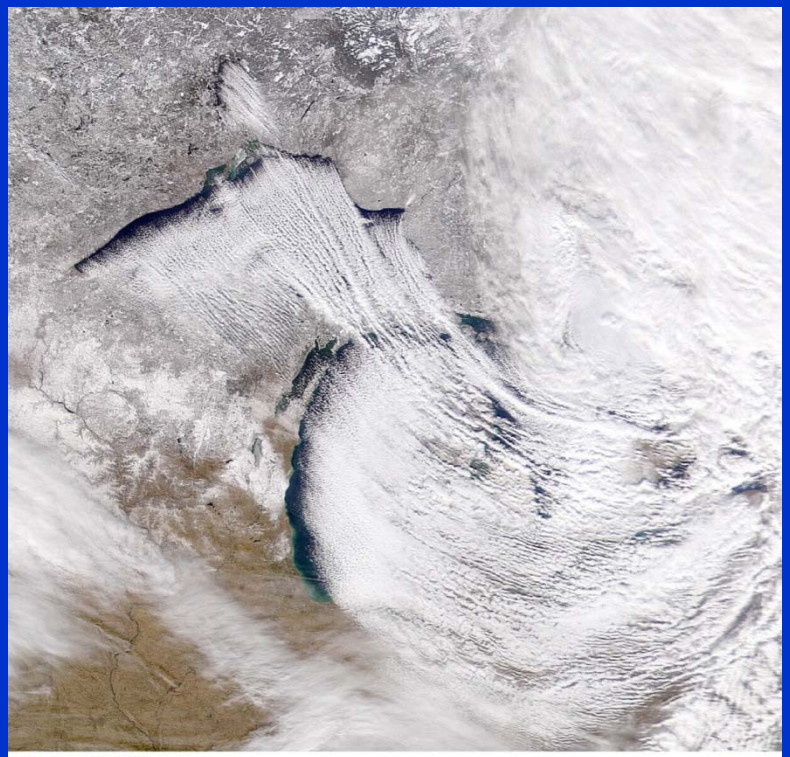
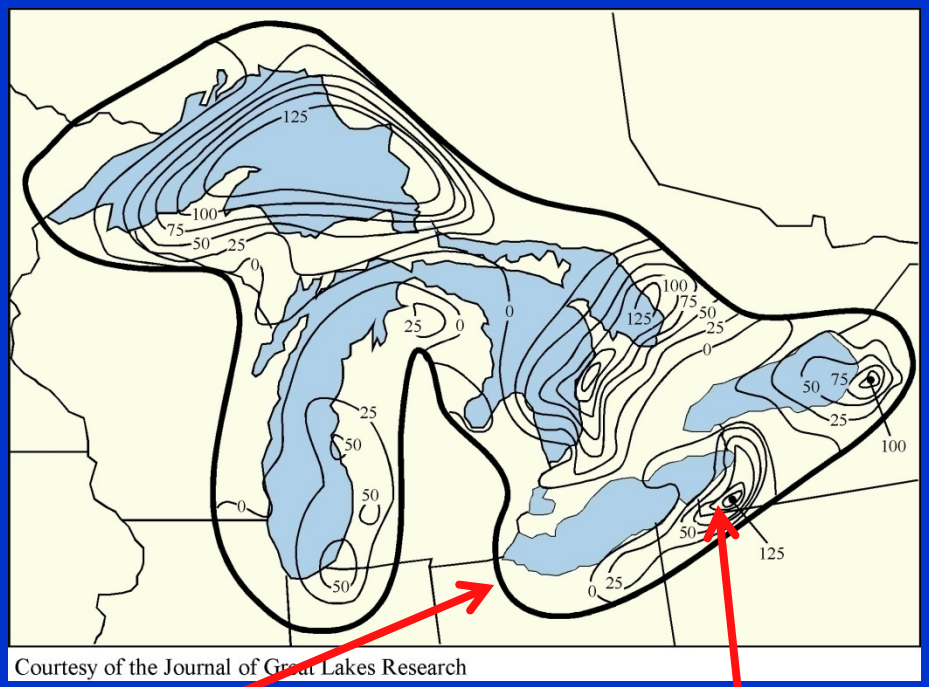
Chapter 13: Lake-Effect Snowstorms



Courtesy of NASA

- Great Lakes snow belts
- Large-scale weather pattern
- How lake-effect snowstorms develop
- How precipitation organizes within the storms

The Great Lakes Snow Belts



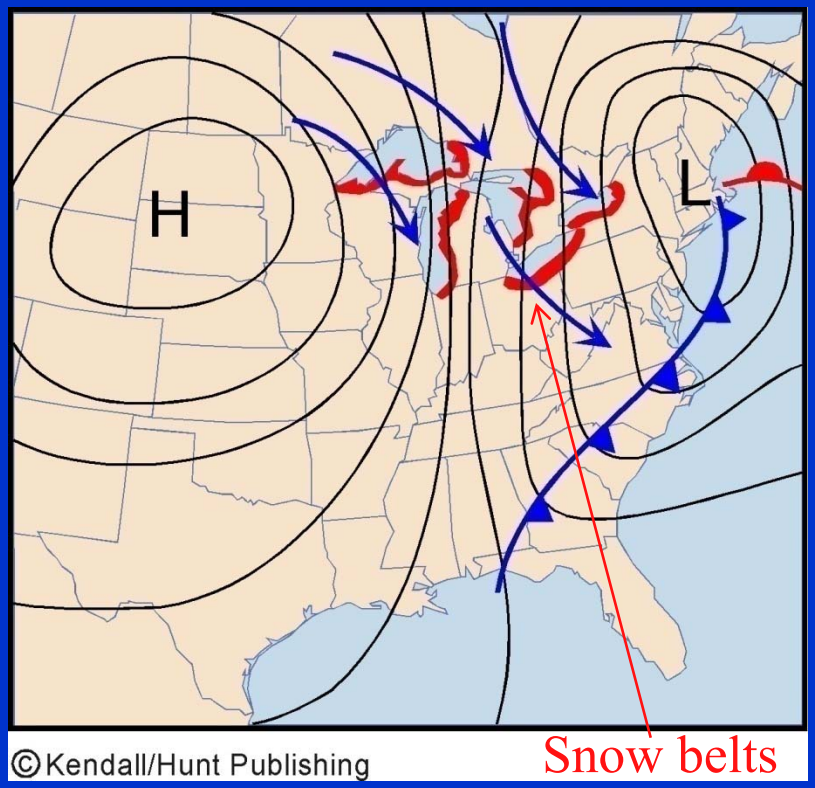
Courtesy of the Journal of Great Lakes Research

