NOAA Technical Memorandum NESS 80

# SATELLITE IMAGES OF LAKE ERIE ICE:

# JANUARY - MARCH 1975

Washington, D.C.
June 1976

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UNITED STATES
DEPARTMENT OF COMMERCE
Elliot L. Richardson, Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator

National Environmental
Satellite Service
David S. Johnson, Director

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# SATELLITE IMAGES OF LAKE ERIE ICE: JANUARY - MARCH 1975

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ABSTRACT. The NOAA-4 environmental satellite provides daily images of portions of Earth in the visible (0.6 to 0.7 μm) and thermal (10.5 to 12.5 μm) spectral regions from a Very High Resolution Radiometer (VHRR) having approximately 1-km resolution. This improved resolution has permitted more detailed observations of Great Lakes ice than was possible with the previous generation of operational satellites. Both visible and infrared imagery are presented to show ice formation and dissipation in Lake Erie and vicinity. Coverage begins on January 21 and ends on March 18, 1975. Only cloudfree or partly cloudy imagery is included.

## INTRODUCTION

The satellite images of Lake Erie ice were selected from NOAA-4 satellite imagery from January to March 1975. Lake Erie was the lake of major concern since, being generally shallower than the other Great Lakes, its waters cool and heat faster. Also included are two Great Lakes ice charts prepared by the Environmental Products Group of NESS, using the same images. The imagery traces Lake Erie ice from early in its formation on January 21 until all but the last fragments have dissipated on March 18, 1975. Fifteen images between these dates show the variation in extent and movement of the ice fields.

Meteorological data from the National Weather Service's (NWS) North American surface charts have been included. Air temperature and wind direction and speed at four major cities around Lake Erie (Toledo, Cleveland, Erie and Buffalo) help to explain the ice formation and movement. Meteorological data were taken from the 3-hourly synoptic chart nearest to the time of satellite overflight.

## SATELLITE AND SENSOR

The NOAA-4 satellite, launched November 14, 1974, was used to obtain the imagery. The satellite scans the Earth in 25 orbits every two days, viewing the same area at approximately the same time each day from an altitude of about 1500 km. The orbit is sun-synchronous and near polar.

The NOAA-4 sensor used for this study is the Very High Resolution Radiometer (VHRR). This instrument senses in both the visible (0.6 to 0.7 μm) and thermal infrared (10.5 to 12.5 μm) regions of the spectrum. Nominal resolution of the VHRR is approximately 1 km at nadir. More information on the satellite and sensor can be found in Schwalb (1972).

## IMAGERY

This collection contains examples of visible imagery, simultaneous visible and infrared imagery, and infrared imagery taken at night (fig. 2, 6-14, and 16-18). Figure 1 shows the area covered by the imagery.

The VHRR normally produces imagery that covers all or most of the Great Lakes on one image. The vicinity around Lake Erie was selected and photographically enlarged from these images. This enlargement process occasionally reveals the individual scan lines of the image.

The radiometer is capable of sensing 256 different energy levels in both the visible and infrared channels. These energy levels are converted to film density levels as gray shades on a photographic negative. The images in this collection are prints from these negatives.

Infrared data, unlike visible data, has no natural relation to gray shades. In this case, warmer objects are displayed as darker shades while the colder objects are displayed as lighter shades. This results in an image in which clouds, ice, and snow (which are normally the coldest objects in view) are displayed in light tones and the warmer lake waters, rivers, and terrain are displayed in dark tones. Infrared imagery produced by this technique can be readily compared to visible imagery which also has clouds, ice, and snow displayed as lighter tones.

