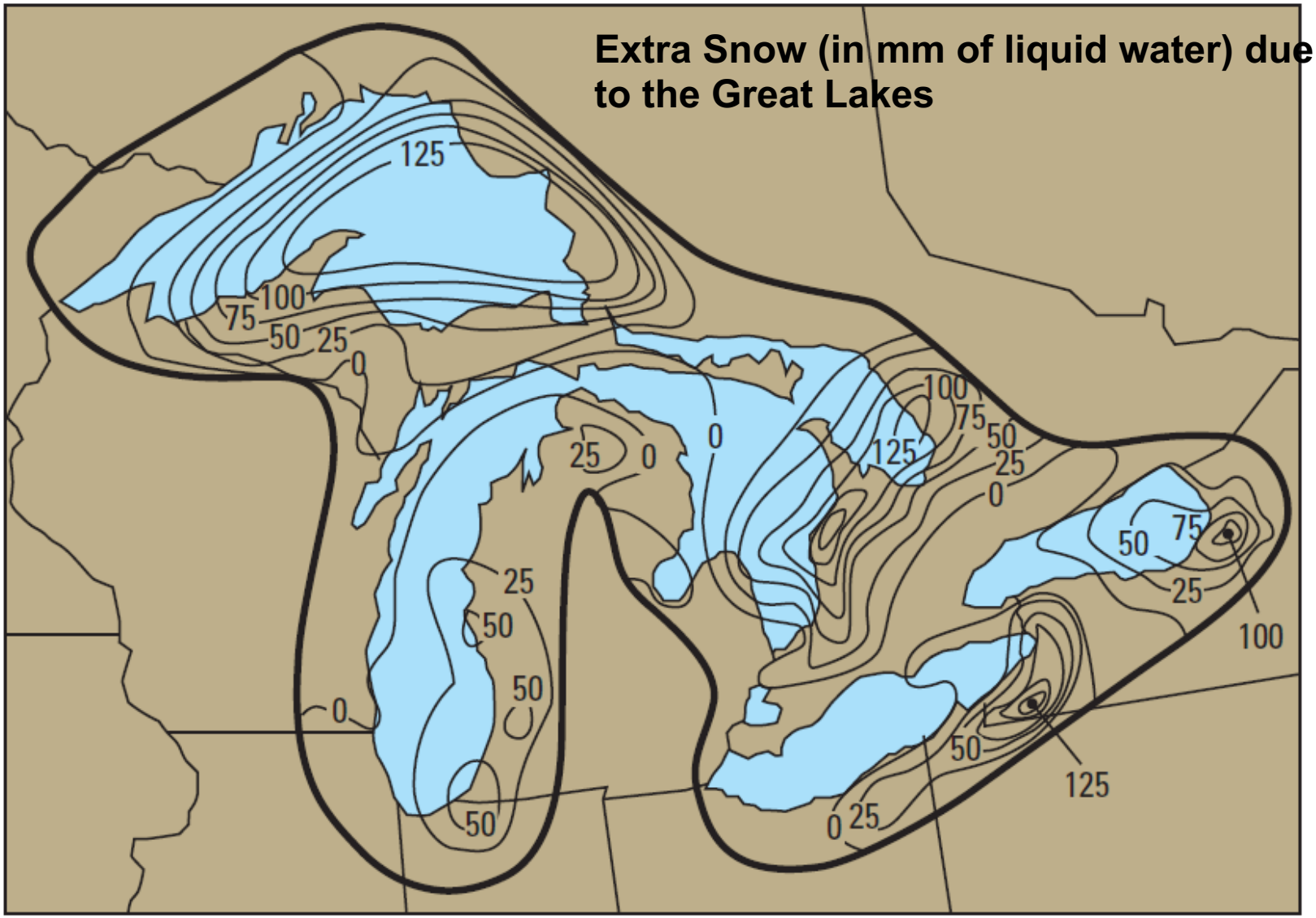
MET 4300

Lecture 13
Lake-Effect Snowstorms
(CH13)

Lake Effect Storms

- Downwind of the Great Lakes, Great Salt Lake, etc.
- Cities in lake-effect snow belts: Syracuse NY, Rochester NY, Buffalo NY, Cleveland OH, Erie PA, London, Ontario..
- Produce a Lot of Snow: up to 1-5 feet
- High cost on snow removal and bad driving conditions & no school/work days

- Mainly between the lake shores and 50-80 km inland

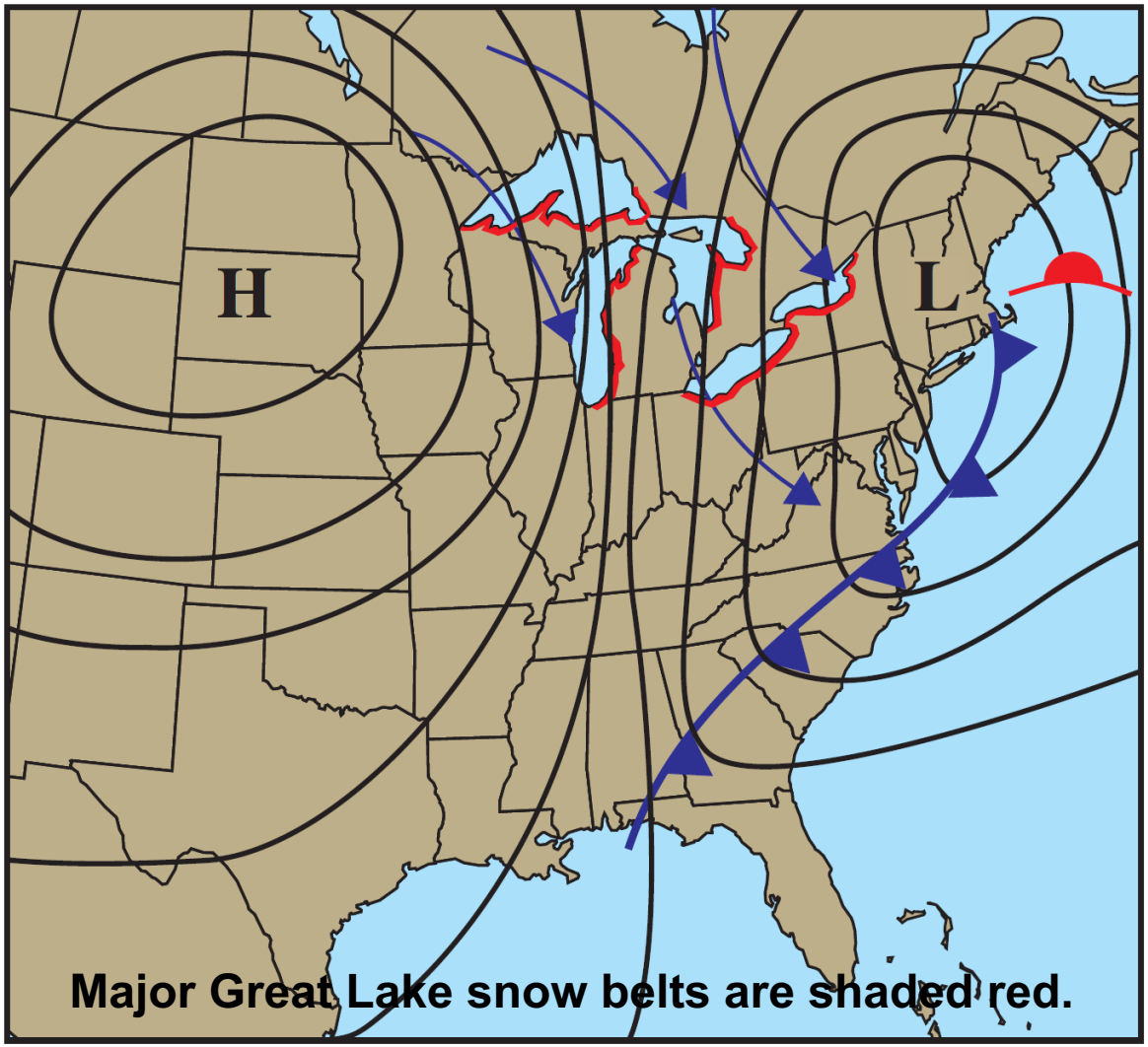


Geography of the Great Lakes

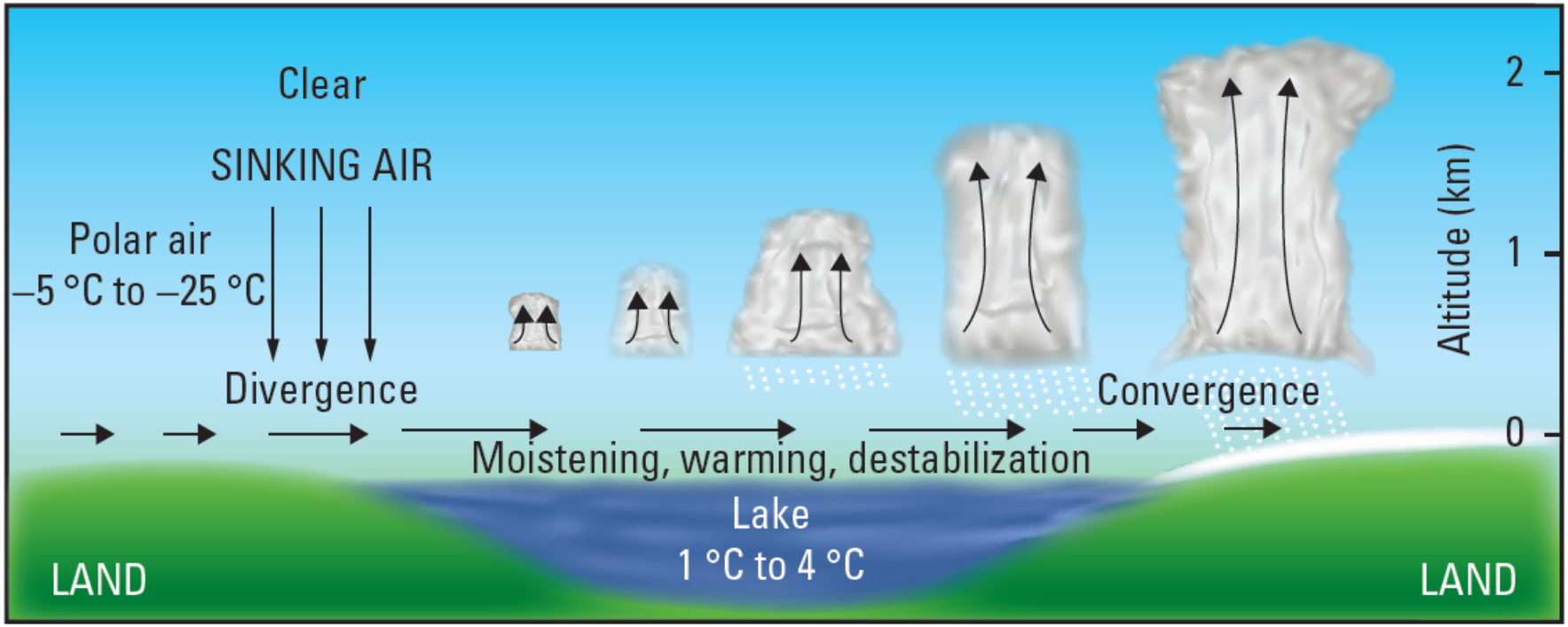
U.S. Army Corps of Engineers, Detroit District