80km boundary around the shoreline

precipitation in mm

- The large cities of Syracuse, Rochester, Buffalo, Cleveland, and Ontario are all located in the lake-effect snow belts.
- Lake-effect snowstorms can produce 0.3-1.5 meters (1-5 feet) of snow in single extreme events and can continues for days.
- The great Lake snow belts cover the lake shores and about 50-80 km (30-50 miles) inland before most of the lake-supplied moisture is removed by precipitation.
- Lake-effect snowstorms can also occur near other inland water bodies, such as the Great Salt Lake in Utah and Aral Sea in Asia.

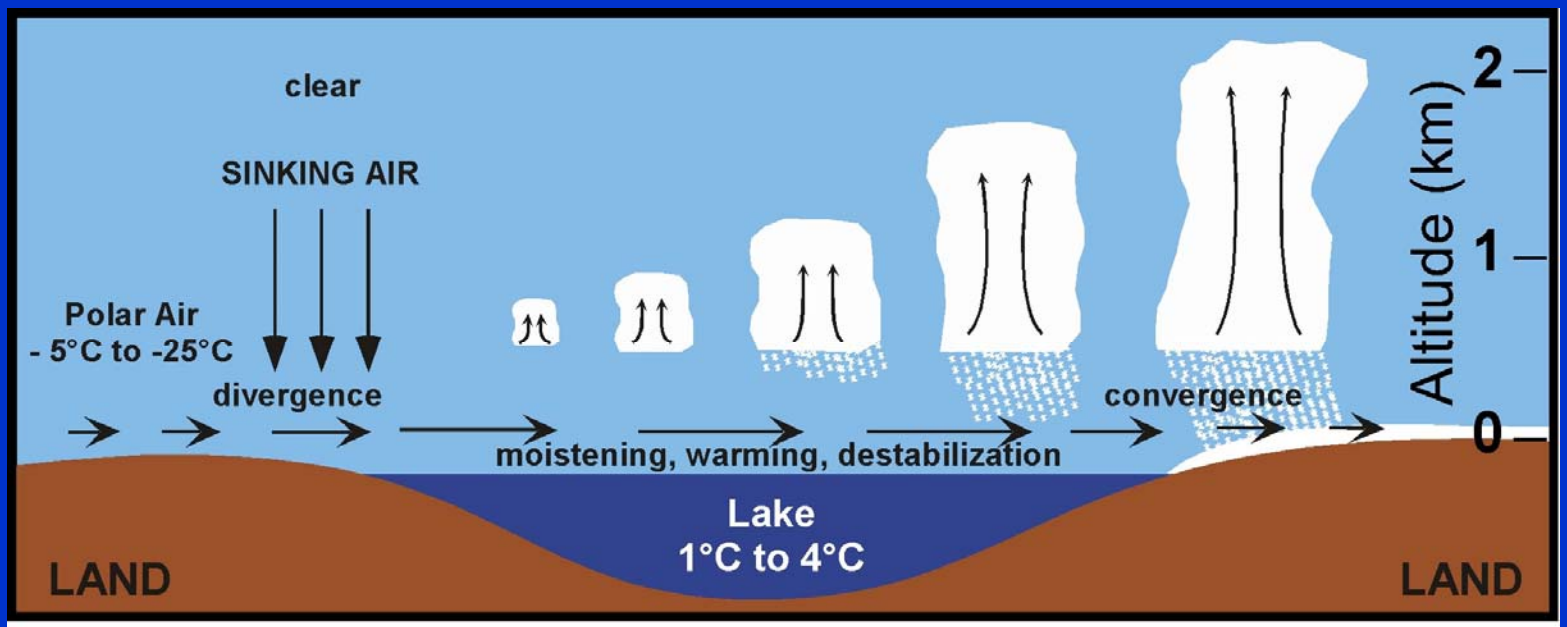
Typical Weather Pattern for Lake-Effect Snowstorms



- Under these conditions, strong pressure gradient develops across the lakes and drive cold air southeastward from Canada to produce the lake-effect snowstorms.

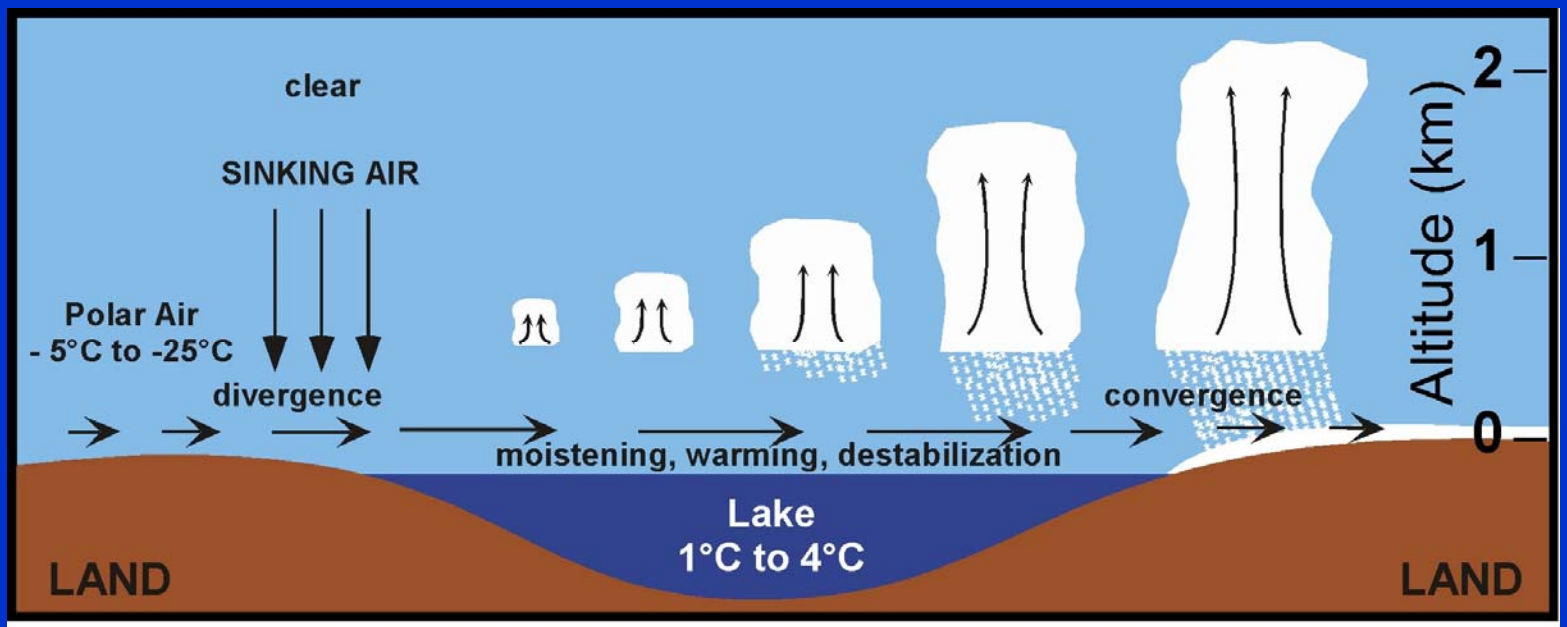
- Very cold air must move across a lake surface for lake-effect snowstorms to develop.
- The warmer the lake temperature and the colder the air, the more extreme the lake-effect snows will be.
- This temperature contrast happens most often between late November and mid-January.
- Typically, lake-effect snow begins after an extratropical cyclone has passed over the region and the cyclone's cold front is well east of the Great Lakes.
- The strength of this flow is enhanced if an arctic high has moved into the central US.