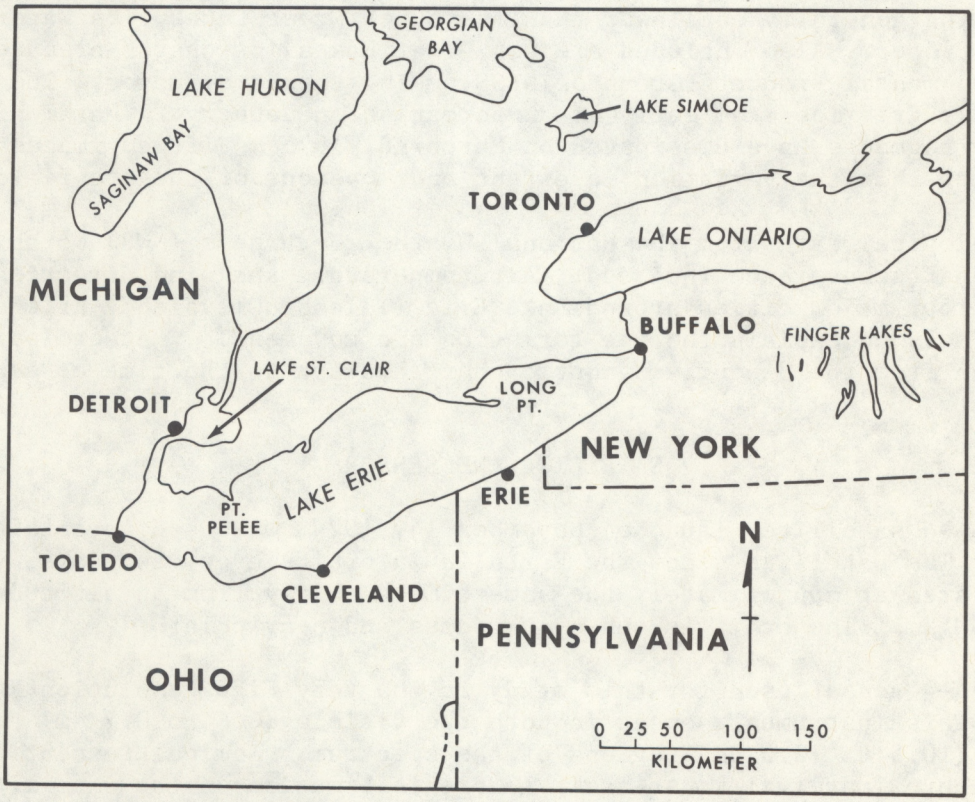


Figure 1.--Index map of Lake Erie and vicinity, the area shown in the satellite imagery in figures 2, 6-14, and 16-18.

The first image in this collection is a nighttime infrared one (fig. 2). Some ice has formed in the western end of Lake Erie and on Lake St. Clair. Temperatures around Lake Erie at time of overpass are in the teens; Buffalo reported 14°F, Toledo, 19°F. Winds are gentle (5 to 10 knots) from the west and south. Lake Erie is clear of most clouds; Lakes Ontario and Huron are partly cloudy. The water in the Great Lakes, the Finger Lakes, and the Ohio River is warmer (darker) than the surrounding terrain. Surface air temperatures were 3°F below normal during the preceding week. One to 4 inches of snow were on the ground around most of Lakes Erie and Ontario on January 20; this snow fell throughout the preceding week.

The ice in Lake Erie (fig. 3) has now formed over most of the western and northwestern parts of the lake. Ice also can be seen in Lake St. Clair and Saginaw Bay. Lake Simcoe, north of Lake Ontario, is completely ice covered. Temperatures around the lake are well below freezing: Toledo, 8°F; Cleveland, 12°F; Erie, 15°F; and Buffalo, 18°F. Winds of 10 knots from the northwest appear to have moved the ice slightly off shore. Note that clouds have formed only over the open water portion of the lake.

Snow covers nearly all ground shown. The region east of Georgian Bay is densely forested, therefore, that snow-covered area appears darker than the snow-covered areas of relatively open terrain.

The line in the lower right corner of the image is a sub-synchronization line. This mark is used for registration of the individual scan lines of the image. Following a week of temperatures 6°F above normal and a melting of the snow cover, temperatures dropped to 1° to 3°F below normal over almost all the lower lakes area during the prior weeks. Depth of snow on the ground on February 10 was generally 6 inches or greater over the entire region; most fell from a storm passing through the area on the 7th and 8th.

The infrared image of figure 4 was acquired at the same time as that shown in figure 3. Ice in Lake Erie can be detected in the form of lighter (colder) areas within the lake. The infrared data also shows a lighter (cooler) band along the western edge of Lake Huron, which is believed to be newly formed thin ice. This new ice, because it was thin and of low reflectance, could not easily be detected in the visible band image (fig. 3). The high clouds over the area are much colder than the terrain, thus they can be more easily detected in the infrared than in the visible image. The clouds are also colder than the ice in Lake Erie, thus permitting an observer to differentiate between ice and clouds.

High but partly transparent clouds predominate in this satellite image (fig. 5). Heavy ice cover now extends over much of Lake Erie; a central core, however, appears ice free. The ice seems to have broken away from the southeastern shore, possibly in response to winds, which at this time are from the south and southeast at 5 knots. Temperatures are now far below freezing: Toledo reported 0°F; Cleveland, 4°F; Erie, 7°F; and Buffalo, 11°F. The high cloud cover almost completely obscures Lake Huron, and a lower layer of cloud covers the center of Lake Ontario.


Figure 2.--Infrared image, orbit 831, 0116 GMT, January 21, 1975.


Figure 3.--Visible image, orbit 1076, 1520 GMT, February 9, 1975.


Figure 4.--Infrared image, orbit 1076, 1520 GMT, February 9, 1975.