Typical Lake Effect Weather Pattern

- After an extratropical cyclone has passed over and the cyclone's cold front is well east of the Great Lakes
- Cold air behind the front then flows SE across the lakes
- An artic high in central US will enhance it.
- Most often Nov-mid-Jan: air is very cold but the lakes are warm and ice free



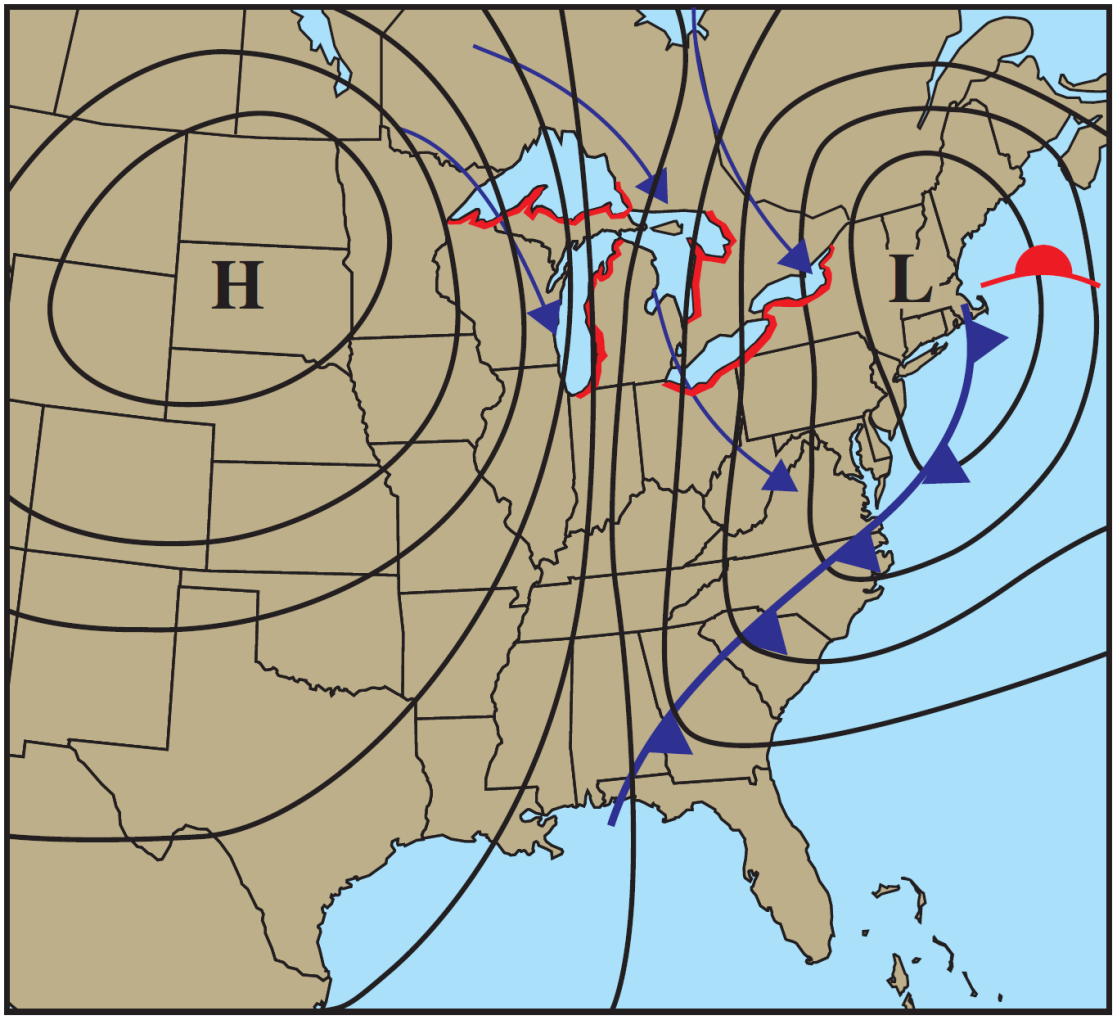
Physical Basis of Lake-Effect Storms



- Air, initially much colder than 0°C, blows across lake water that is near 0°C. The air accelerates due to less friction on the water.
- Divergence occurs near the surface along the upwind shoreline, sinking, clear.
- When cold air moves over the warm lake, it is warmed (can warm as much as 20°C), then moistened, and destabilized.
- Clouds begin to form soon after air moves out over the lake, growing closer to the downwind shoreline (shallow clouds), causing heavy snowfall (snow squalls) on the lee (usually E or S) shore of the lake.
- At the downwind shore, frictional convergence and topographic effects trigger more clouds & snow

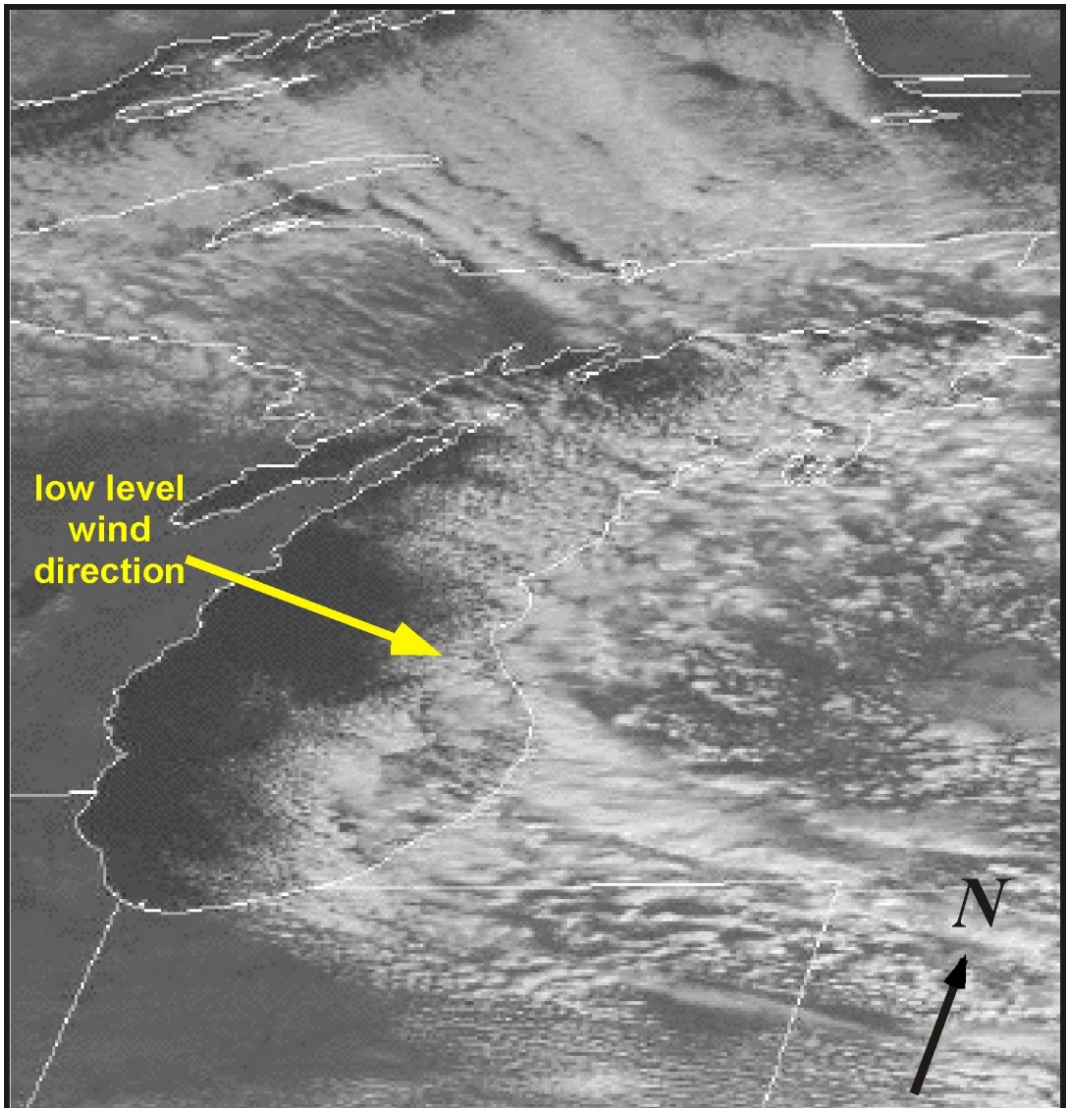
How about the N & W shores?