Key Processes Lead to Lake-Effect Snowstorms



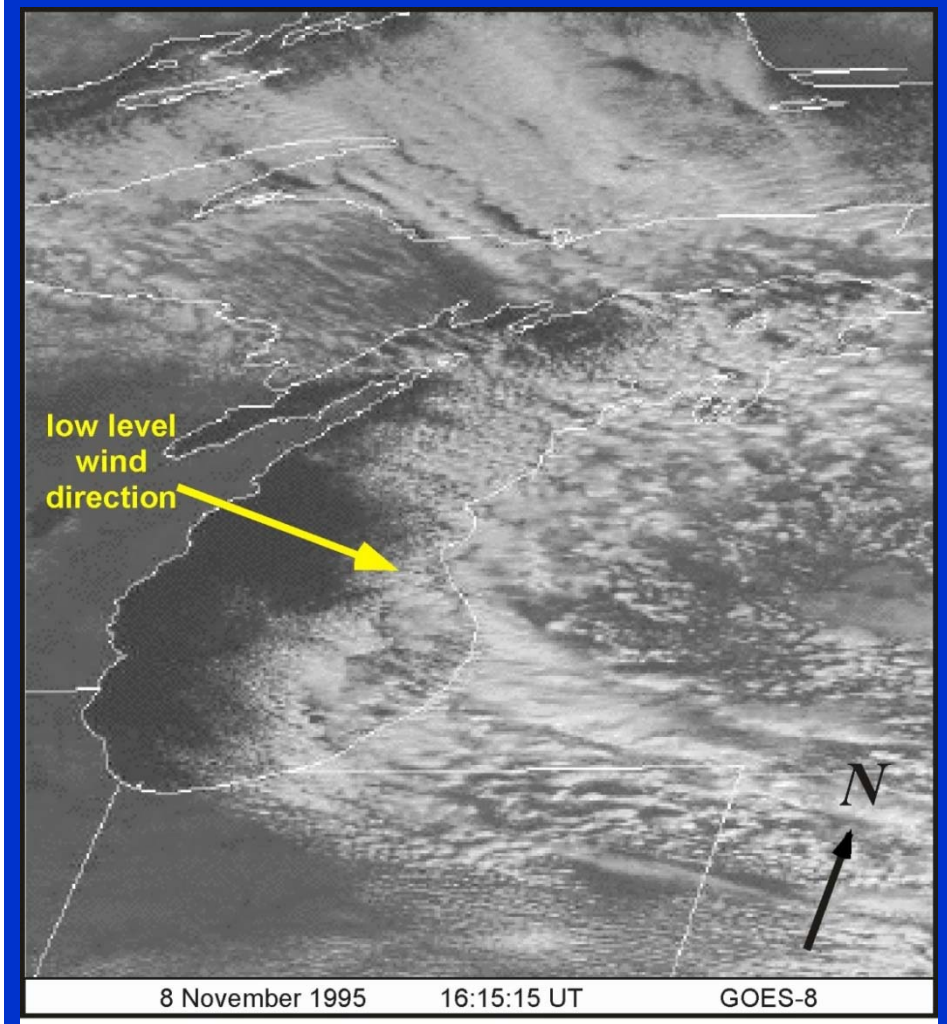
- The air approaching the lake has temperature near -5°C~-25°C, while the unfrozen lake has a temperature near 0°C~4°C.
- Surface friction is smaller over lake than over land ➔ Air moves faster over lake than over land ➔ divergence of air is produce on the upwind side of the lake and convergence is produced on the downwind side of the lake ➔ descending (clear sky) in the upwind side and ascending in the downwind side.
- Due to the divergence, descending occurs on the upwind side and produce clear sky.

Key Processes Lead to Lake-Effect Snowstorms



- As cold air moves over the warm lake, it is heated up by the warmer lake water and receives more moisture from the lake evaporation.
- As a result, the air directly above the lake surface can be heated up as much as 20°C while crossing the lake.
- Above the warming surface layer, air remains cold, a condition leads to rapid destabilization.
- Clouds begin to from soon after air moves out over lake, growing in height and intensity downwind shoreline ➔ ***snow squalls*** are produced.

