MET 4300

Lecture 19

Seabreeze Thunderstorms and Mesoscale Convective Systems (CH18)

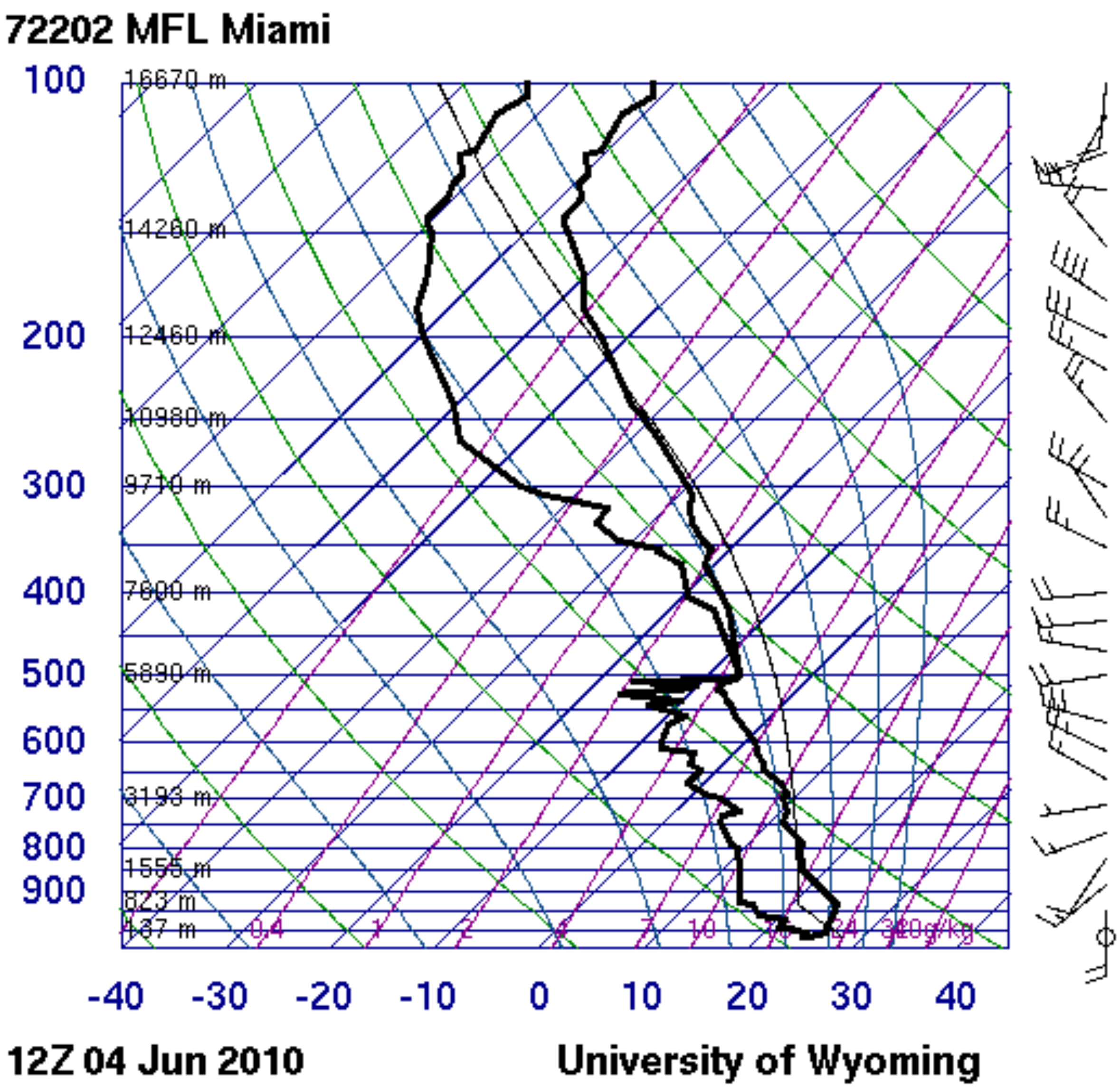
Review

- Ingredients for Severe Thunderstorms
  1. Moisture Source
  2. Conditionally Unstable Atmosphere
  3. Mechanism to trigger updraft
  4. Vertical wind shear
- Airmass Thunderstorm
  - Little or no vertical wind shear
  - 20-30 minute lifetime due to downburst squashing the updraft
  - New cells form on outflow boundary
  - Example: FL summer seabreeze storms

Seabreeze Thunderstorms

- Responsible for majority of rain in South Florida in summer “wet season”
- Seabreeze caused by pressure gradient between land and ocean
- Formation and movement mostly depends on the following factors:
  - 1. Synoptic-scale wind flow
  - 2. Temperature in upper atmosphere (500 mb)
  - 3. Amount of moisture in atmosphere (TPW)

Example: Miami 12 Z Sounding



- Weak vertical shear, storms will move slowly W→E
- Moist lower and mid levels
- Relatively cold in mid-levels (especially between about 675 mb and 300 mb)
- 500 mb temp. about -8 °C
- Capping inversion around 925 mb

12 Z （8am）:

•Nocturnal land breeze

•No clouds over land

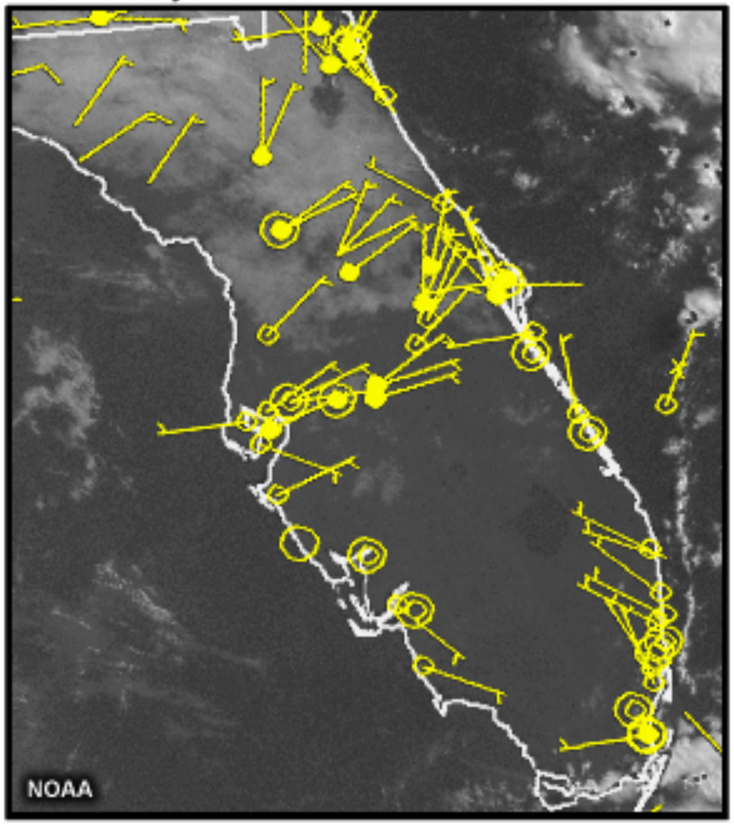
17 Z (1pm):

•Surface heating picking up

•Convergence near coastline

•Cumulus formation over land

GOES-10 VIS image with surface observations
1215Z 30-May-02



GOES-10 VIS image with surface observations
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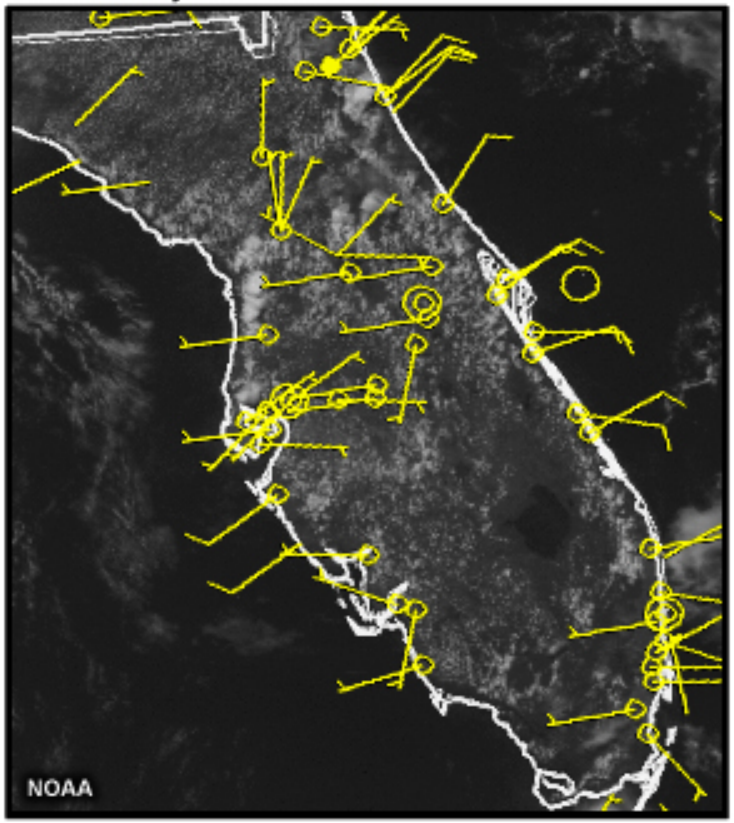
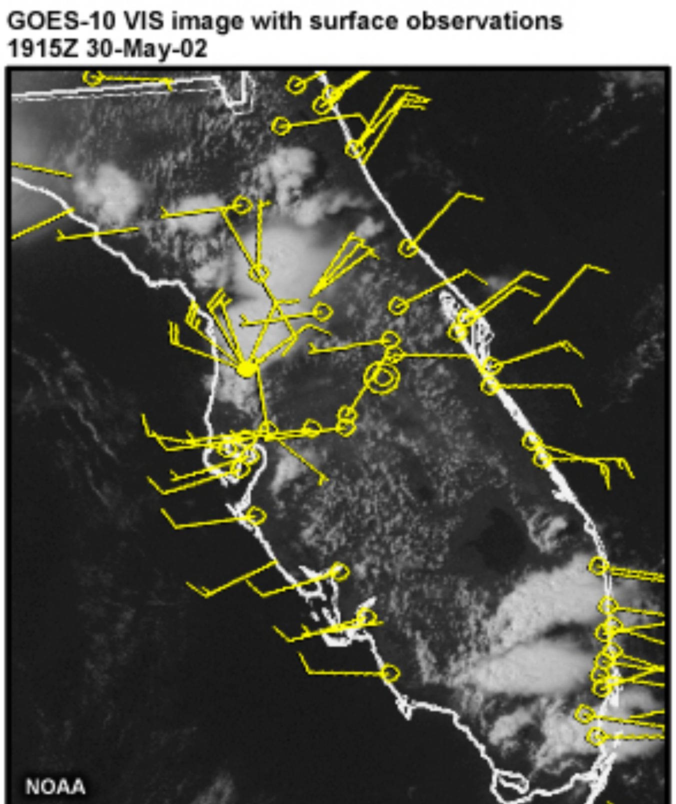