- Typically, the temperature difference between the lake and the air flowing over it needs to be >= 10°C to form lake-effect snow
- Winds from S & E are mild and warm, not enough temperature difference



Visible Satellite Image of Lake Michigan & Southern Lake Superior

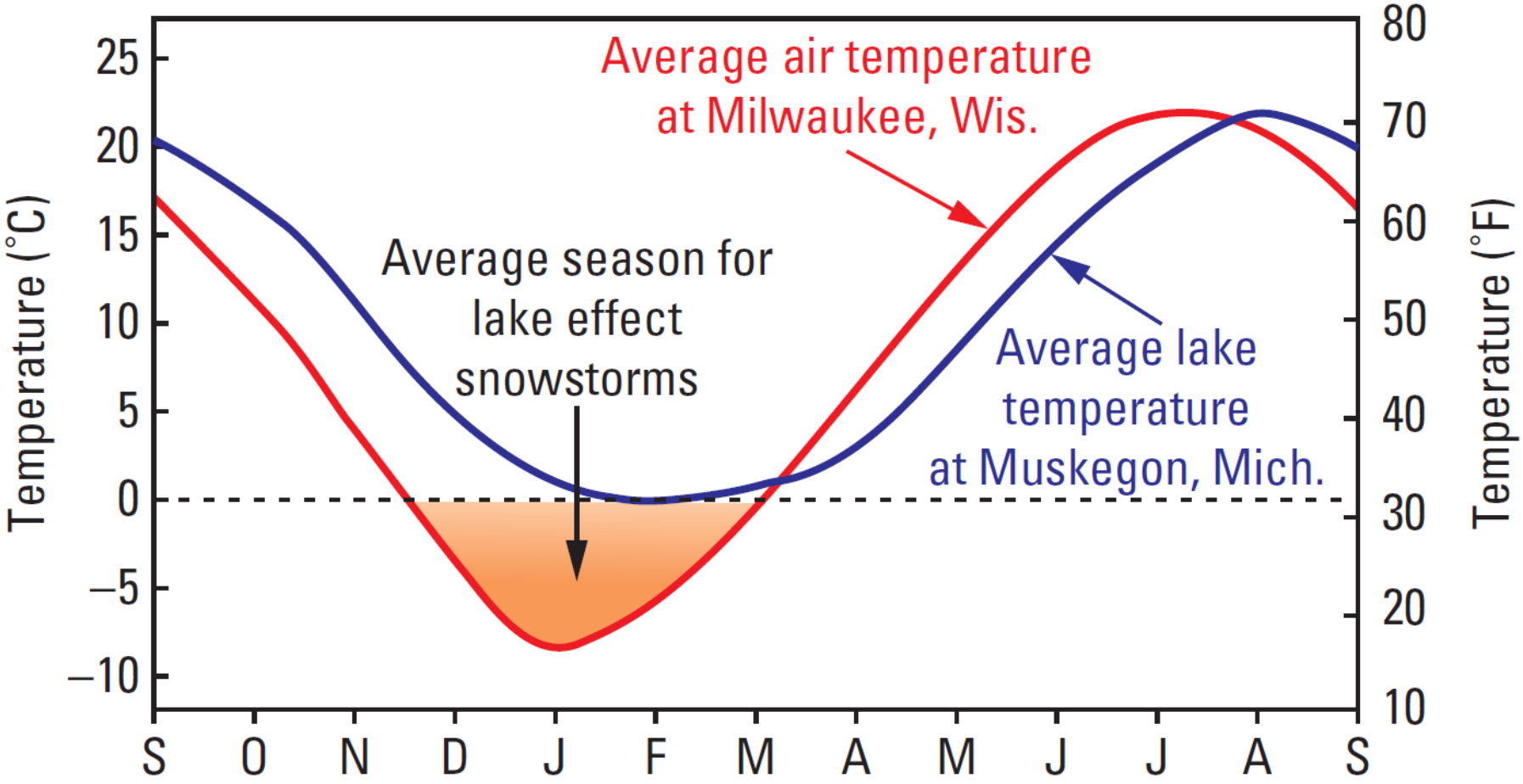
- Clouds are on the downwind shore
- Northern & western shores are usually free of clouds & snow



Climatology of Lake-Effect Snows

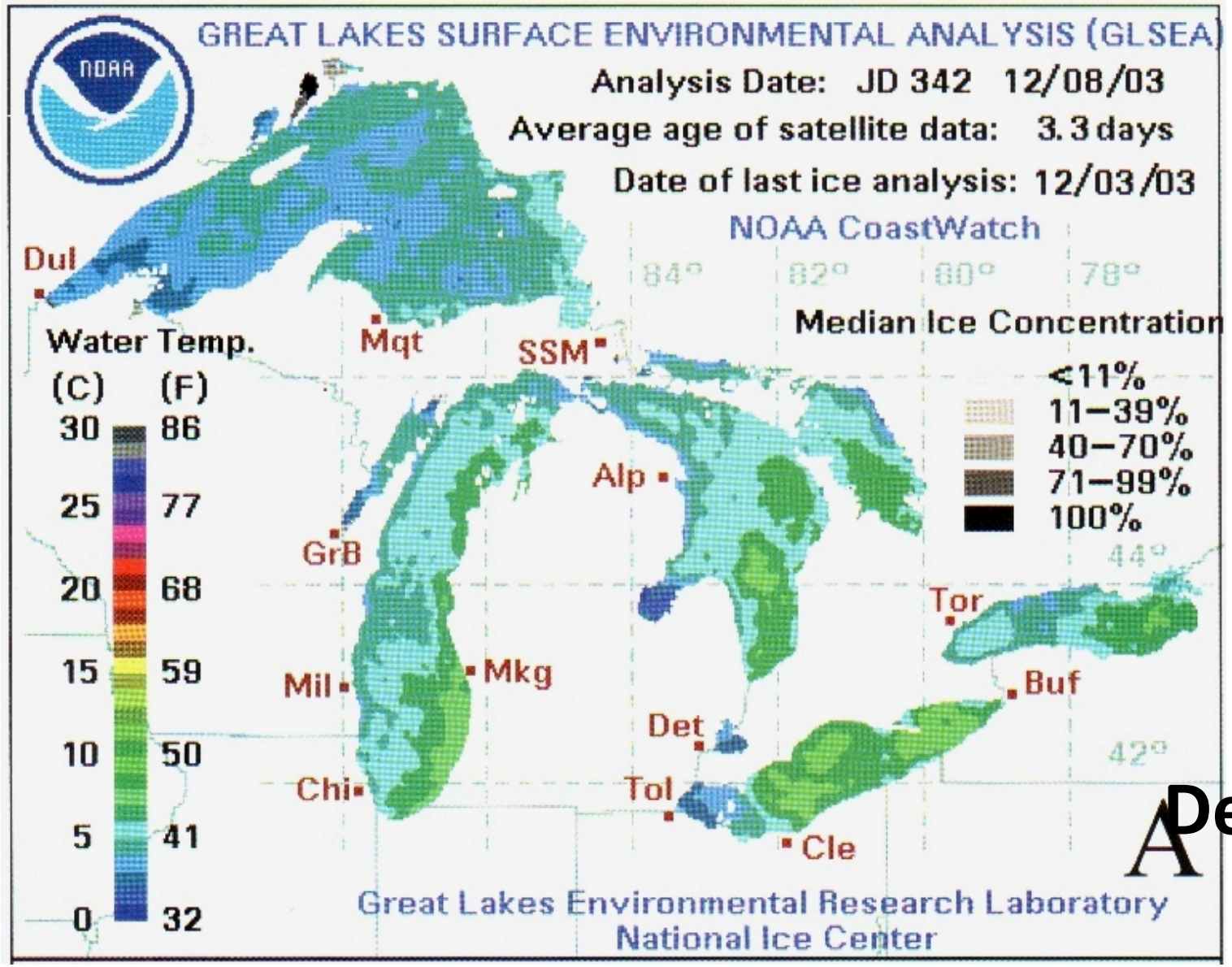
- The amount of snow depends on the temperature of each lake, the temperature of air about to cross each lake, the wind direction, the wind speed, the amount of ice cover on each lake, and the topography downwind of the lake.
- The larger the air-lake temperature difference, the likelihood of a lake-effect snowstorm increases.

Seasonality of Lake Effect Storms (Lake Michigan as an example)