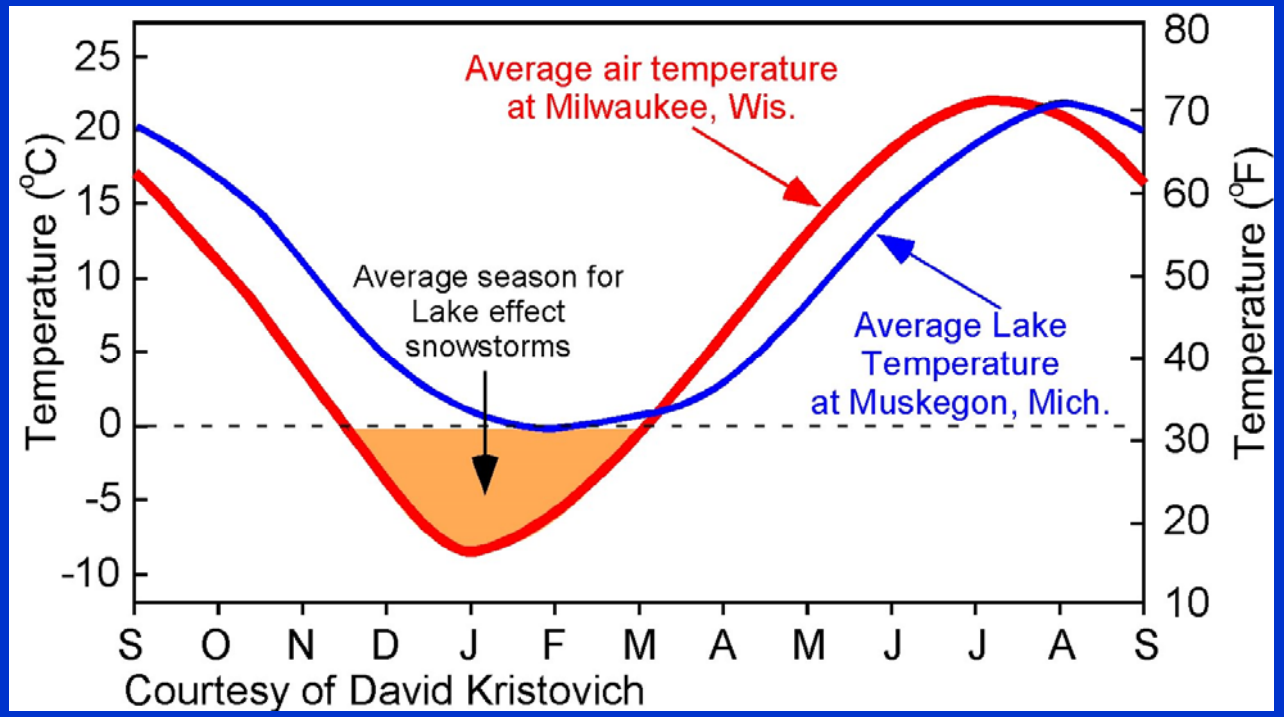
Visible Satellite Image of Lake-Effect Snowstorms



Courtesy of Cooperative Institute for Meteorological Studies
University of Wisconsin-Madison

- As air cross the downwind shoreline, friction with the land surface reduce the wind speed, result in convergence near the shoreline and forcing air upward.
- Heaviest snows fall within and just downwind of this convergence zone.

Season for More Frequent Lake-Effect Snowstorms



- The amount of snow that falls during lake-effect snowstorms depends on (1) lake temperature, (2) air temperature, (3) wind direction and speed (affect ***air resident time***), (4) ice cover on the lake, (5) topography downwind of the lakes.
- The temperature difference between air and lake has to be larger than 10°C (18°F) to develop the lake effect.
- The air-lake temperature is largest in late December and early January, the most favorable time for lake-effect snow.

- ***Residence Time***: The longer it takes the air to cross the lake, more water vapor can be evaporated into the air and produce stronger lake-effect snowstorm.
- ***Topography***: Rough topography at the downwind side of lake can increase surface friction, increase downwind convergence, and leave to stronger lake-effect snowstorm.
- ***Ice Cover***: It can shut off the lake-effect by stopping the transfer of heat and water vapor from lathes to the air.

Organization of Lake-Effect Snowfall

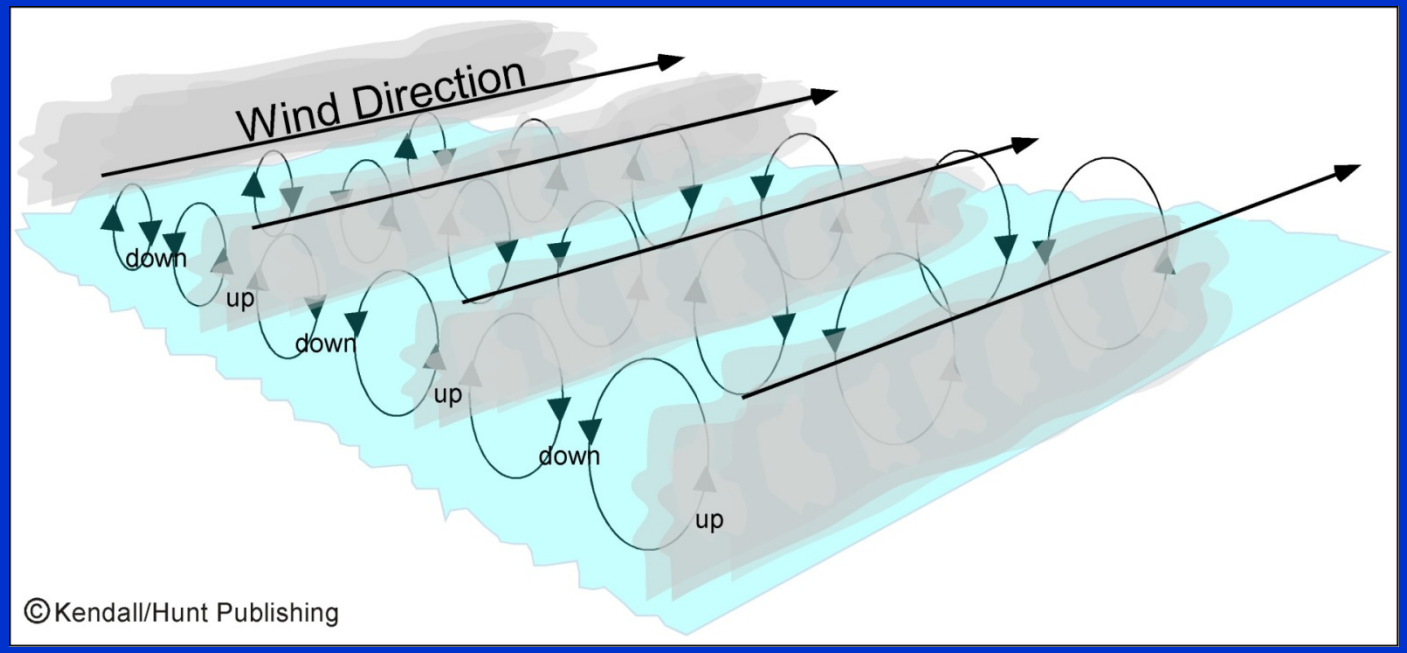
- Lake-effect clouds and precipitation organize in three primary ways:

(1) Wind-induced rolls

(2) Shore-parallel bands

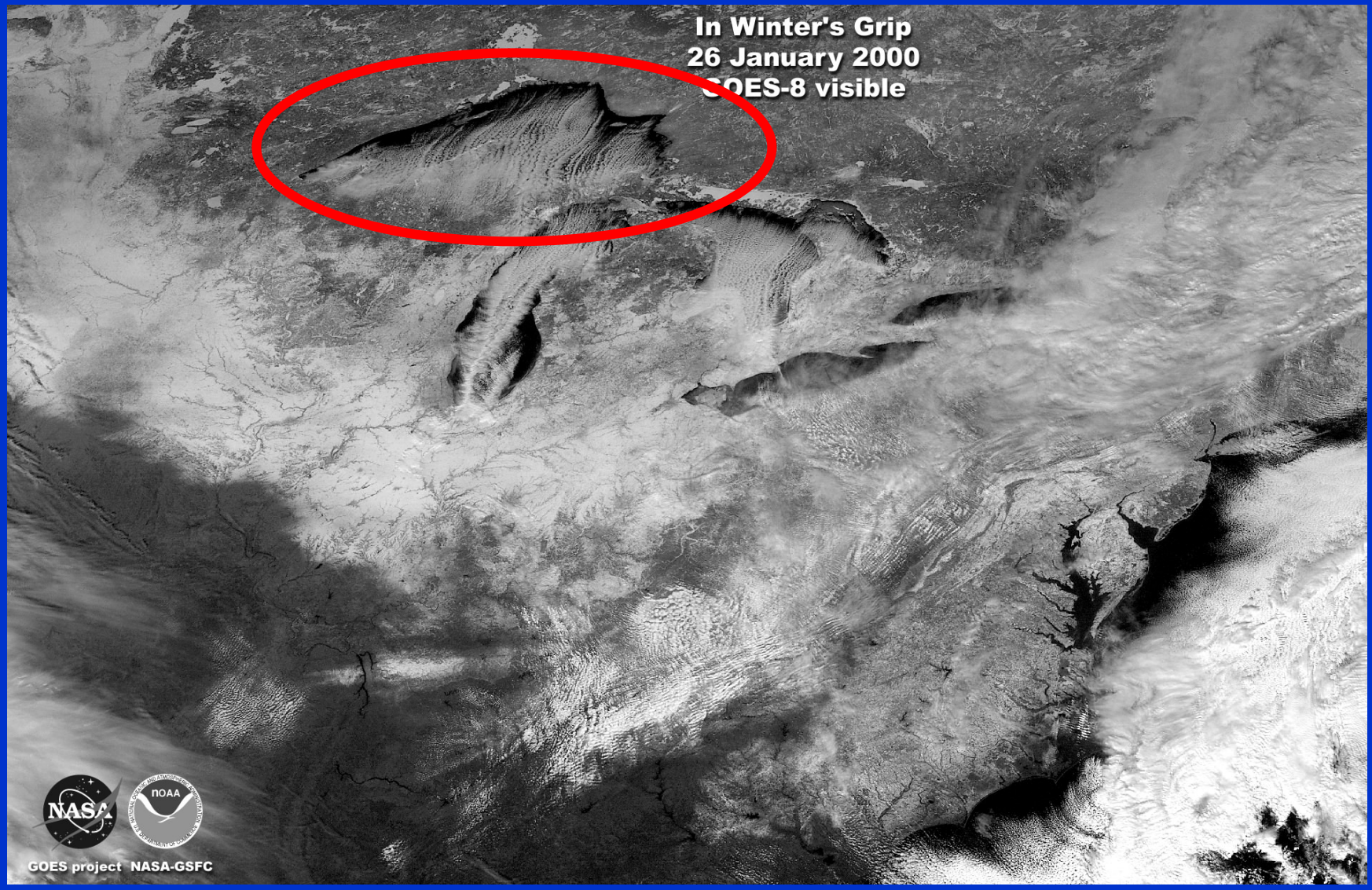
(3) Vortices

Wind-Parallel Rolls



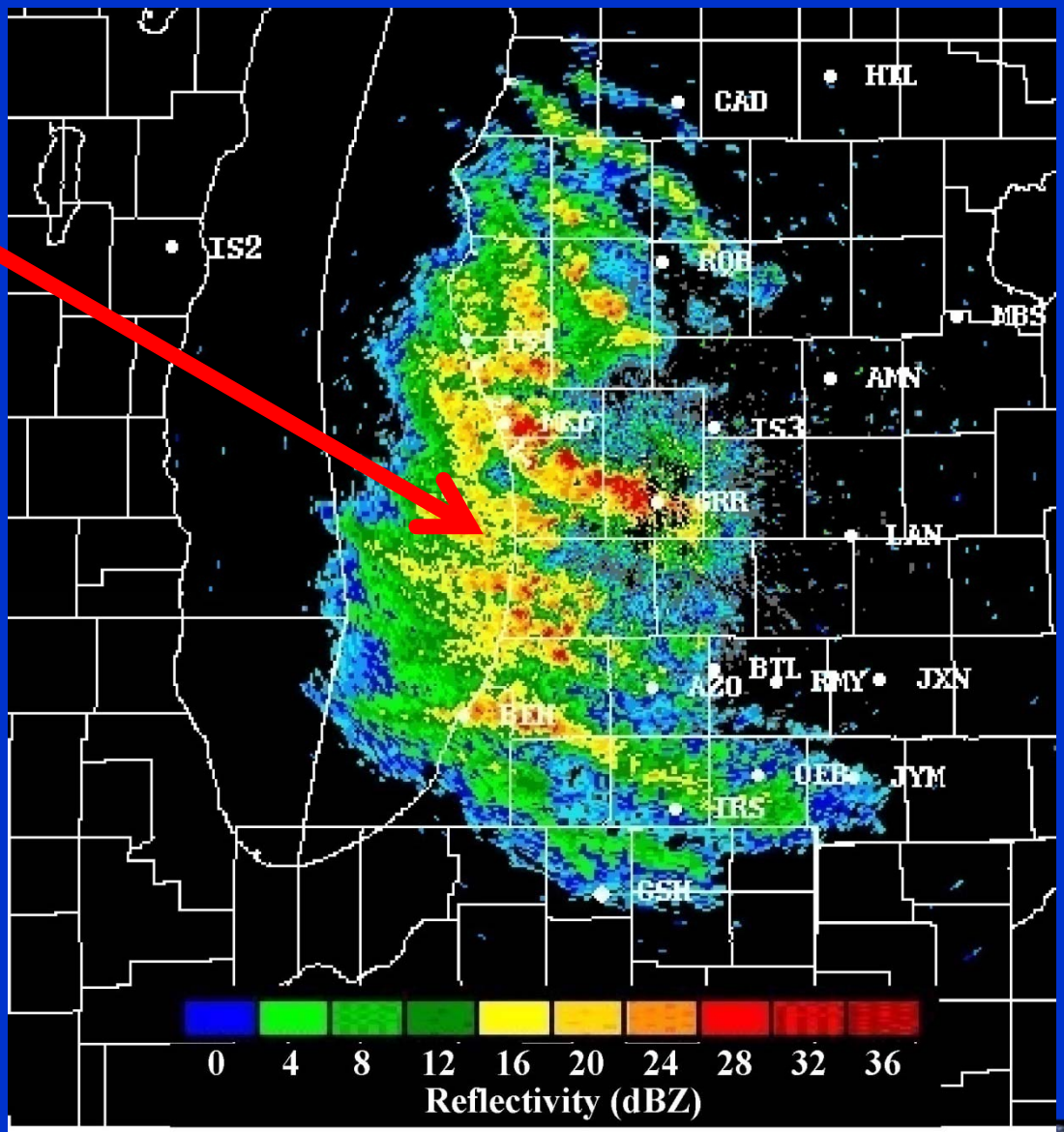
- In cases when winds are strong and blow with a component across the short axis of a lake, wind-parallel rolls may form.
- When the cool air moves across the warm lake, cooler air aloft must sink to replace the warmer rising air.
- These rising and sinking motions often take the form of rolls that align parallel to the wind.
- The upward branches (develop clouds and precipitation) of the rolls are typically 1 to 2 km wide and spaced (by the clear sky associated with the sinking branches) up to 10km.