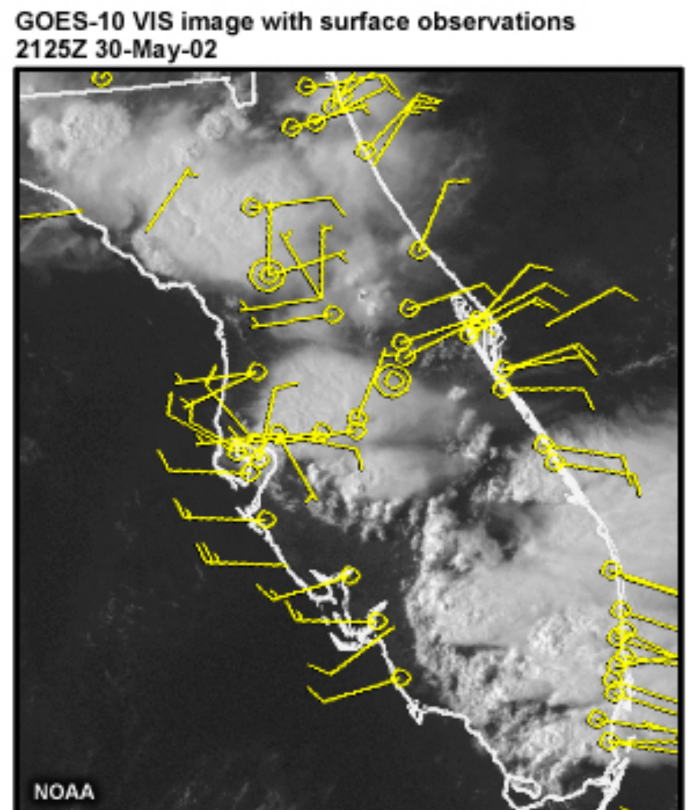
19 Z (3pm):

- Seabreeze on both coasts pushes inland
- First storms develop over Everglades
- Synoptic flow pushes anvils to east

21:30 Z (5:30pm):

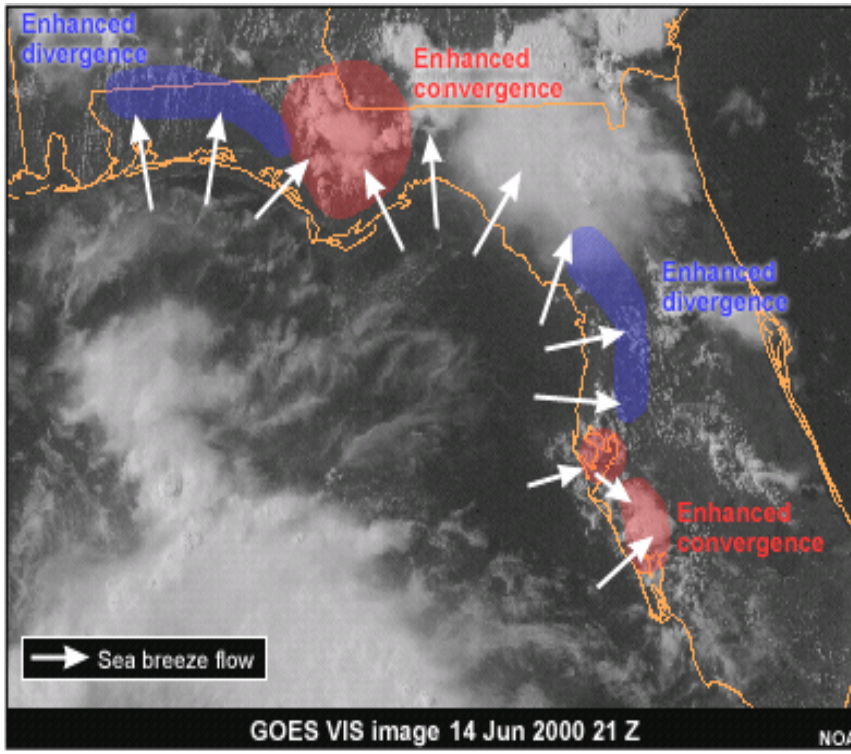
- Convection continues to develop/grow
- More storms form on old outflow boundaries



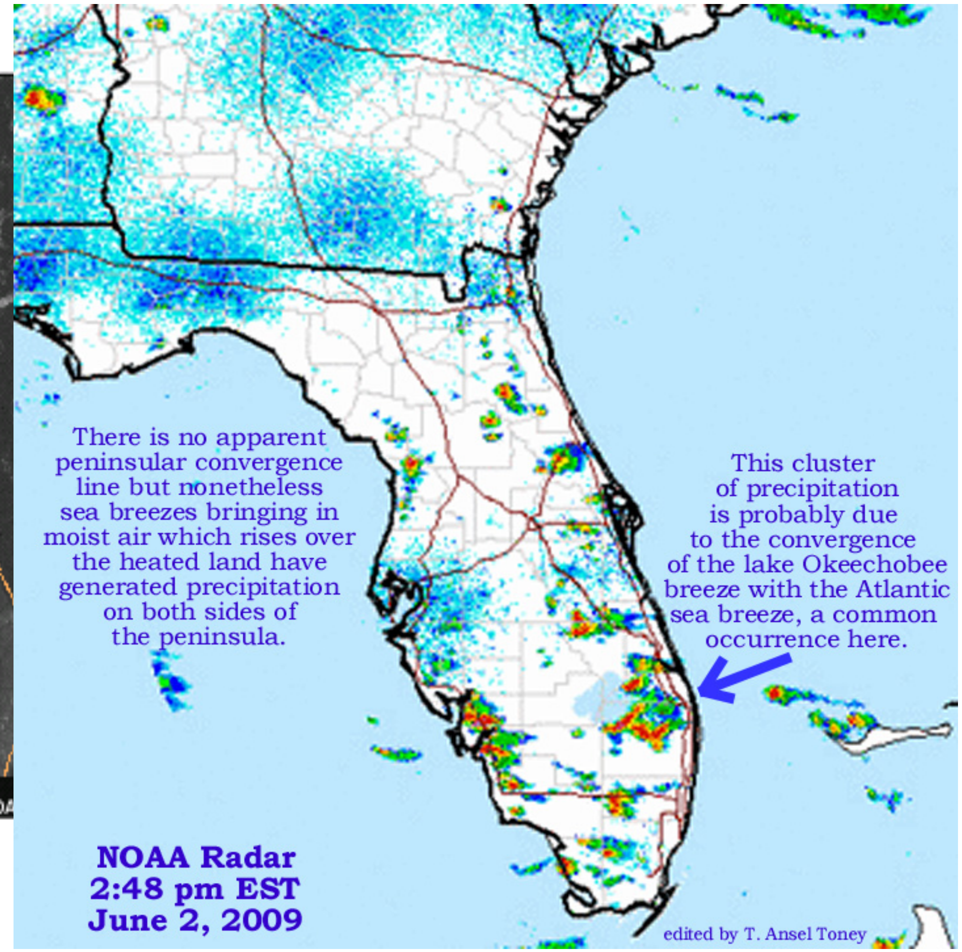


Local Geography can influence development:

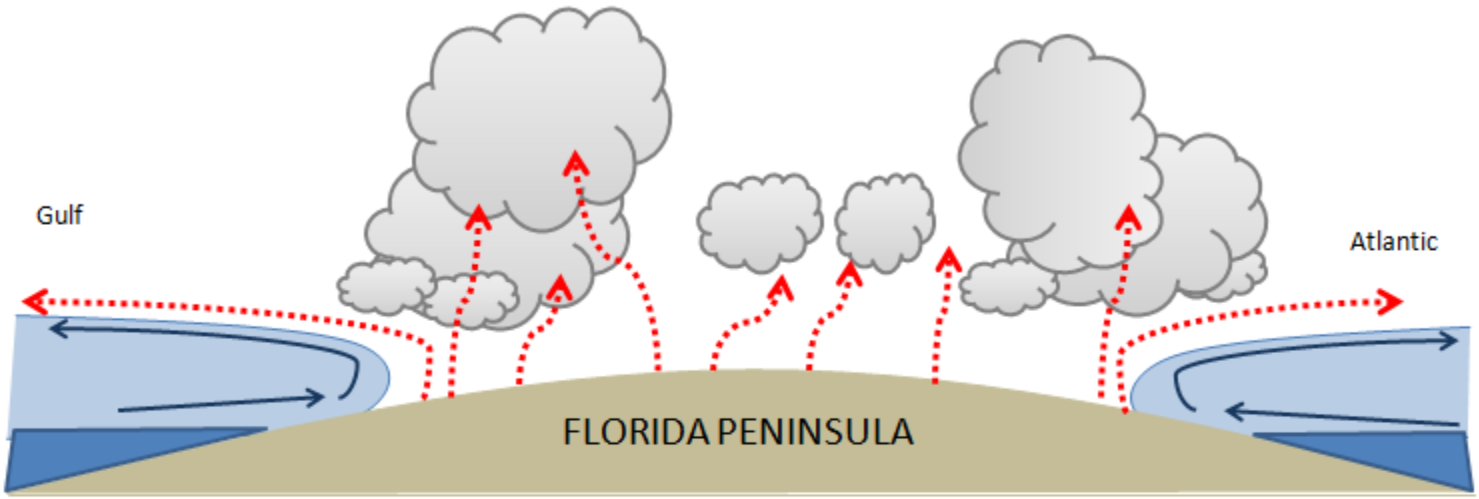
Coastline shape:



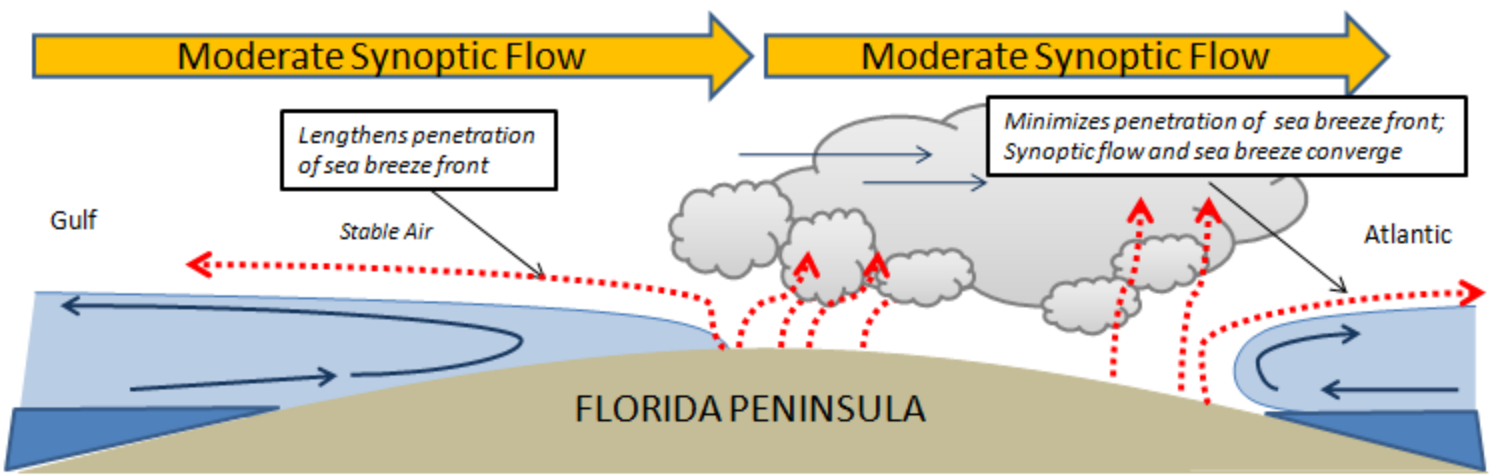
Lake Okeechobee:



Importance of Synoptic Flow



Without Synoptic Flow



With Moderate Synoptic Flow

Seabreeze Storm Hazards

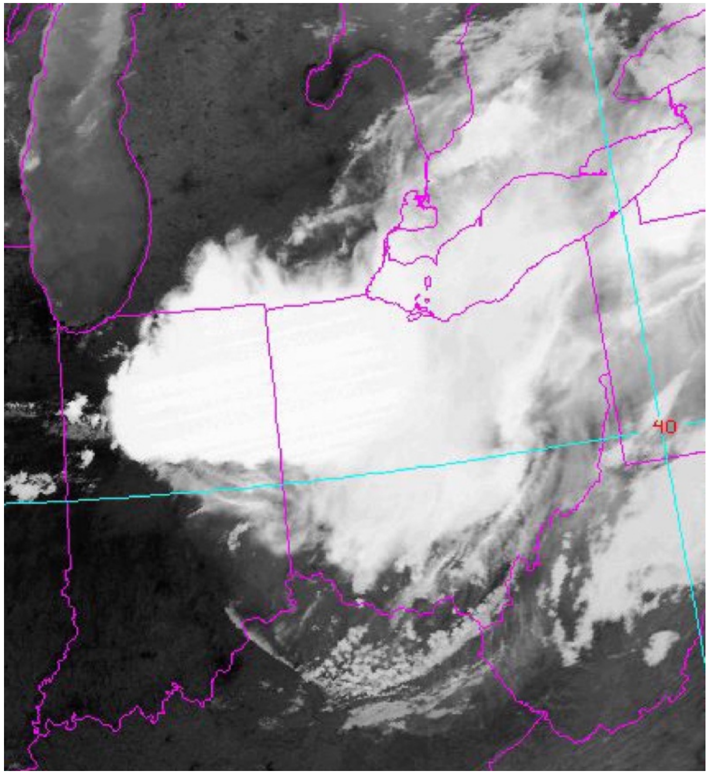
- Flash flooding—if storms persist or redevelop over same areas
- Lightning—especially dangerous when it is not raining or even sunny
- Hail and gusty winds may occur if a synoptic disturbance increases wind shear and cools the mid-level temperatures
- Non-supercell tornadoes are possible where merging outflow boundaries enhance rotation

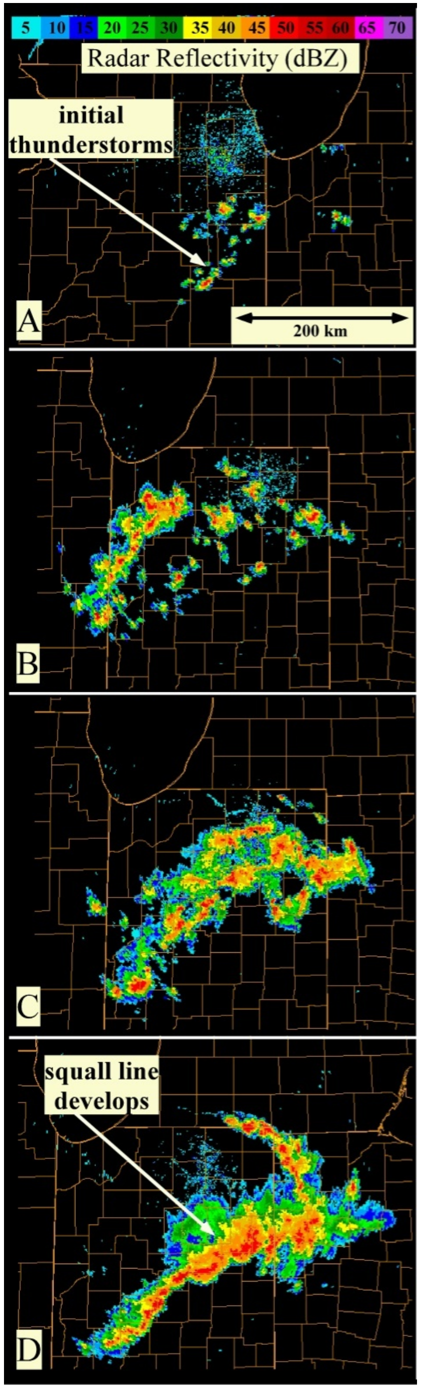
Waterspouts

- Usually occur in mid-morning when land/sea-breeze boundary is located just offshore

What are MCSs?

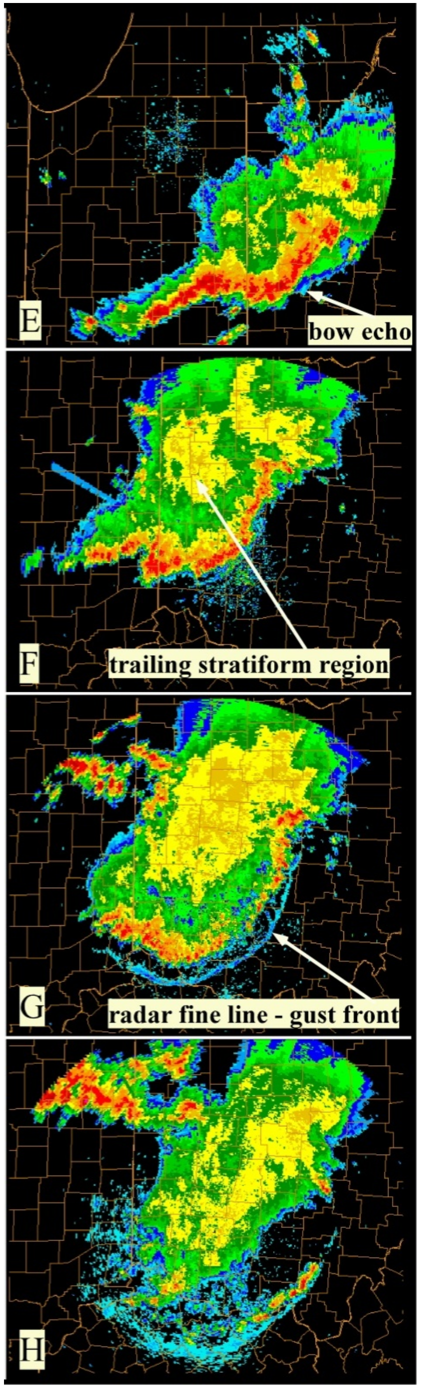
- **Mesoscale convective system (MCS)**: An organized cluster of convective clouds that is larger than an individual cloud, but smaller than a frontal cyclone and can last for hours. In satellite imagery the system may appear round or linear. “MCS” is a generic term that includes **squall lines, severe thunderstorms, and mesoscale convective complexes (MCCs).**
- Responsible for much of the summer rainfall.
- MCS cloud shield can cover larger than a large state.