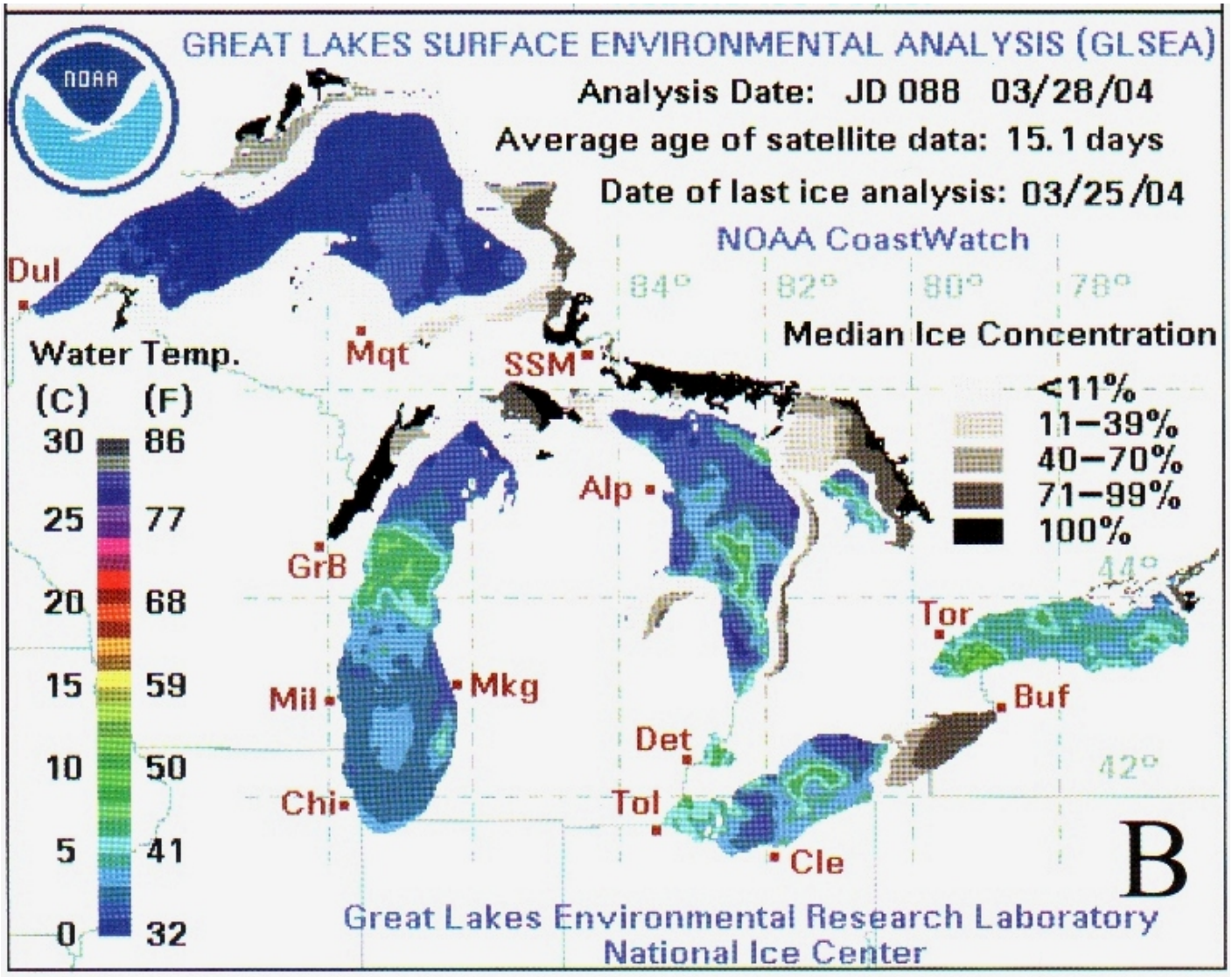
Effect is greatest when the lake-air temperature difference is largest (at least 10 deg warmer) and the lake is not frozen (Late December & early January).

Lake temperature and ice concentrations of the Great Lakes estimated from satellite measurements



