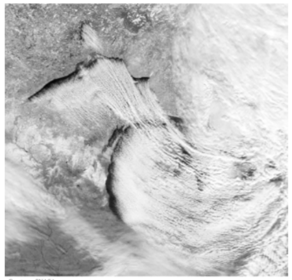
Chapter 13: Lake-Effect Snowstorms

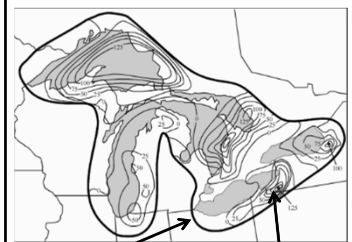


Courtesy of NASA

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

ESS124
Prof. Jin-Yi Yu

The Great Lakes Snow Belts



Courtesy of the Journal of Great Lakes Research

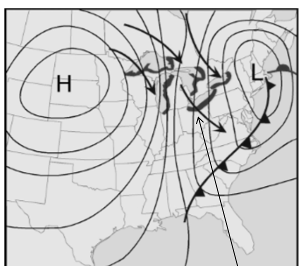
80km boundary around the shoreline

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.

ESS124
Prof. Jin-Yi Yu

Typical Weather Pattern for Lake-Effect Snowstorms



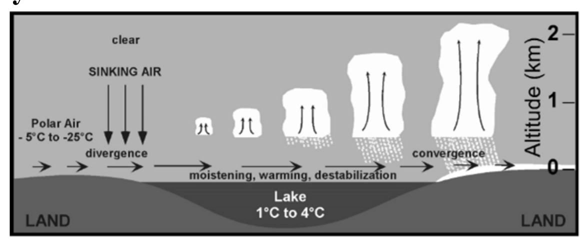
©Kendall/Hunt Publishing

Snow belts

- ❑ 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.

ESS124
Prof. Jin-Yi Yu

Key Processes Lead to Lake-Effect Snowstorms

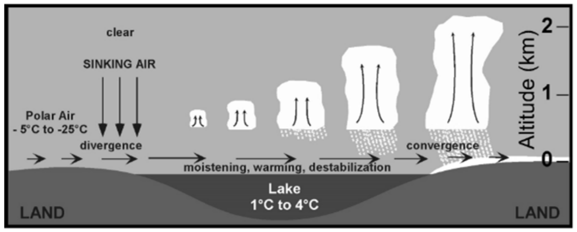


©Kendall/Hunt Publishing

- ❑ 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.

ESS124
Prof. Jin-Yi Yu

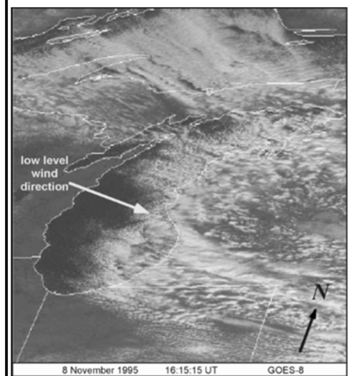
Key Processes Lead to Lake-Effect Snowstorms



©Kendall/Hunt Publishing

- 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.

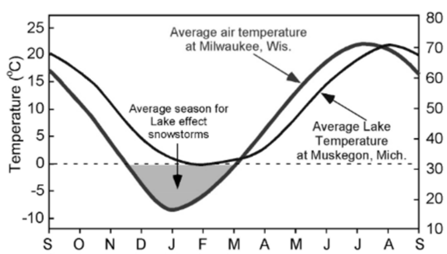
Visible Satellite Image of Lake-Effect Snowstorms



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



Courtesy of David Kristovich

- 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:

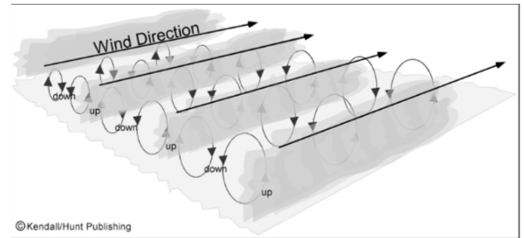
(1) Wind-induced rolls

(2) Shore-parallel bands

(3) Vortices

ESS124
Prof. Jin-Yi Yu

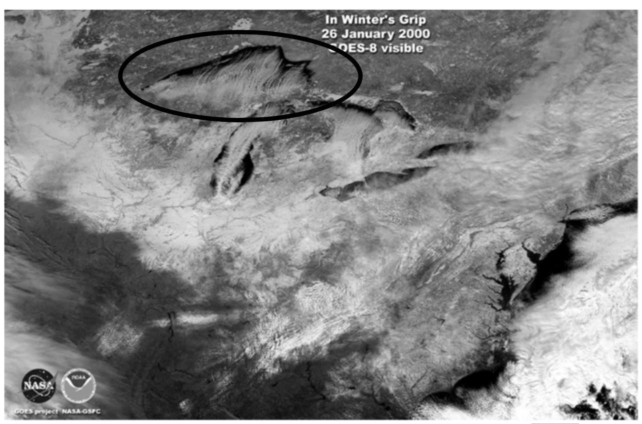
Wind-Parallel Rolls



- ❑ 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.

