Chapter 13: Lake-Effect Snowstorms

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

The Great Lakes Snow Belts
- 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 continue 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
- 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 form 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

- As aircross 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 downstream 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 lakes 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 10 km.
Shore-Parallel Bands

- 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.

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Satellite image of the upper Great Lakes.

Radar Image of a vortex over eastern shore of Lake Michigan

Vortex 1

Vortex 2

Vortex 3

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