Wind-Parallel Rolls / Visible Satellite Image



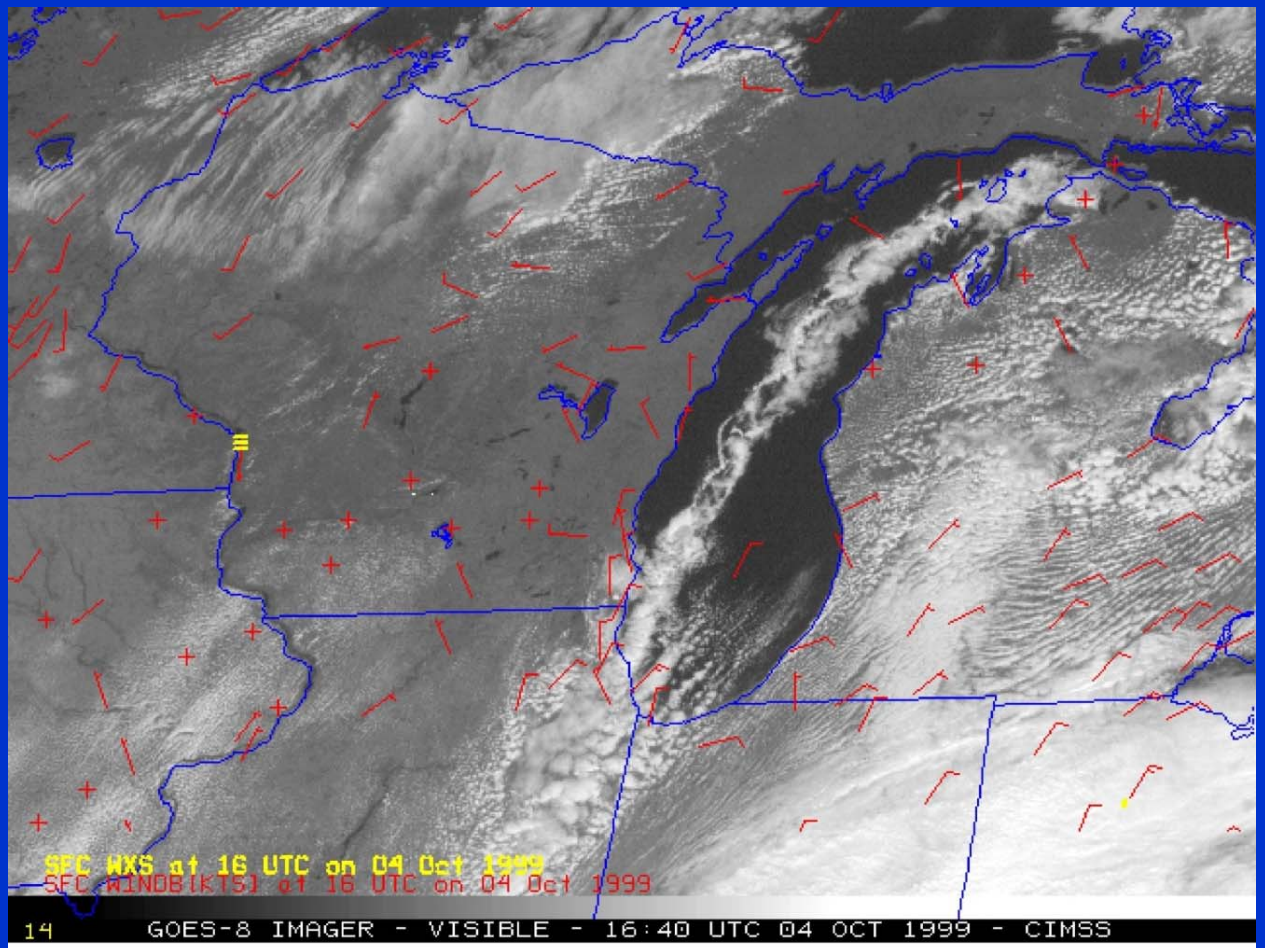
Wind-Parallel Rolls / Radar Image

Northwest winds



Courtesy of Neil Laird

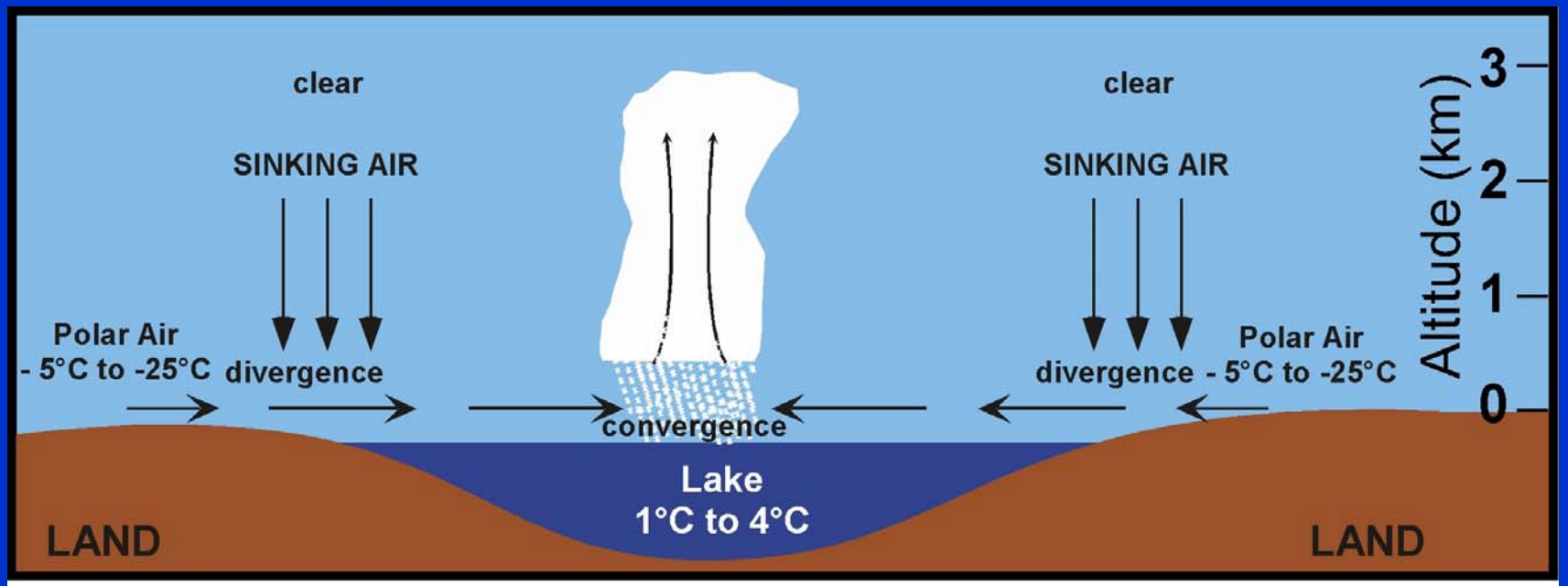
Shore-Parallel Bands



Courtesy of the Cooperative Institute for Meteorological Satellite Studies