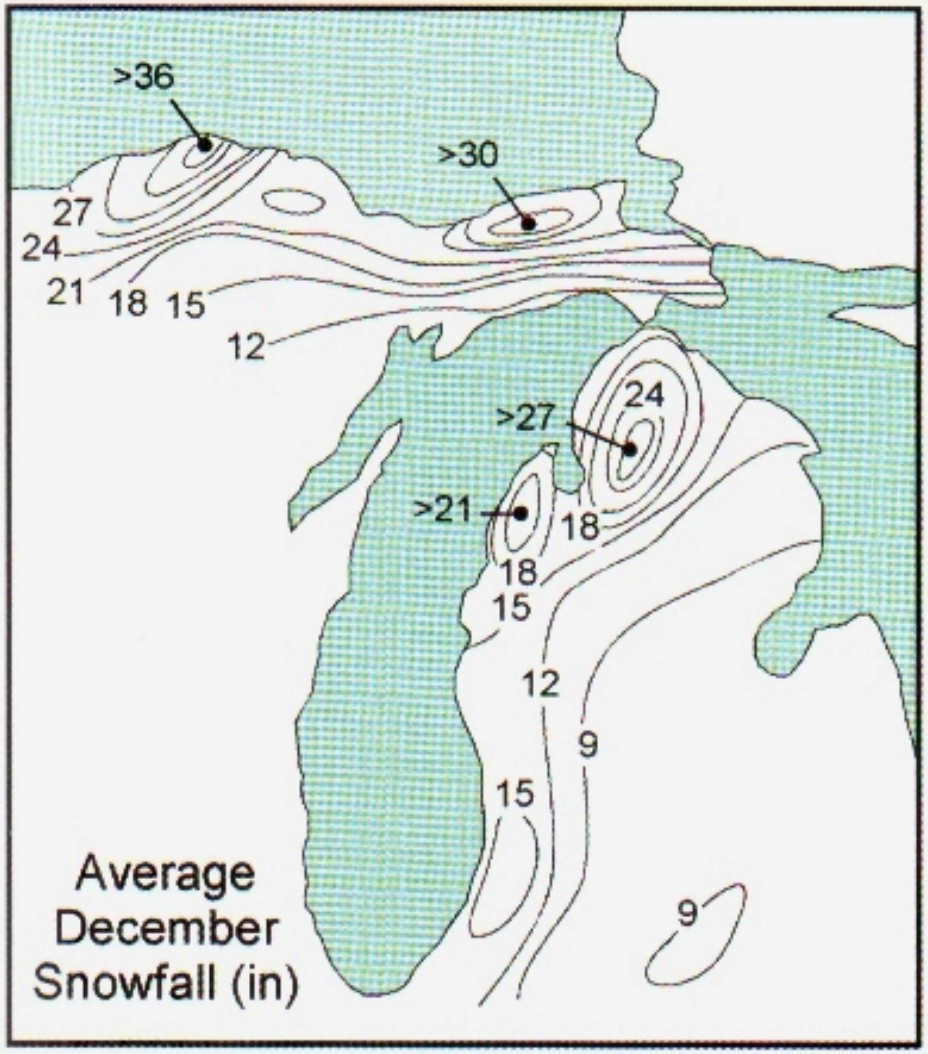
A December 2003

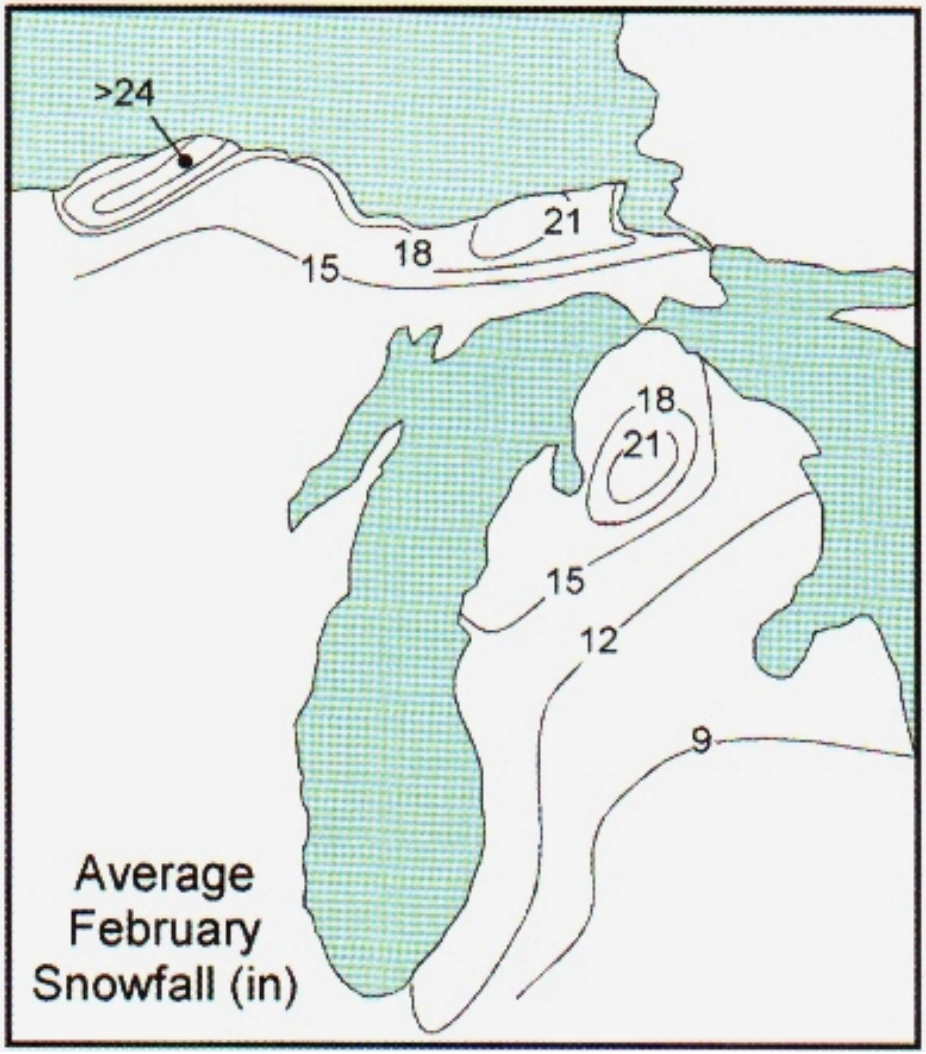
March 2004



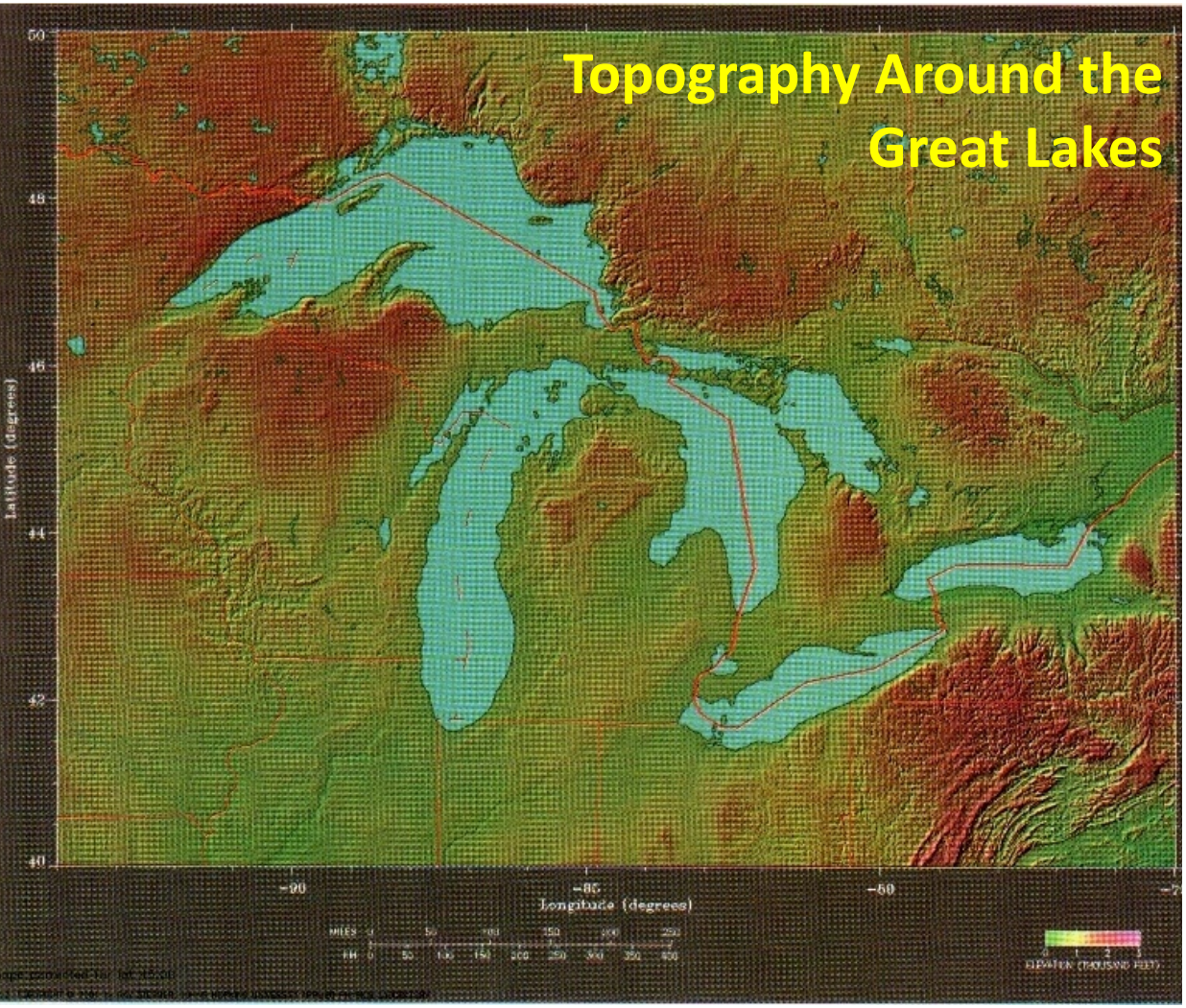
- More extensive ice cover in March, particularly over lake Erie
- In general, the lakes are the coldest in February

Effect of Lake Temperature and Ice Cover on Snowfall: more snow in Dec over Lakes Superior & Michigan



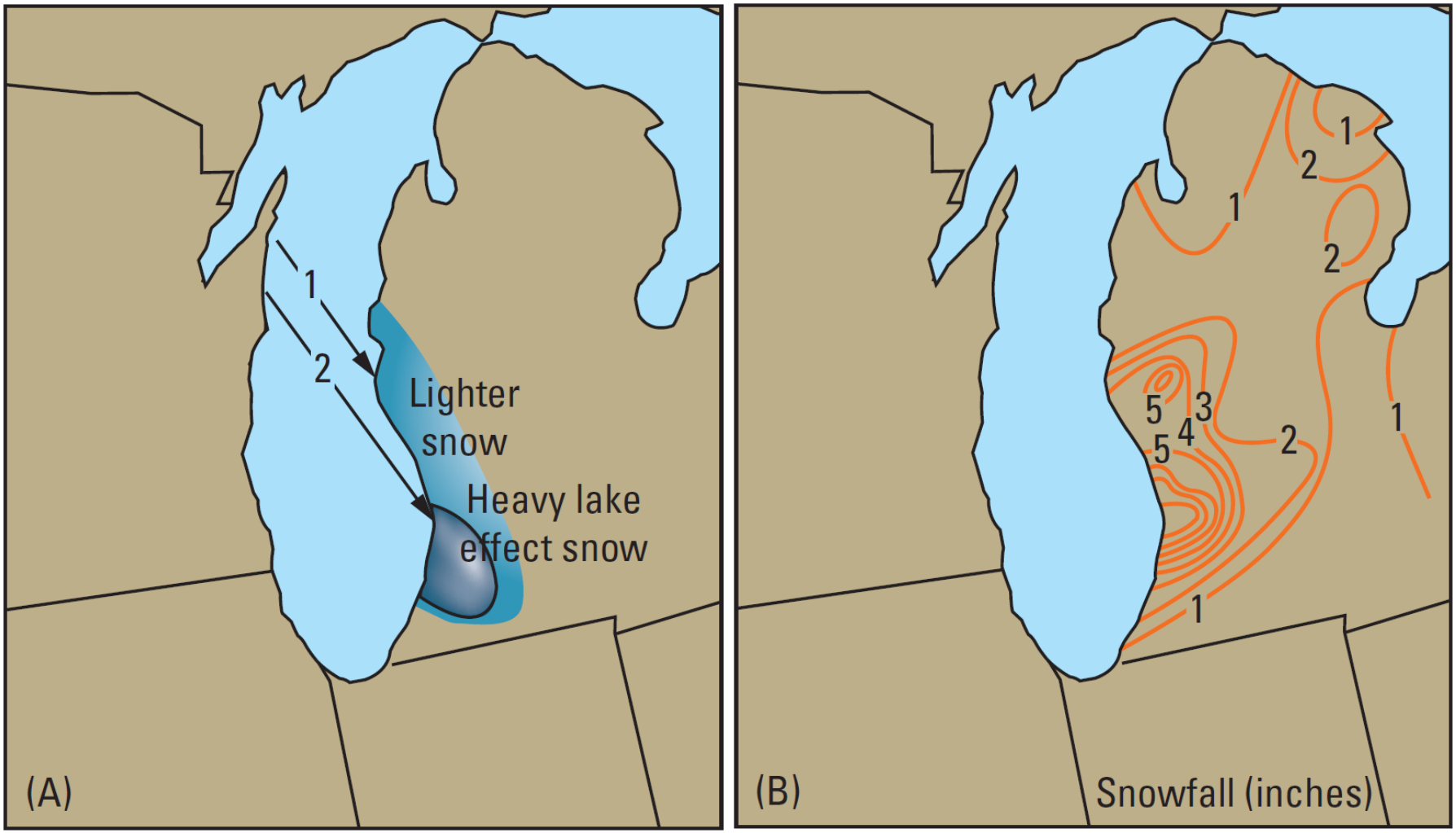


Topography Effect: enhance snowfall



- Tough terrain enhances surface friction, therefore, increasing convergence and lifting on the downwind side of the lake
- The hills force air to rise → upward motion

Effect of Over Water Trajectory on Snowfall (residence time)

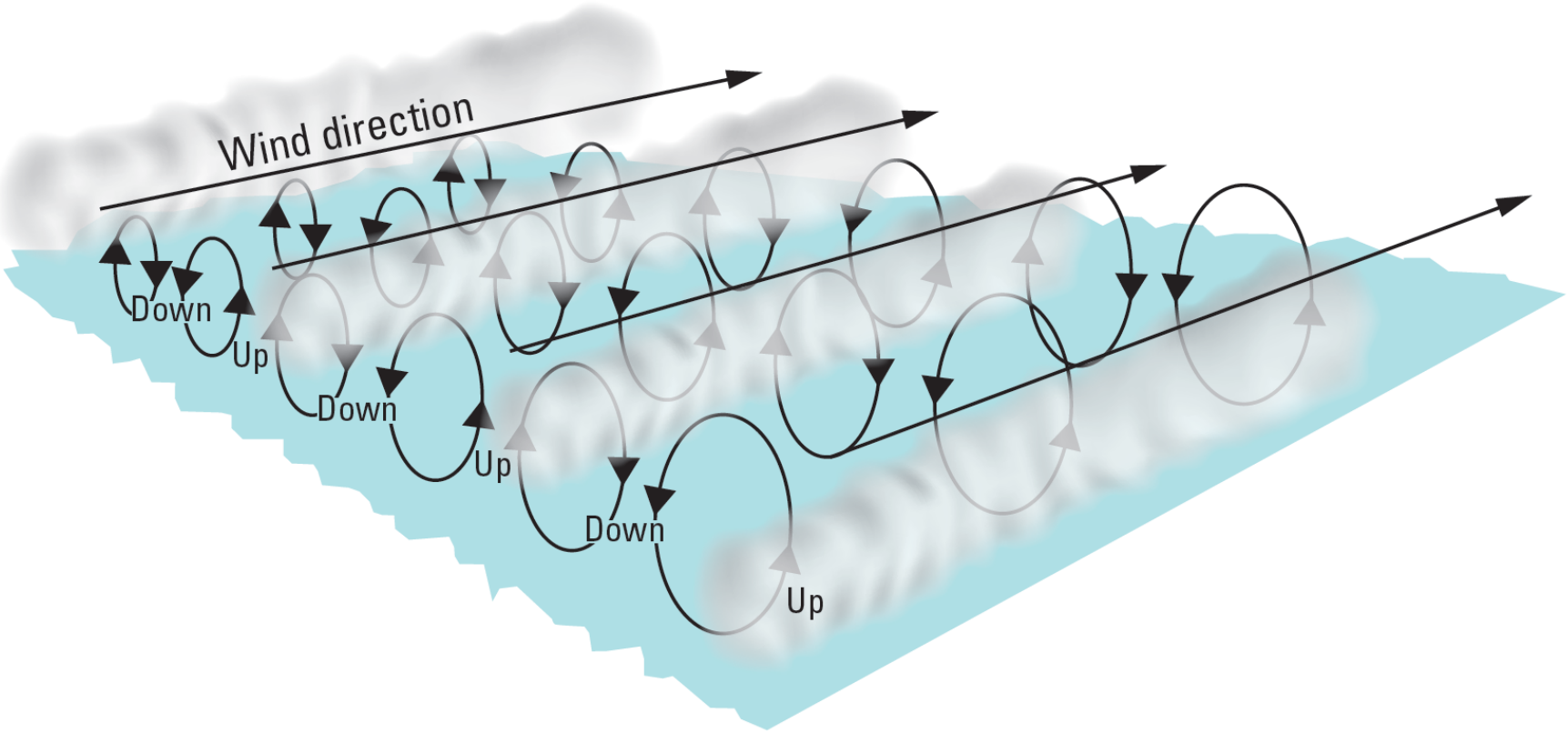


Organization of Lake-effect Snowfall

Lake-effect clouds and precipitation organize in 3 primary ways:

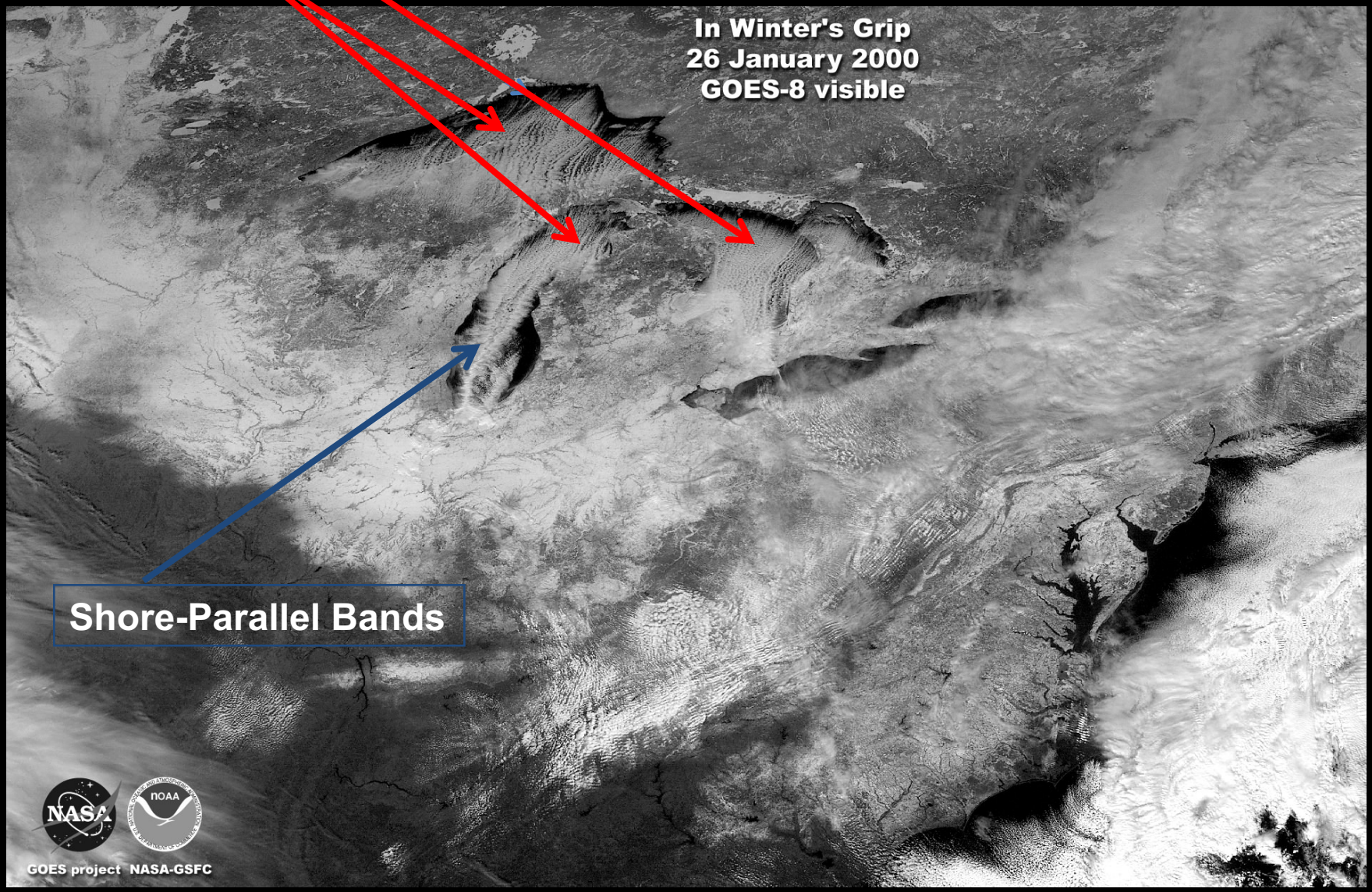
- Wind-Parallel Rolls
- Shore-Parallel Rolls
- Vortices

Wind Parallel (sort of) Rolls in Lake Effect Storms

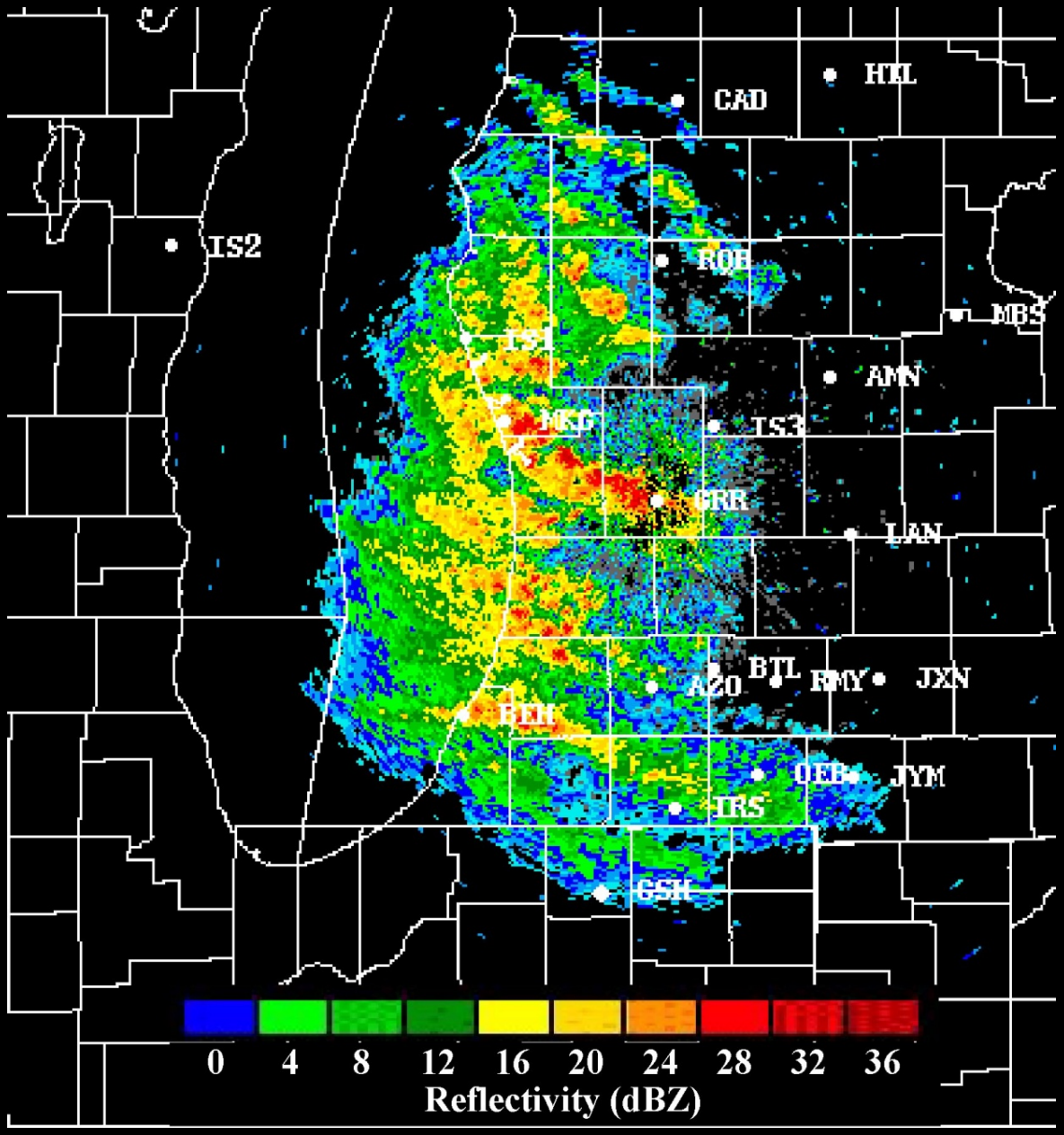


- In cases where winds are strong and blow with a component parallel the short axis of a lake, heat transfer between lake & air will cause air to rise. Due to compensation, Warm air rising → cooler air must sink → form rolls like the image above.
- Rolls are actually parallel with the vertical wind shear across the surface mixed layer; clouds in the upward branches in 1-2 km wide and spaced about 4-6km.