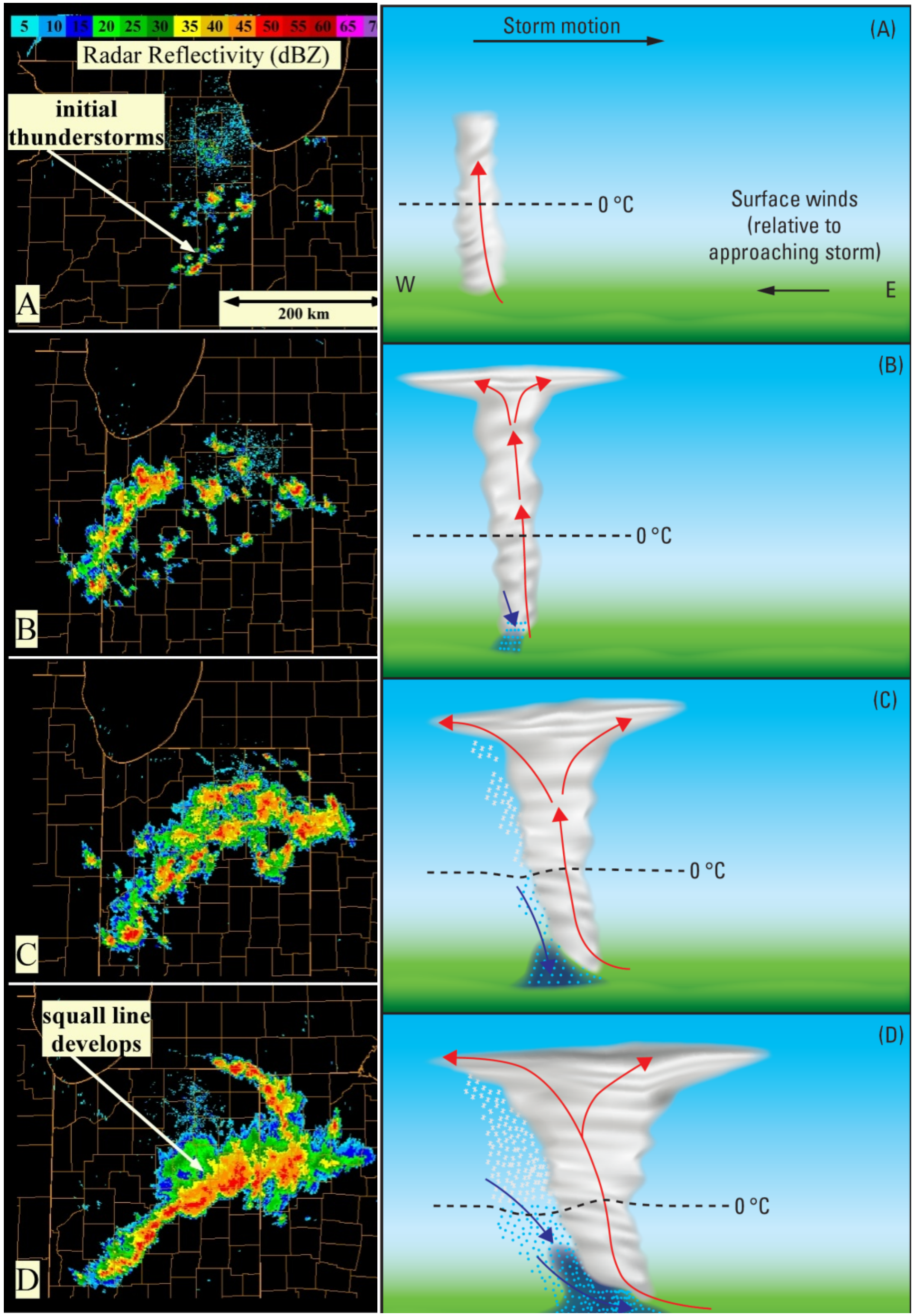
Life cycle of a typical MCS

- During warm season, lifting of air along weak airmass boundaries often trigger thunderstorms.
- Sometimes the storms will appear as a disorganized cluster (panel A).
- Then they will begin to organize (panel B & C)
- More intense & progressively aligning into an arc-shaped line called **squall line** (panel D).
- “Squall”: a violent burst of wind.
- A squall line is a long line of thunderstorms in which adjacent thunderstorm cells are so close together that the heavy precipitation from the cells falls in a continuous line.



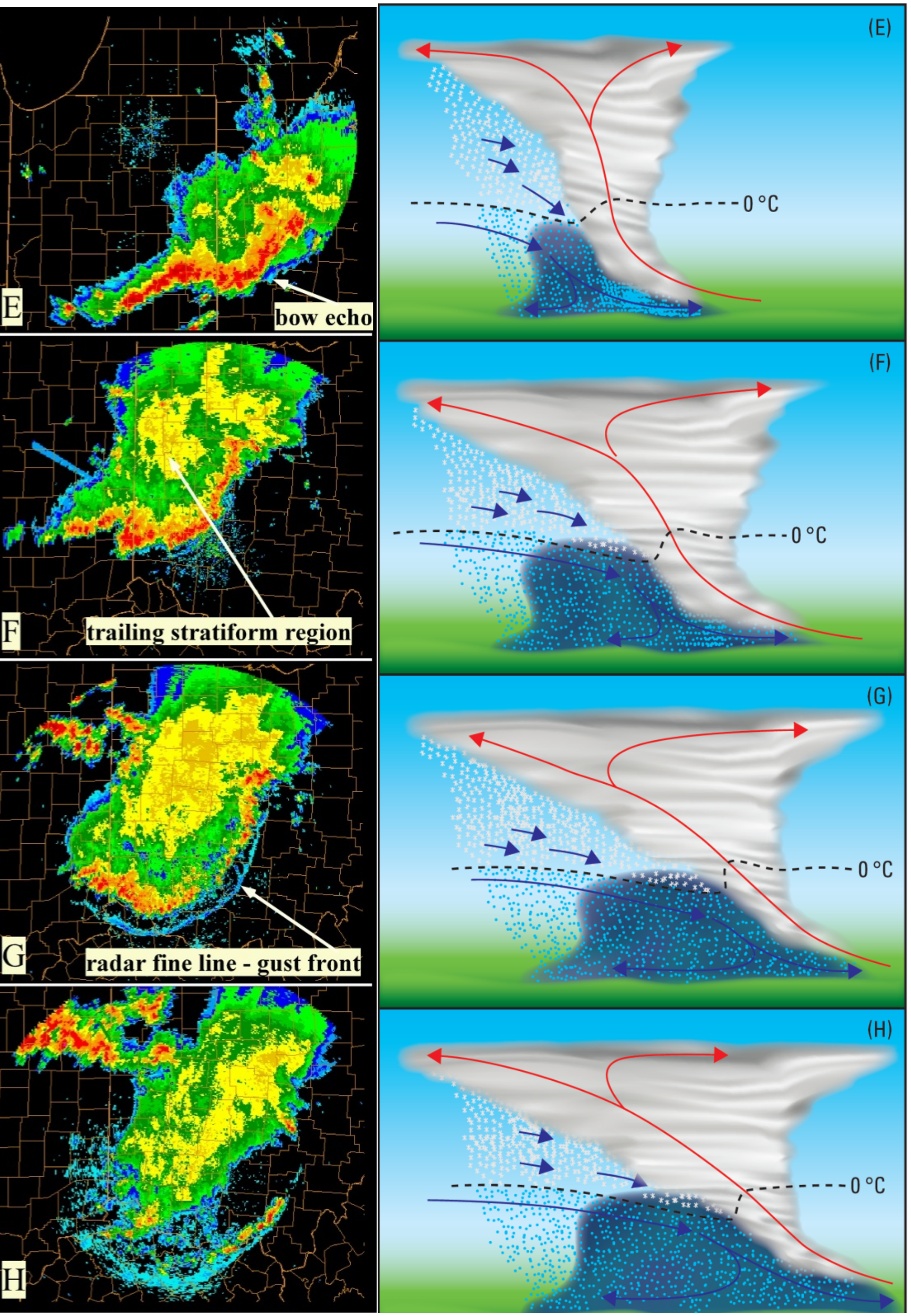
Life cycle of a typical MCS

- Panel E: one or more segments along the squall line may bow outward, producing a **bow echo** on radar.
- Panel E & F: **stratiform region**– a region of less intense precipitation develops to the rear and become progressively larger and more widespread.
- Panel G: The thunderstorm cells spread along a progressively widening arc (**gust front**).
- Panel H: new thunderstorm cells may develop ahead of, on the periphery, or even to the rear of the original MCS. These cells may later organize into a new MCS.



Cross Sections

- **Panel A:** the **updrafts** are upright or slightly tilted
- **Panel B:** A **cold pool** is developed as rain falls & evaporates into the lower atmosphere.
- **Panel C:** cooler air spreads outward & rearward.
- **Panel D: new updrafts** form along and over the advancing cold pool air. This leads to the **formation of the squall line**.

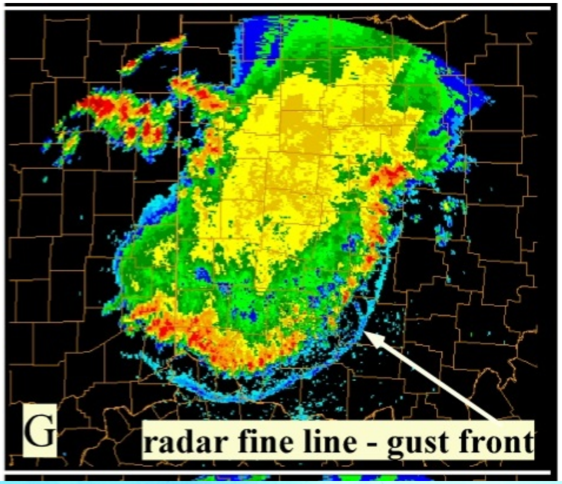


Cross Sections

- **Panel E:** As the cold pool develops and advances forward into the warmer air, the **updrafts tilt rearward.** Rain falls to the rear (drier), enhancing the evaporation rate and coldness.
- **Panel D-F**: The **cold pool** becomes deep enough & cold enough to rush outward, forming **a gust front.**
- **Panel E-H: rear inflow jet:** air in the evaporation region at middle level flows forward toward the line of storms.