University of Wisconsin-Madison

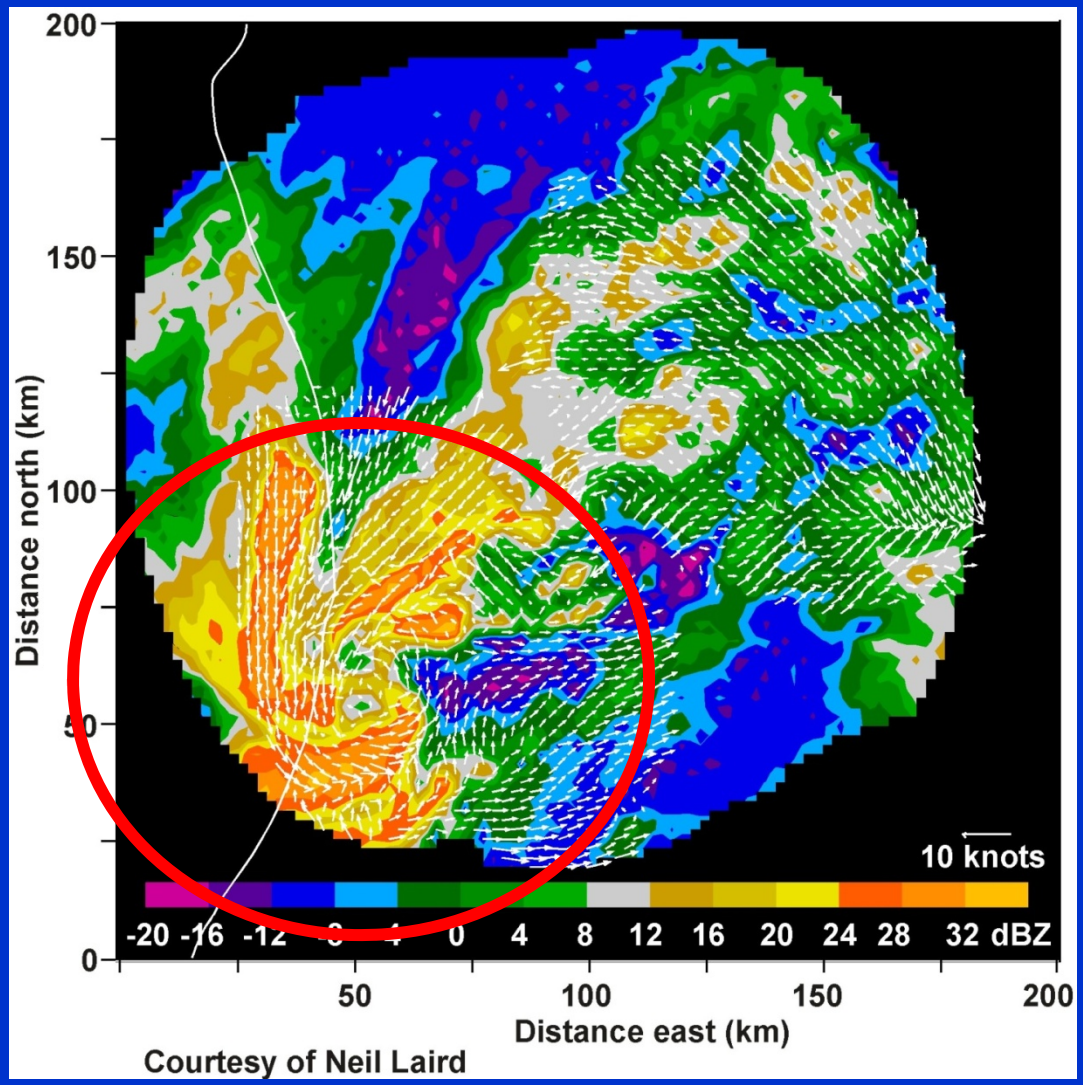
- When winds are relatively weak, the clouds system over the lakes sometimes take the form of shore-parallel bands but not the wind-parallel rolls.
- The cloud bands are along the long axis of the lake.

