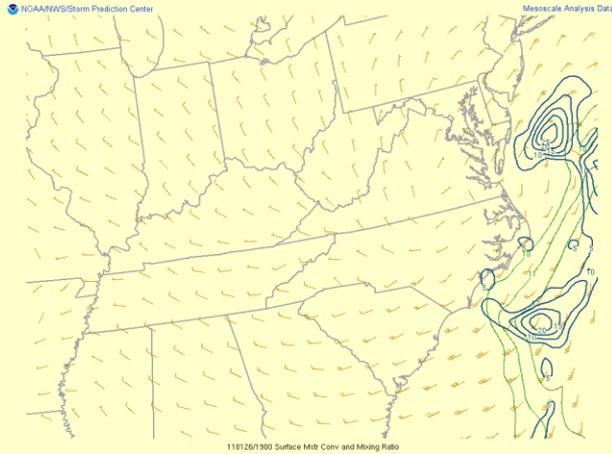
Jan 26, 2011 1815z

Can you find the CCB on the west side of the WCB?

Think about what is going on in the clear area off Virginia...this is not the dry conveyor belt yet



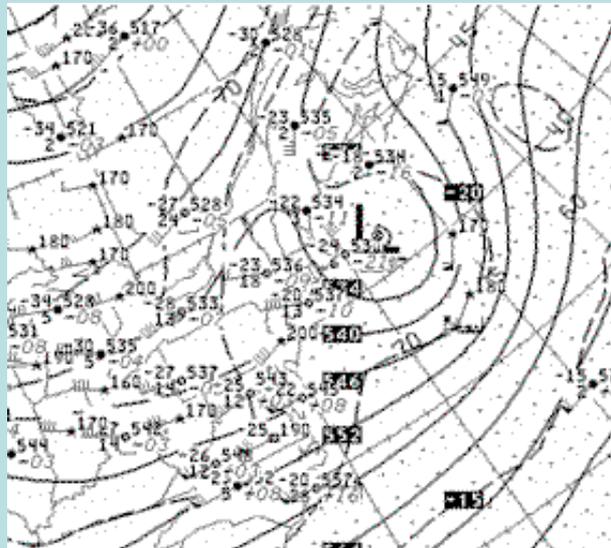
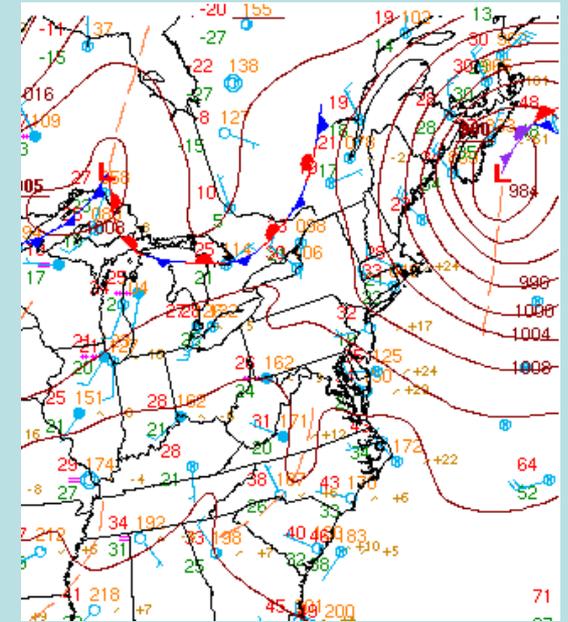
What's going on in the clear area off the Virginia coast 18-19Z Jan 26, 2011



- Quiz time -



Ocean storm Jan 26-27, 2011



Surface map 1500Z

500mb chart 1200z

Vis GOES 1645z

Monday's Arctic Cold.

Numerous minus 30s reported...