Gust Front and Shelf Cloud

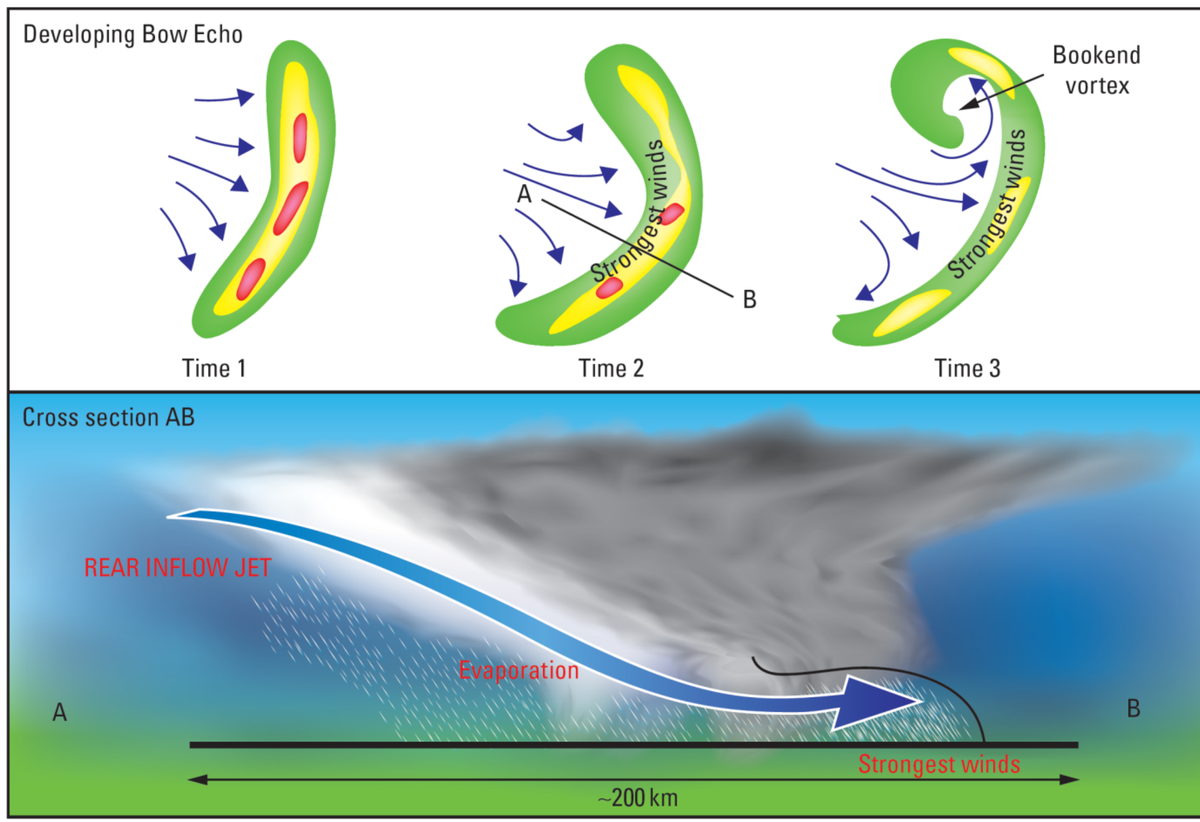
- Surface winds behind the gust front can be severe, ranging from 20 to 100kts.
- A shelf cloud (or called roll cloud) often develops over the gust front.
- On radar, it appears as a fine line of lower reflectivity.
- Droplets in the shelf cloud is non-precipitating, but large enough to be detected by radar.



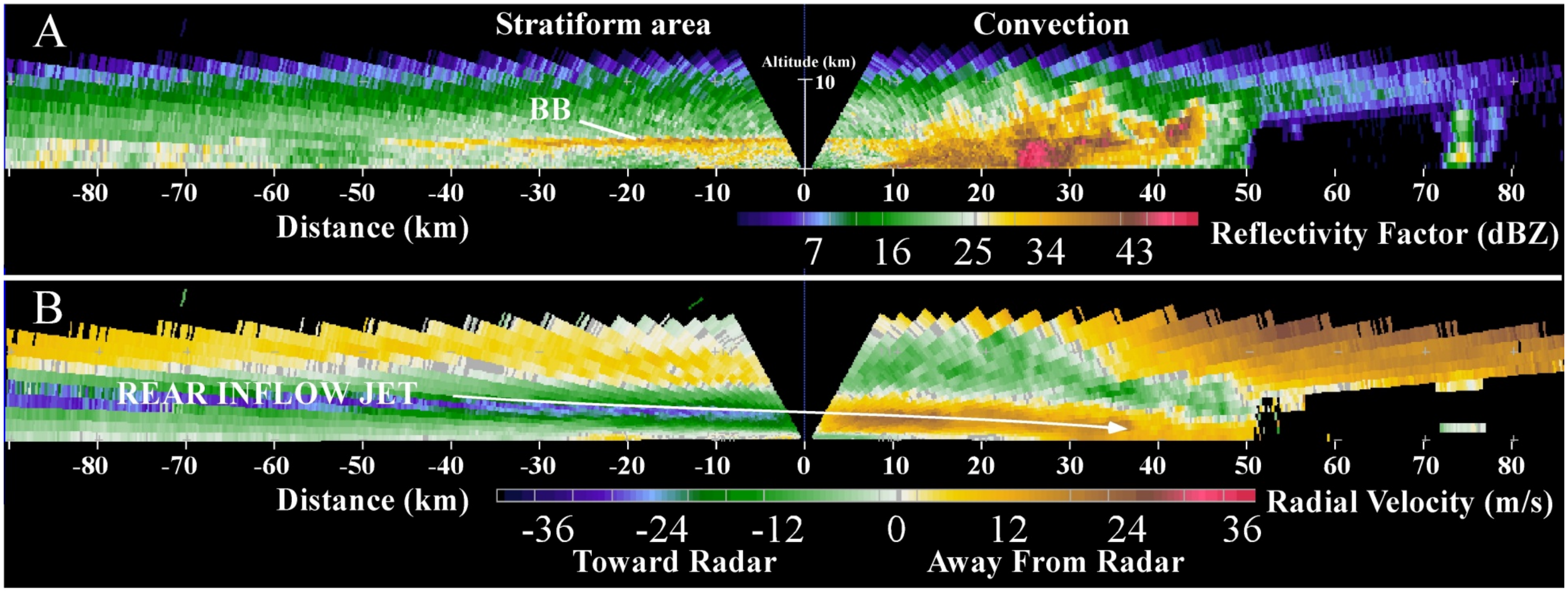
Bow Echo and Rear Inflow Jet

- New thunderstorms align along and over the out-rushing air from the cold pool, creating the **bow echo** visible on radar.
- The bow echo provides a distinct signature of **strong straight-line winds**.
- **Bookend vortices**: rotating eddies on either end of the bow echo.

- **Mini-bows**: 6-12 miles
- **Large bow echo**: 90-125 miles long
- **Derechos**: widespread severe thunderstorm generated wind storms
- **Small tornadoes** may occur within the northern bookend vortex.
- **Tornadoes in MCSs** are short-lived, small, & weak.

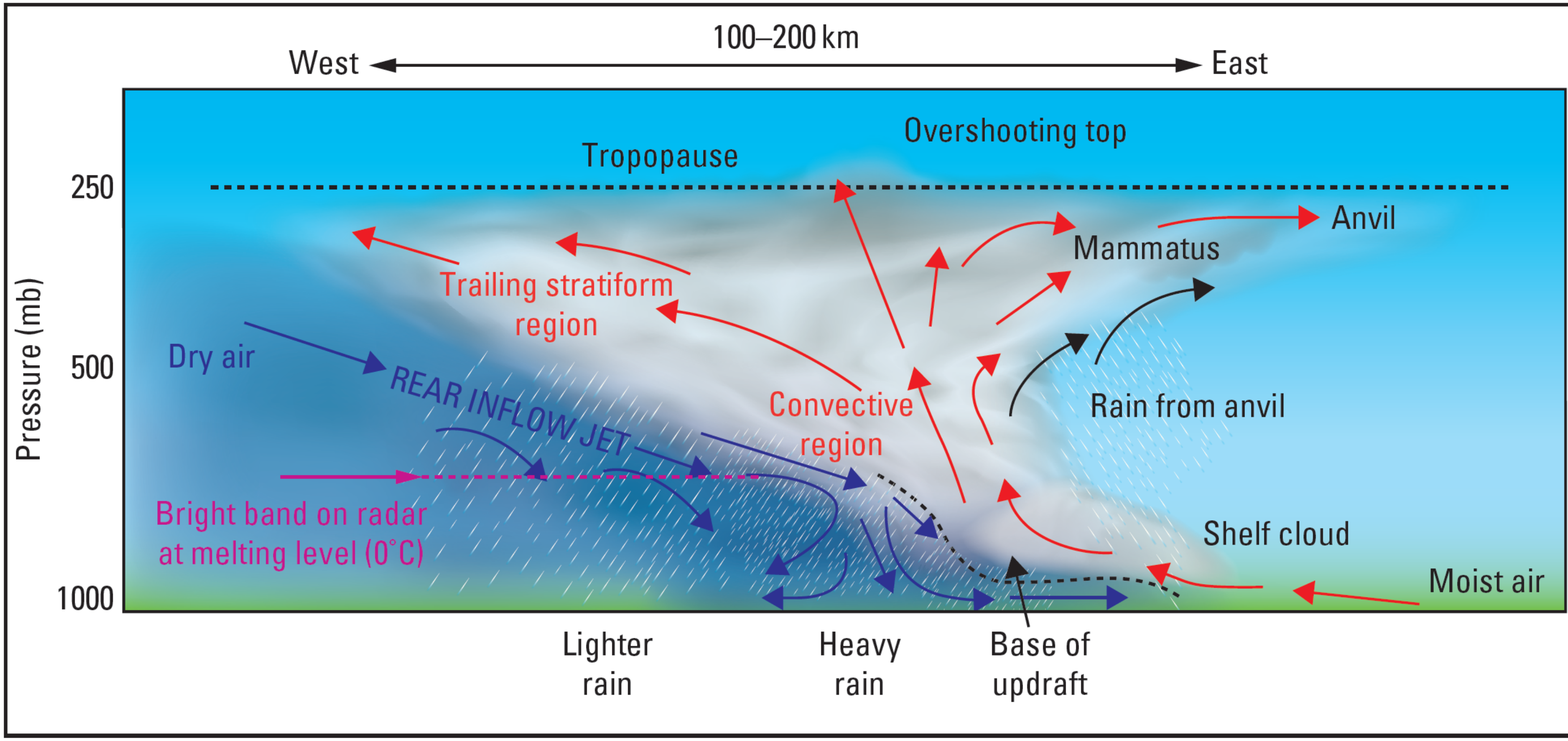


Radar vertical cross section through a mature squall line over Oklahoma & Kansas on 11 June 1985