Wind Parallel Rolls Over the Great Lakes

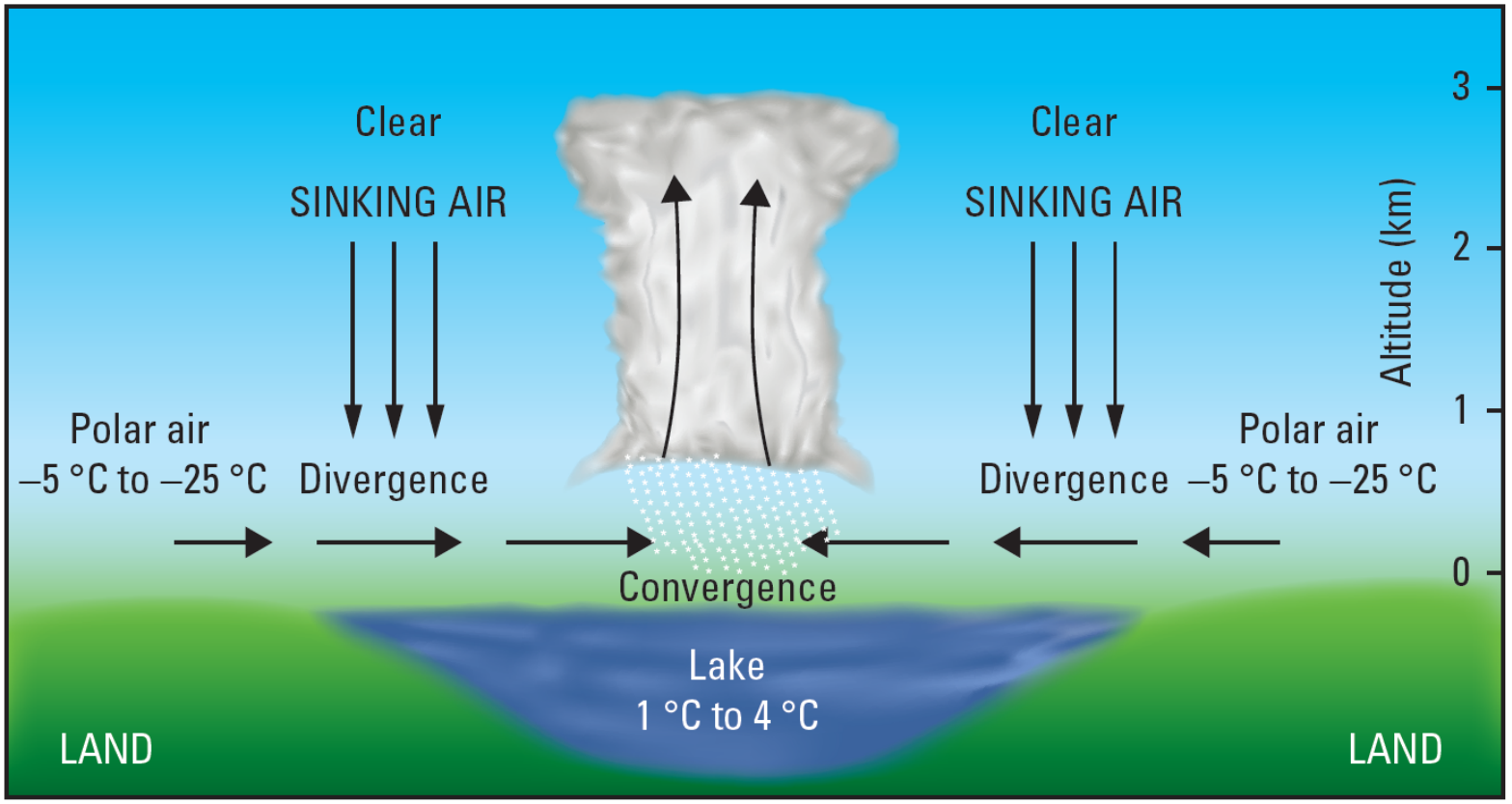


Wind Parallel Rolls over Lake Michigan



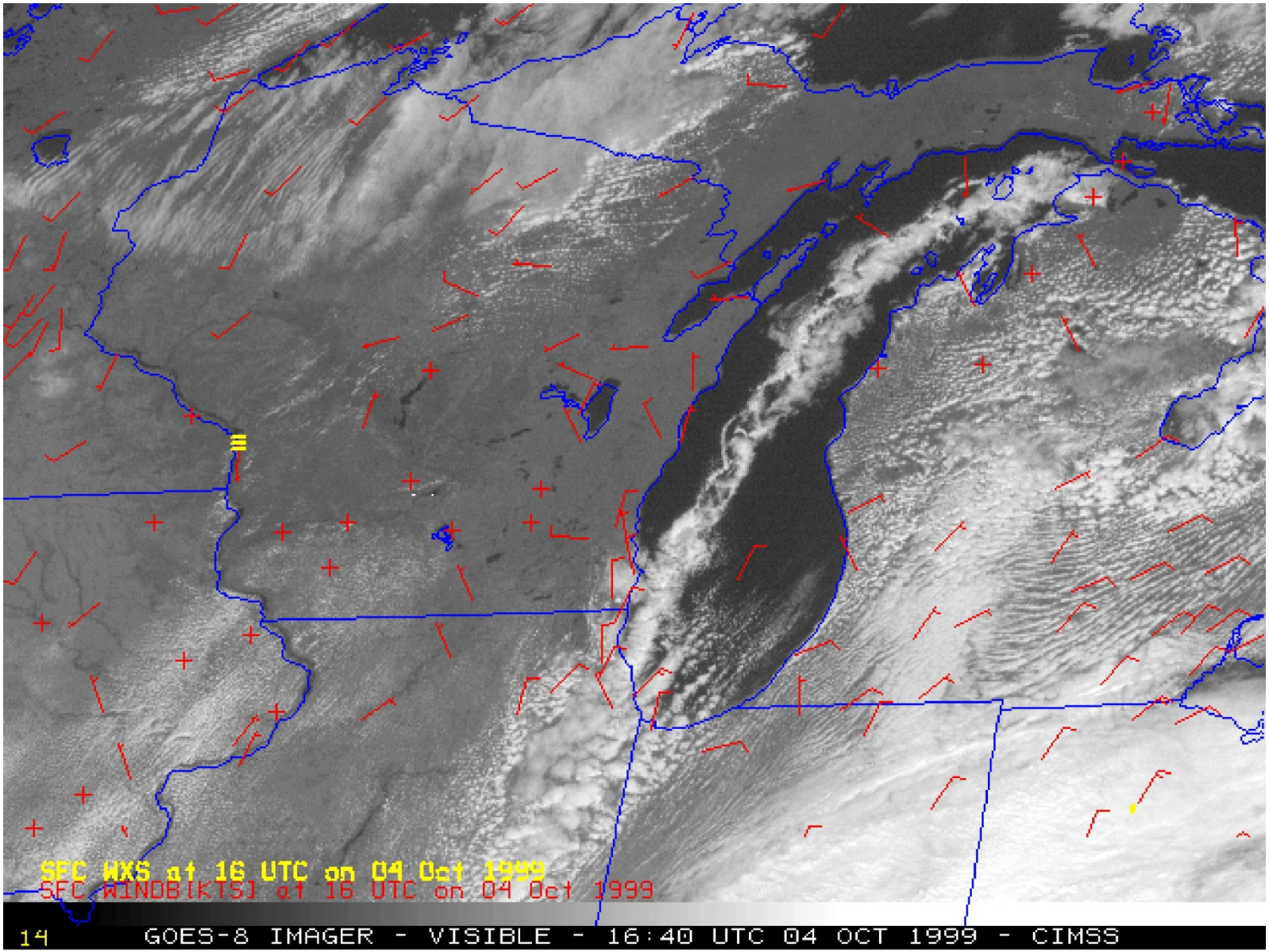
Note: Band horizontal dimensions are typically a 1-10 km

Shore Parallel Bands



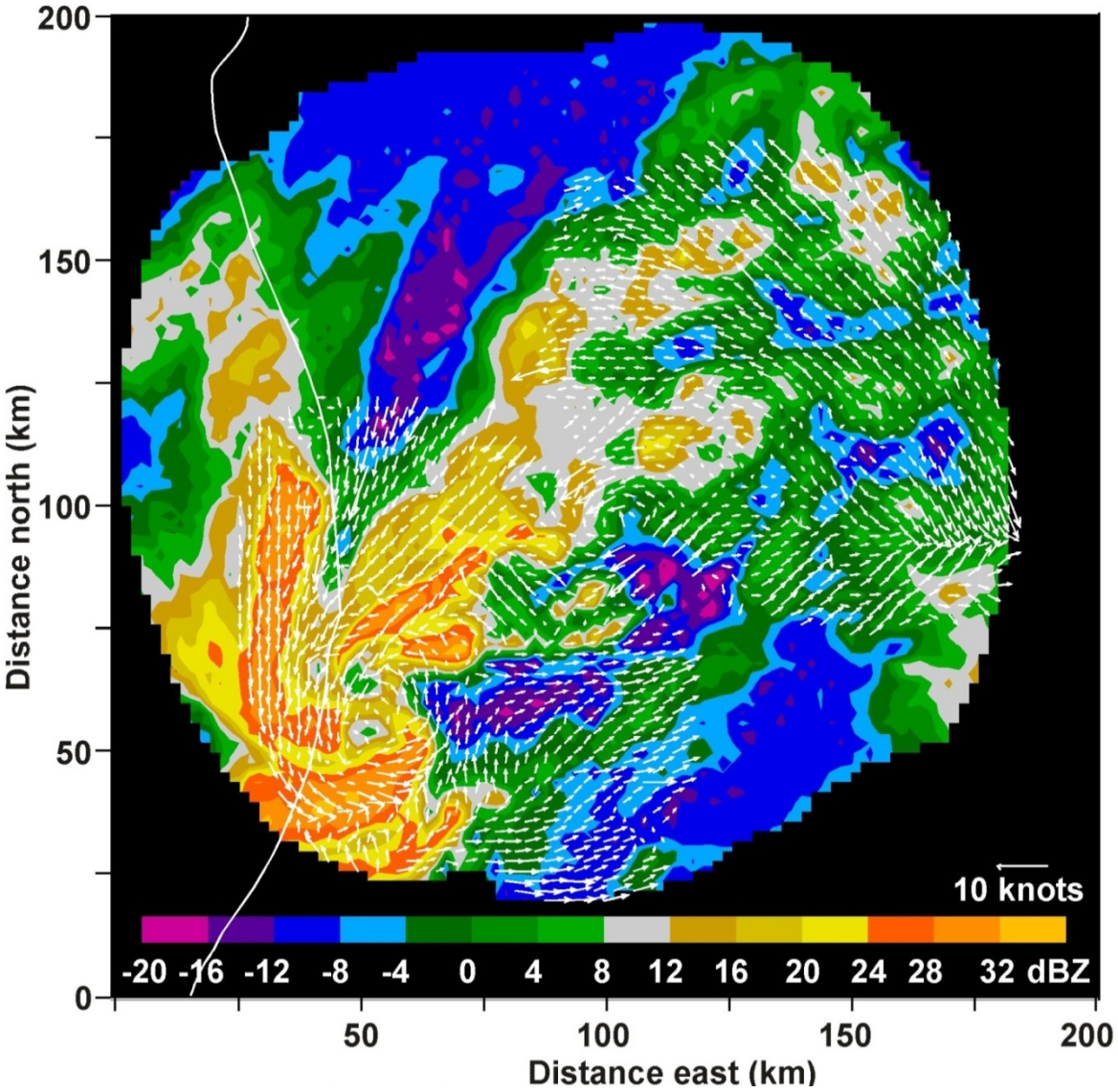
- **Form in weaker winds than wind-parallel bands: the heat of the lake forces air over to rise, drawing air in from both shores toward the centers of the lake**
- **It also could form when the wind is strong, but blows parallel with the long axis of the lake**
- **Often larger in horizontal extent and deeper**
- **Driven by buoyancy due to heat extracted from the lake**
- **Can drop a lot of snow on the lee shore**