How to Produce Shore-Parallel Bands



- When winds are weak, the heat of the lake will force air over the lake to rise, drawing air in from both shores toward the center of the lake.
- A snow band develops where these airflows meet.
- Shore-parallel bands are typically deeper than wind-parallel rolls, often extending to a depth of 3km.
- Shore-parallel bands are common over Lakes Erie and Ontario, where the lake axis is west-east.

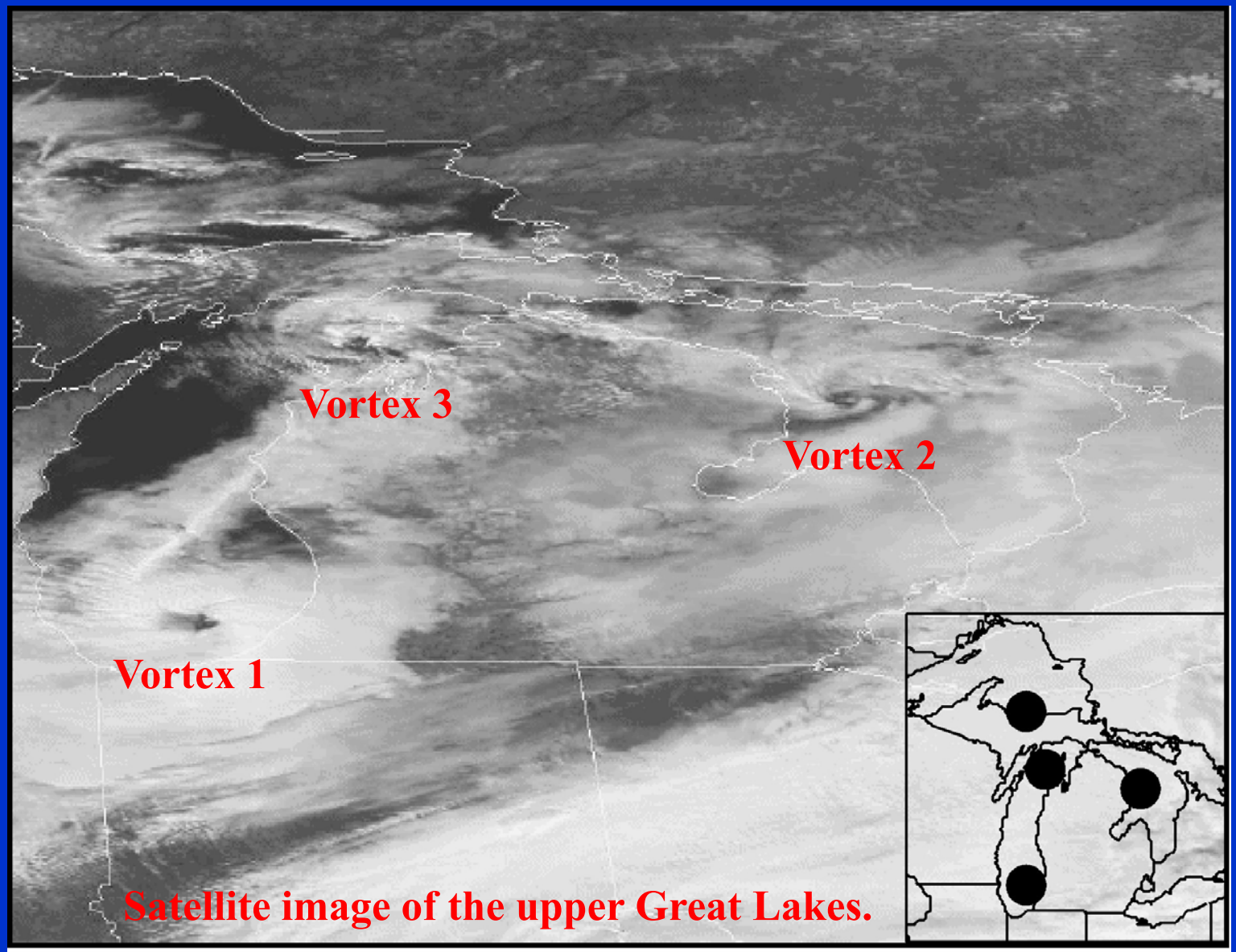
Lake-Effect Vortices



- Lake-effect vortices sometimes develop over the Great Lakes.
- The vortices drift slowly with the background flow and can maintain their closed circulations for several hours.
- The vortices sometime have a precipitation-free center called "eye".
- The diameters of these vortices ranges from about 10 to over 100 km.
- The forming mechanism for the vortices is still unknown.

Radar Image of a vortex over eastern shore of Lake Michigan

Lake-Effect Vortices



Satellite image of the upper Great Lakes.

Courtesy of the American Meteorological Society