- **Bright band**: in the **Trailing stratiform region.**
- **Rear inflow jet:** in the Doppler radial velocity field

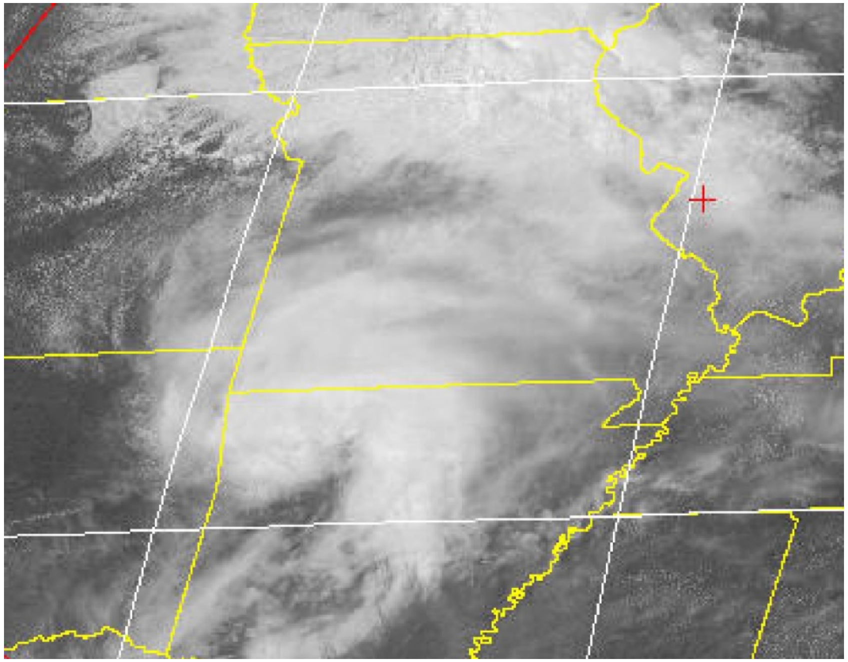
The Key Structural Features of a Thunderstorm in a Mature MCS



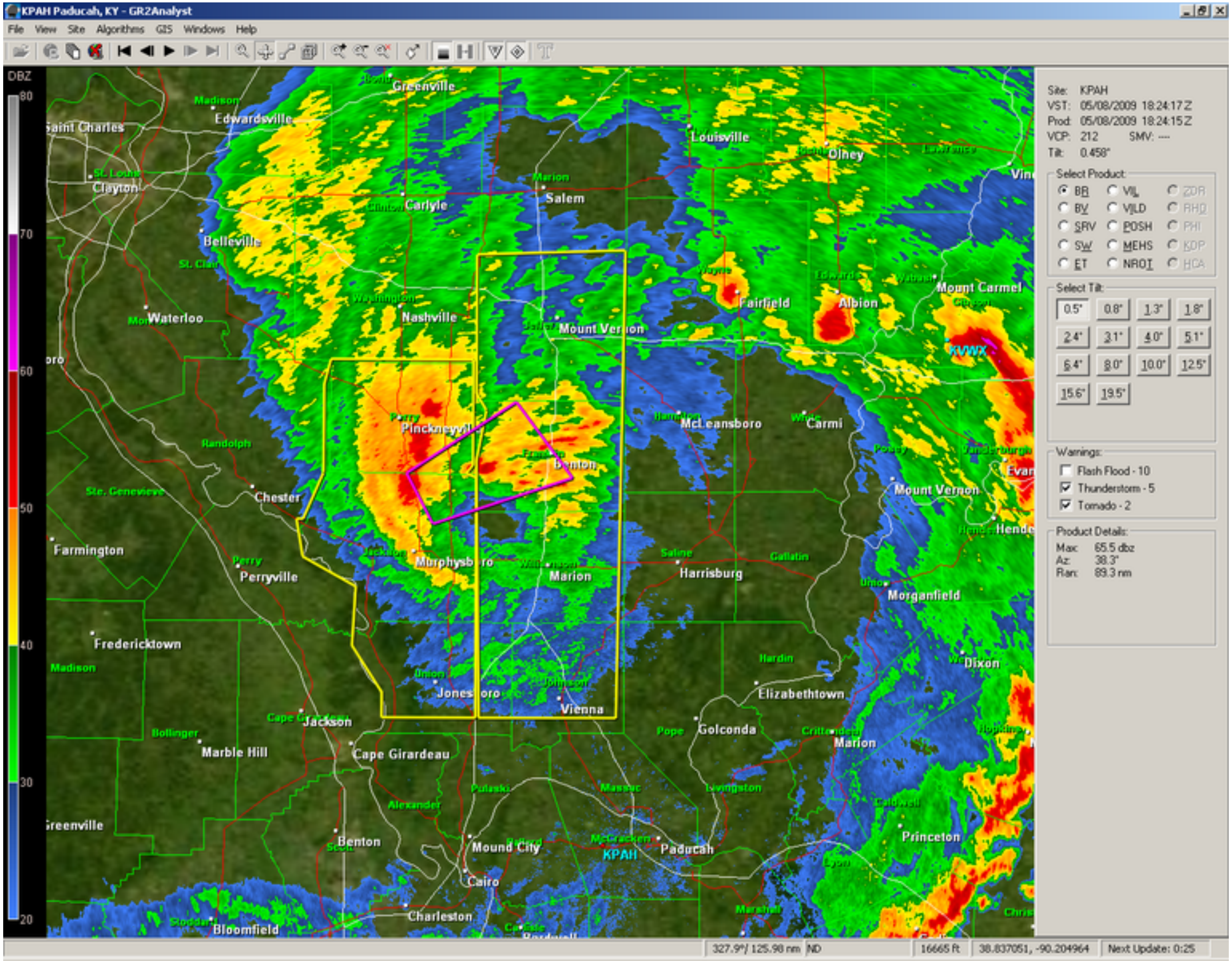
- **Convective region**: heavy rain
- **Trailing stratiform region**: lighter rain at surface, bright band at the melting layer, and slowly rising air

Mesoscale Convective Vortex (MCV)

- As a MCS dissipates, occasionally, the large amount of latent heat release in the stratiform region of an MCS can create a localized low-pressure center—MCV.
- The entire MCV will rotate and develop an eye-like feature
- Looks cool on radar.
- MCV is often the focal point for a new thunderstorm outbreak the next day.
- In rare cases, can move over ocean and develop into a Tropical Cyclone