Shore-Parallel Band Over Lake Michigan

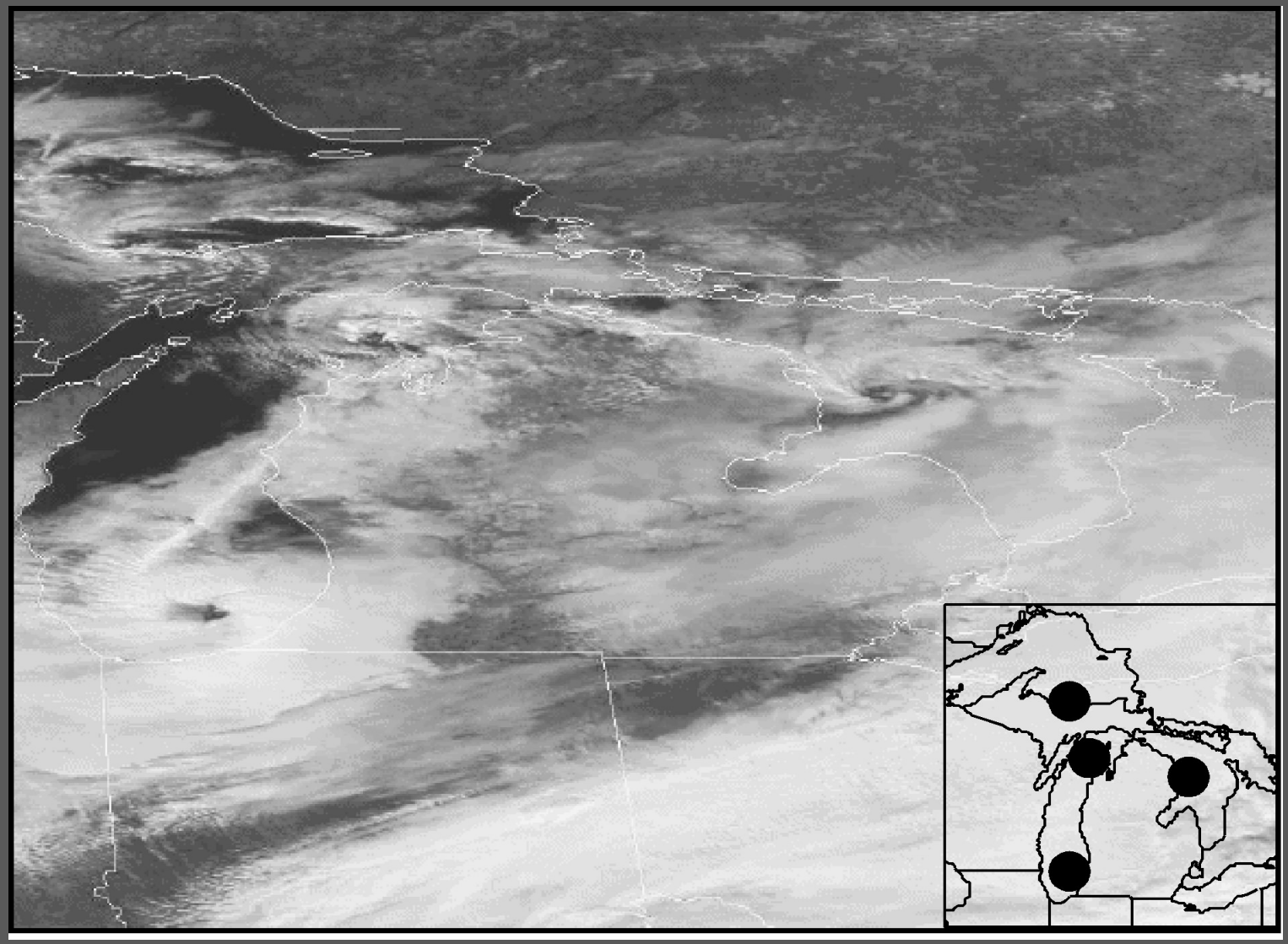


Lake Effect Vortices

- Often form near shore
- Drift slowly downwind
- Formation is not well understood, related to wind shear, wind speed, Stability, temperature difference?
- Similar to hurricane structure: eye, eyewall, spiral bands, but not winds (not stronger than 5-15 kts); Diameter between 10-100 km.
- snow bands can deliver heavy snow over shore.



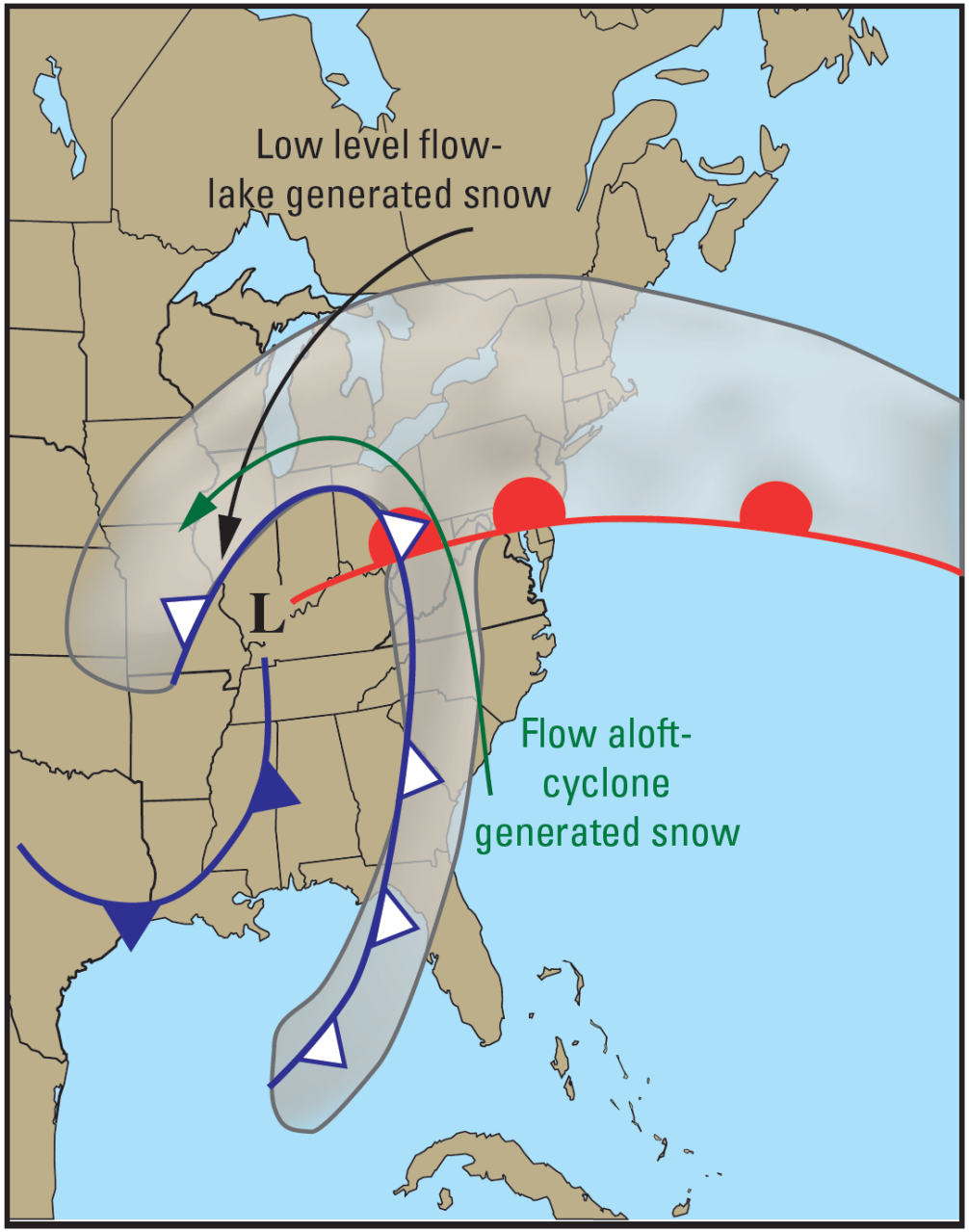
Four Vortices at the same time



Fraom Laird, N.F. "Observation of Coexisting Mesoscale Lake-Effect Vorticles over the Western Great Lakes," *Monthly Weather Review,* 127(1999):1137–1141, Courtesy American Meteorological Society, Reprinted with permission.

Lake- Enhanced Snowfall (Chicago)

Lake effect increases snowfall that would occur without the lakes during a cyclone passage



Summary

- Lake Effect: Air much colder than 0^{o}C blows across an unfrozen lake
  - Interaction moistens, warms and destabilizes it
  - Causing heavy snowfall on lee shore
  - Behind a cold front
  - More severe when the lake is still relatively warm and unfrozen
- Wind parallel bands: Shallow, 1-10 km horizontal extent, form in strong winds
- Shore parallel bands: Deeper, > 10 km horizontal extent, form in weaker winds
- Lake Effect Vortices…
- Lake-Enhanced Snowfall in E or NE winds