ESS124
Prof. Jin-Yi Yu

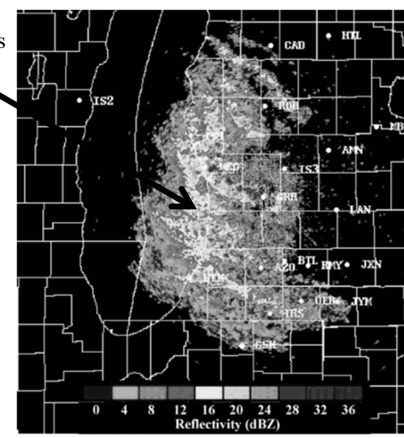
Wind-Parallel Rolls / Visible Satellite Image



ESS124
Prof. Jin-Yi Yu

Wind-Parallel Rolls / Radar Image

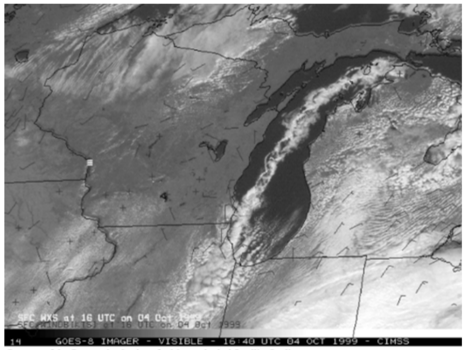
Northwest winds



Courtesy of Neil Laird

ESS124
Prof. Jin-Yi Yu

Shore-Parallel Bands

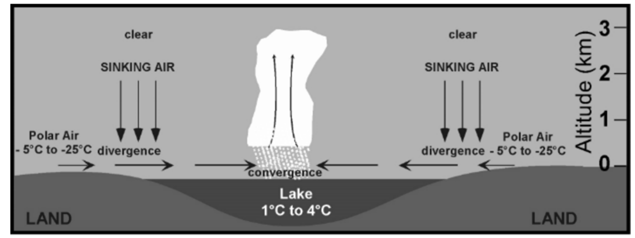


Courtesy of the Cooperative Institute for Meteorological Satellite Studies
University of Wisconsin-Madison

- ❑ 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.

ESS124 Prof. Jin-Yi Yu

How to Produce Shore-Parallel Bands

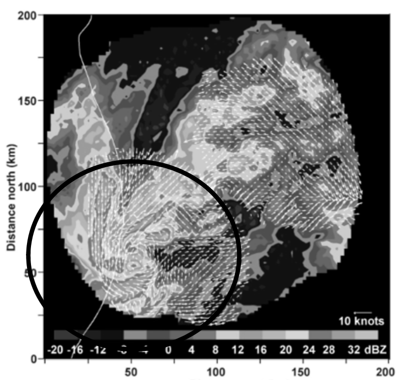


©Kendall/Hunt Publishing

- ❑ 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.

ESS124 Prof. Jin-Yi Yu

Lake-Effect Vortices



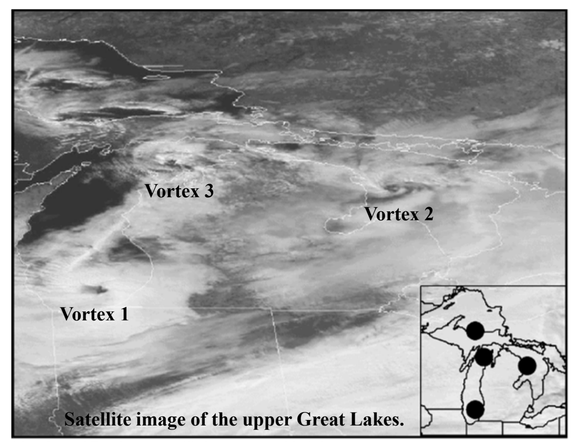
Courtesy of Neil Laird

- ❑ 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

ESS124 Prof. Jin-Yi Yu

Lake-Effect Vortices



Satellite image of the upper Great Lakes.

Courtesy of the American Meteorological Society

ESS124 Prof. Jin-Yi Yu