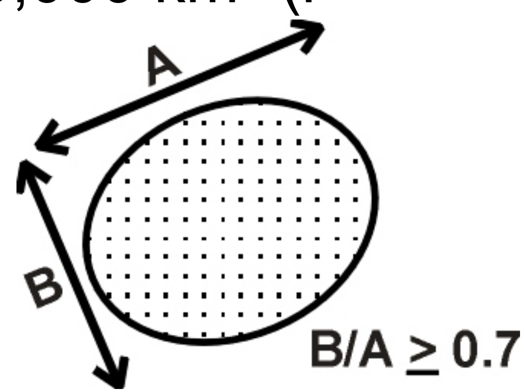


MCV Example on Radar



What are MCCs and MCSs

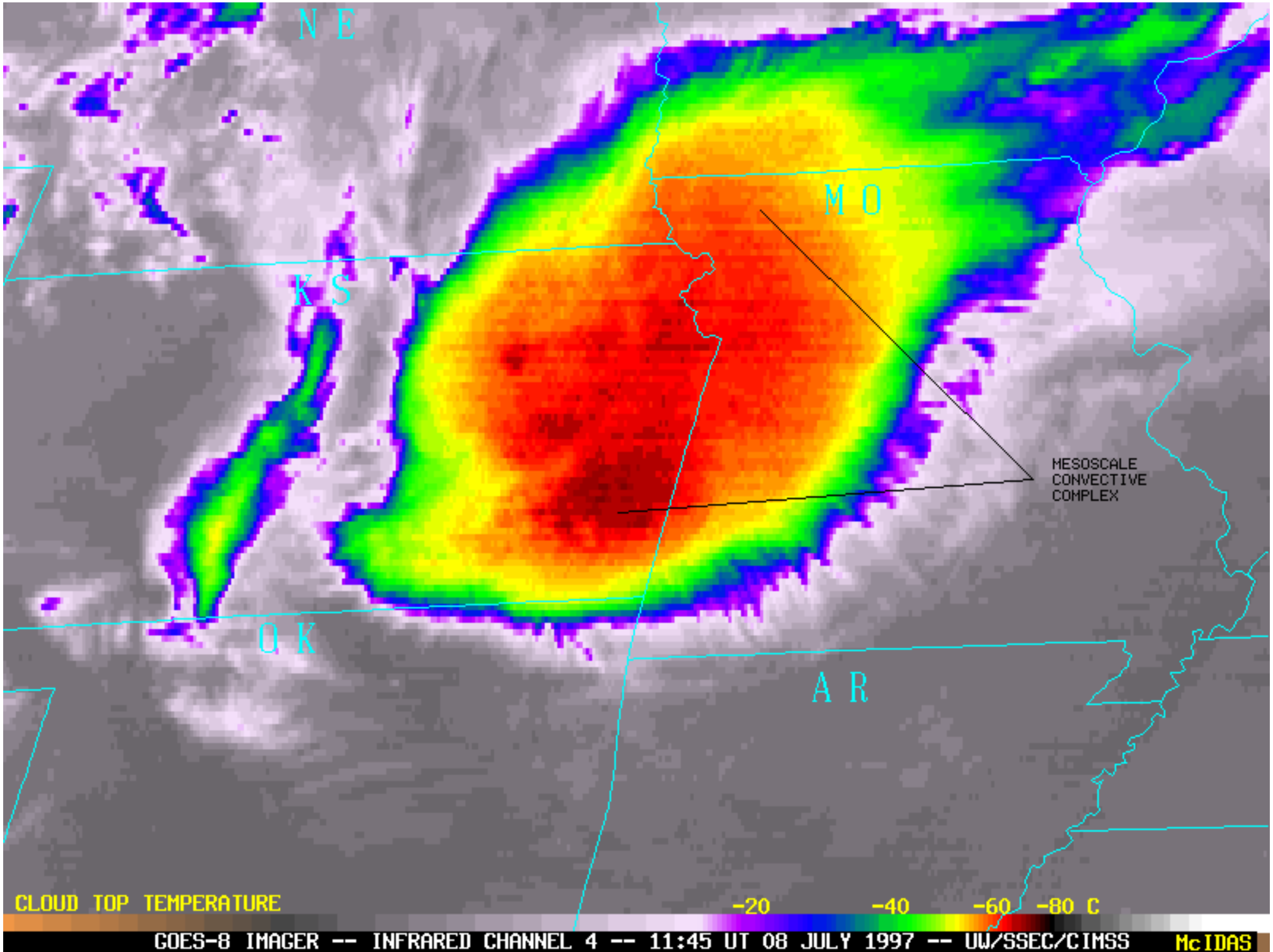
- **MCS**: Mesoscale Convective System—Any mesoscale weather feature that exhibits convective overturning.
- **MCC**: Mesoscale Convective Complex---Much more restrictive
  - Cloud tops colder than -32C over $\geq$ 100,000 km^2 (r = 180km) ***AND***
  - Cloud tops colder than -52C over > 50,000 km^2 (r = 125 km)
  - Both sizes last longer than 6 h
  - Eccentricity $\geq$ 0.7 at maximum extent



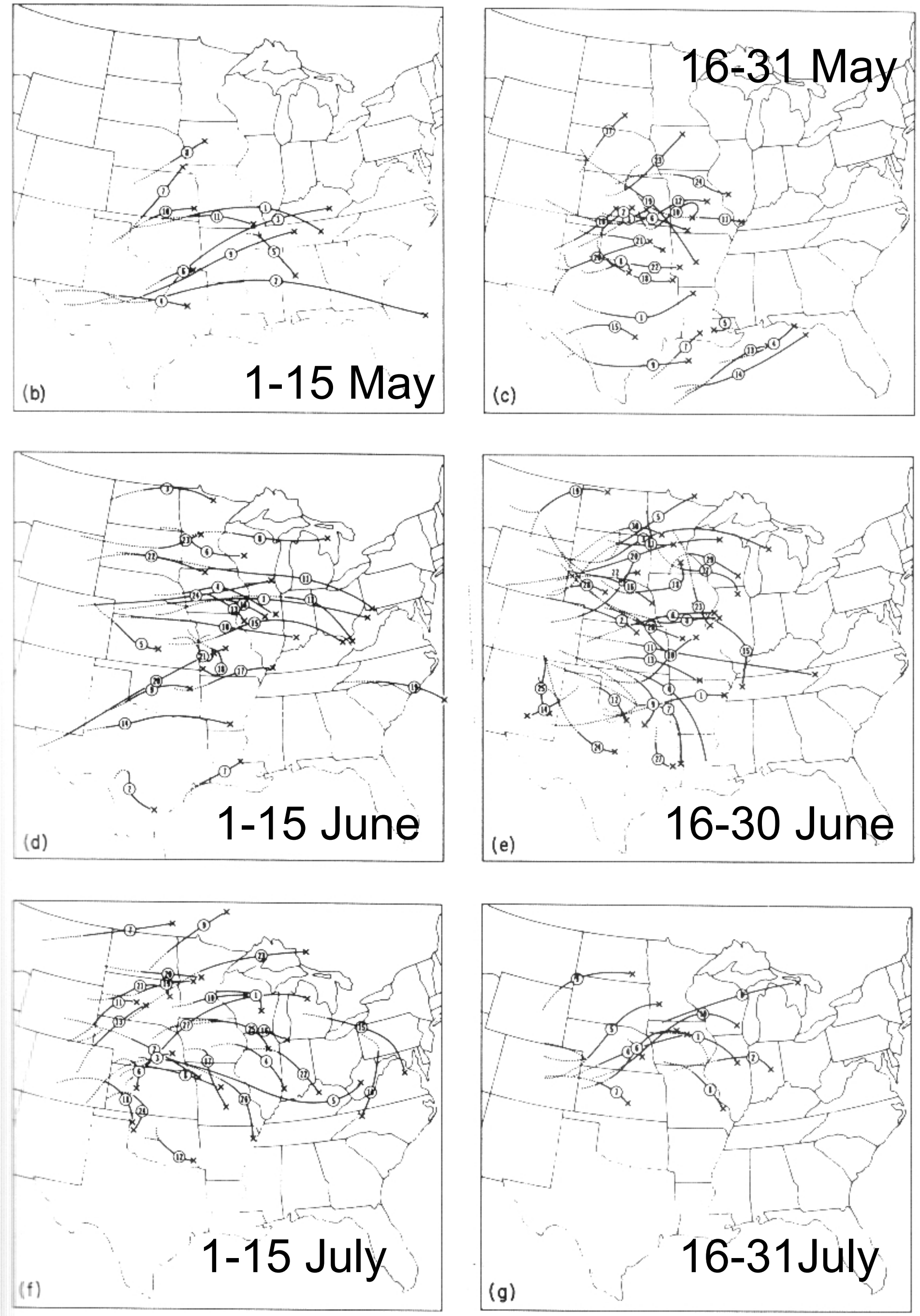
Properties of MCCs

- First detected in satellite imagery
- Climatology derived from satellite tracking
- Produce significant, beneficial growing-season rain over wheat & corn belts
- Also cause locally intense rain and flash flooding
- Usually known for damaging winds and lots of lightning, also can produce tornadoes/hail
- One in 4 causes injury or death
- Tend to move with the 700-500 mb winds

IR Satellite



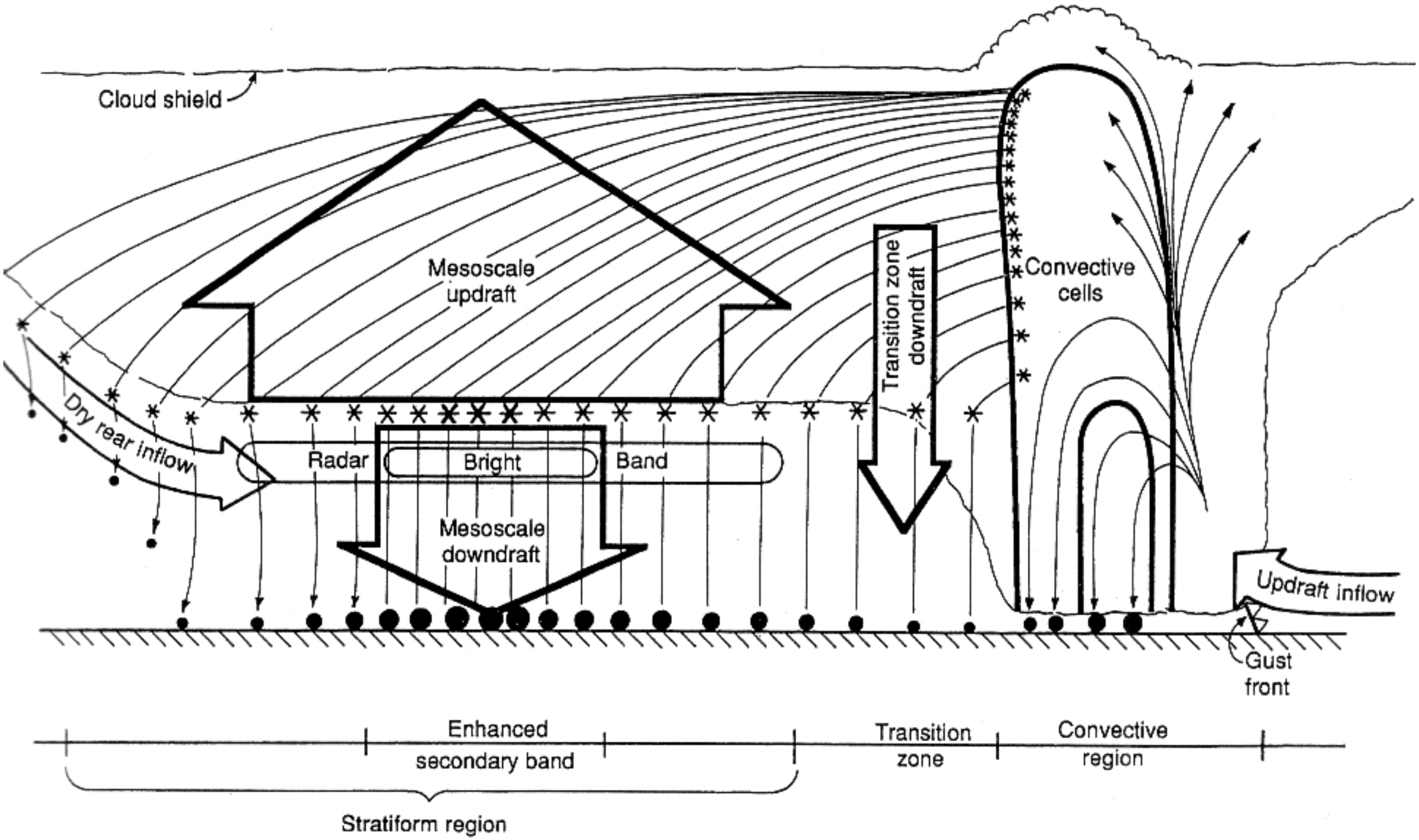
MCC Tracks 1978-1982



Formation

- Form from
  - Mergers of individual cells
  - Old squall lines
- Many start where the plains rise to the foothills of the Rockies
- Preferred location shifts northward as season progresses
- Rare on East Coast and West of the Rockies
- Half form west of Lon. 100 W, half between 90 & 100 and only a few east of 90W

Stratiform & Convective Precipitation



MCC Life Cycle

- Storms form in Plains during mid-day (usually ahead of a low-pressure system)
- Storms start out as individual cells, later merging into a large cluster
- Propagate east over the plains following 500-700 mb winds
- Reach maximum size around midnight – 4 AM
  - When the nocturnal low-level jet is strongest
- Can persist into morning hours

Life Cycle, cont.

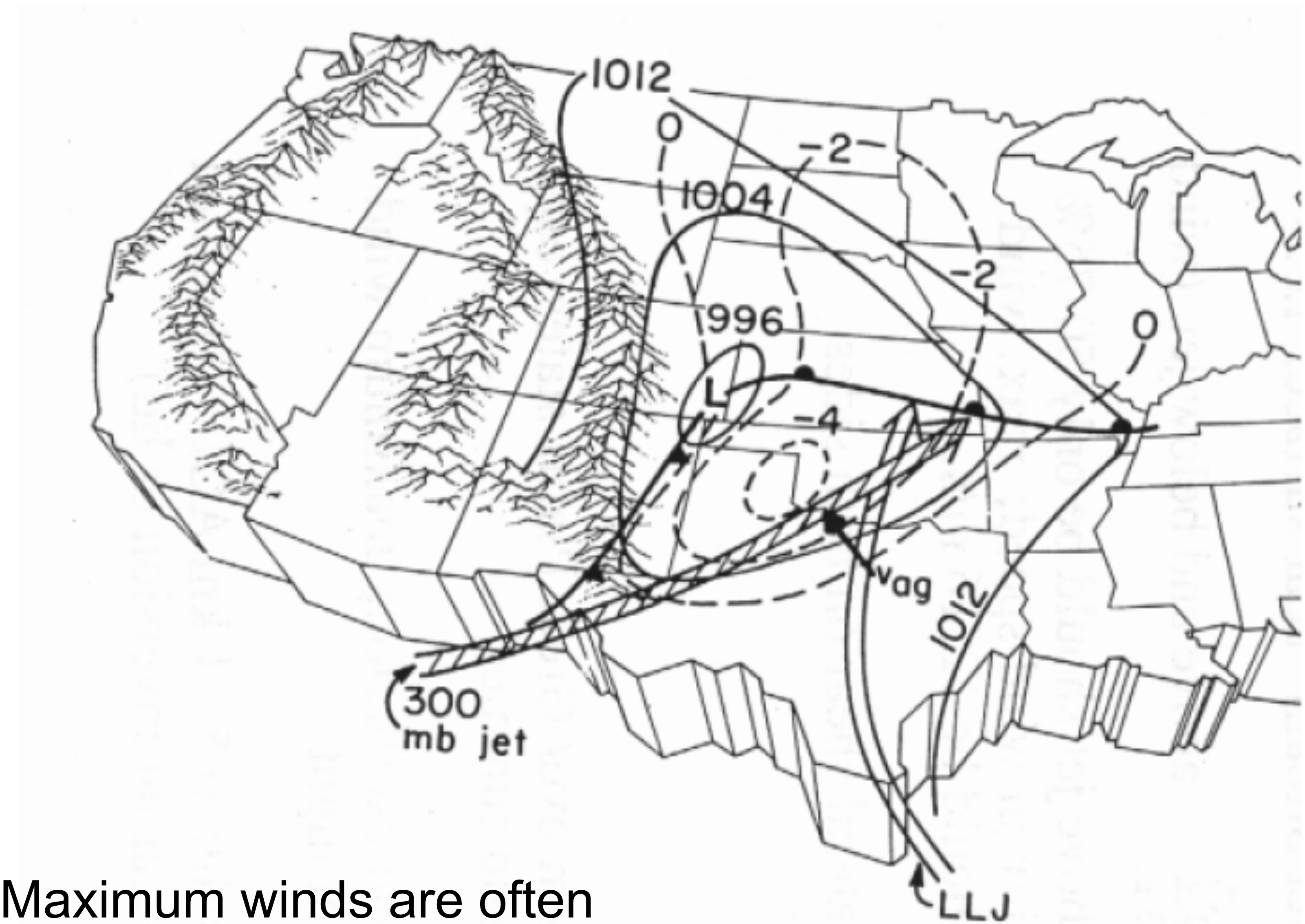
- **Stages:**
  - **Initiate:** First storms to continuous cloud shield that meets size criteria
  - **Development:** From initiation to maximum size
  - **Mature:** Maximum extent until size criteria no longer met (termination)
  - **Dissipating:** Termination until new convection ceases to form
- Leftover outflow boundaries serve as focus point for convective initiation the next day
- A nightmare to forecast:

  1. Initiation and movement are difficult to predict

  2. Lingering cloud cover/outflow boundaries can change location/intensity of new storms the next day

Nocturnal Low Level Jet (LLJ)

- Fast ribbon of warm, moist air moving north from Gulf of Mexico to Central Plains
- Located above nocturnal boundary layer (~925 mb)
- Develops after sunset, max around 2 AM, persists into morning hours
- Caused by radiational cooling, which creates a thermal wind gradient between high and low elevations
- An essential ingredient for sustaining MCCs after diurnal heating disappears
- For more info: http://twister.ou.edu/MM2005/Chapter2.3.pdf



•Maximum winds are often supergeostrophic in LLJ

Global View of MCC Formation

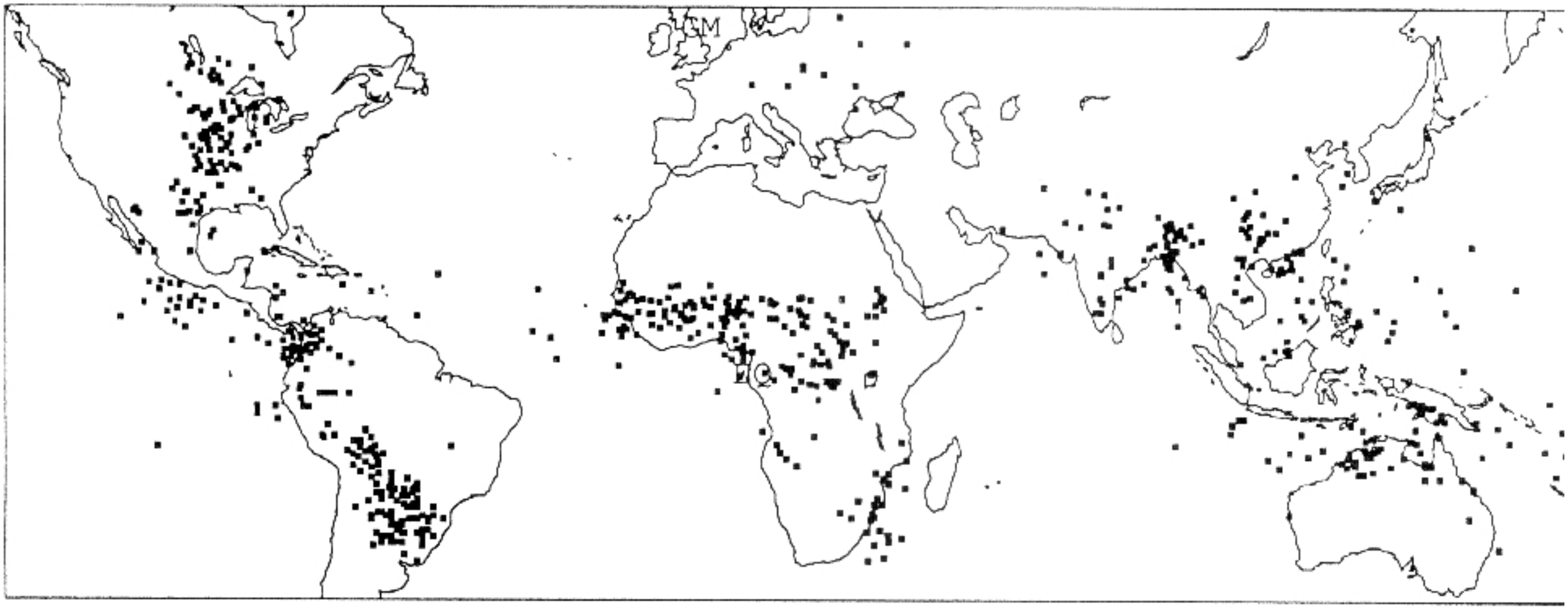


FIG. 9.2. Locations of MCCs based upon 1–3-yr regional samples of satellite imagery (from Laing and Fritsch 1997). Locations are shown for the time of maximum extent of the cold-cloud shield. Additional data concerning the samples are given in the appendix.

Mostly over land
Elongated belts in easterlies & westerlies
Generally downstream of N-S mountains

MCC Environmental Interaction

- Upper-air data shows that MCCs warm and moisten their environment
- Conditionally unstable atmosphere ahead of MCCs
- Veering of wind overnight increases warm inflow and influx of unstable air
- Moist air around convective elements decreases downdraft strength and increases precipitation efficiency
- MCCs usually die when the LLJ fades out around 8-10 AM.

What's Really Happening With MCCs?