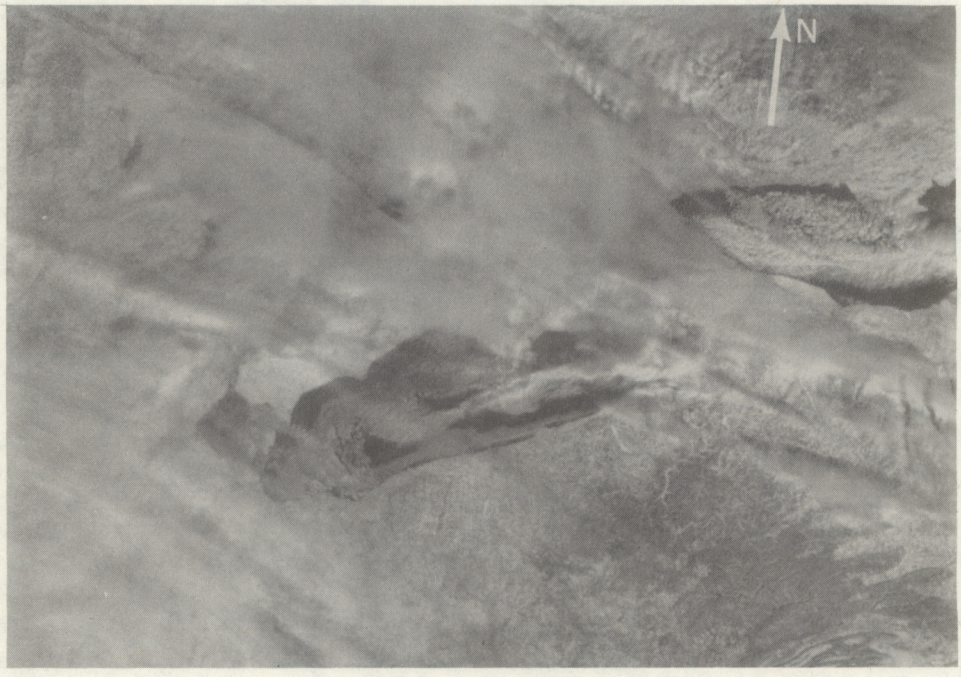


Figure 5.--Visible image, orbit 1088, 1423 GMT, February 10, 1975.

This infrared image (fig. 6) displays the cloud extent more clearly than the simultaneously acquired visible image (fig. 5). The ice breakup in the west-central part of Lake Erie is also easier to detect. The Allegheny River and Finger Lakes can readily be detected because of their higher temperatures.

Satellite ice charts (figs. 7 and 15) are prepared twice weekly during the ice season and are disseminated over National Facsimile. Customers wishing to obtain these charts non-operationally may contact the Environmental Products Group of NESS; charts will be sent by mail. (See Concluding Remarks for details on ordering.)

A heavy deck of clouds covers much of Pennsylvania and western New York (fig. 8). The ice cover in Lake Erie appears to be dispersing. The north shore east of Pelee Point is now ice free, and ice has also moved away from Long Point. Temperatures in the area are somewhat higher but still below freezing: Toledo reported 21°F; Cleveland 26°F; Erie reported light fog and 25°F; and Buffalo had light snow falling and 20°F. The winds at the time of the satellite orbit were light to moderate (5 to 20 knots) and generally from the northeast. Cold weather continued over the area; Ohio experienced record low temperatures on February 10 with Cleveland and Toledo averaging 4° and 6°F, respectively, below normal for the week ending on the 16th. More snow fell on the 12th and 15th; snow on the ground averaged about 4 inches on the 17th.

Ice can no longer be detected in the extreme western end and along the central northern shore of Lake Erie (fig. 9). It has moved eastward and is compressed against the western shore of the islands south of Pt. Pelee, a break is evident in the ice pack south of Long Point and some areas of open water show along the western shore of Lake St. Clair. The open areas along the western and northern shores of both lakes seem to be due to the action of the winds. Erie and Cleveland report winds 15 to 20 knots from the west and northwest, while Buffalo and Toledo had winds from the west at 5 knots. Clouds cover most of Lakes Ontario and Huron, and the south half of Lake Erie.

In this infrared version (fig. 10) of figure 9, the break in the ice pack south of Long Point is seen. Cold cloud layers hinder the interpretation of ice features in other parts of the lake. Land stations around the lake reported quite low temperatures, 15° to 16°F, which emphasizes the contrast between the land and the warmer (darker) waters of Lake Erie, Lake Ontario, and the Finger Lakes.

A wide band of clouds dominate this visible band image (fig. 11). All of Lake Huron and half of Lakes Erie and Ontario are cloud-covered. Ice can be seen in the extreme western half of Lake Erie, however, stretching from Pelee Point to the southwestern shore. Some ice also appears to be covering much of the west-central southshore waters, but some cloud is present here also (this is more evident in figure 12). The eastern end of Lake Ontario contains a small patch of ice. The winds at this time were light (5 to 10 knots), and generally from the southwest. Temperatures around the lake, ranging from 21° at Buffalo to 26°F at Toledo, were still sufficiently cold to form or maintain ice.

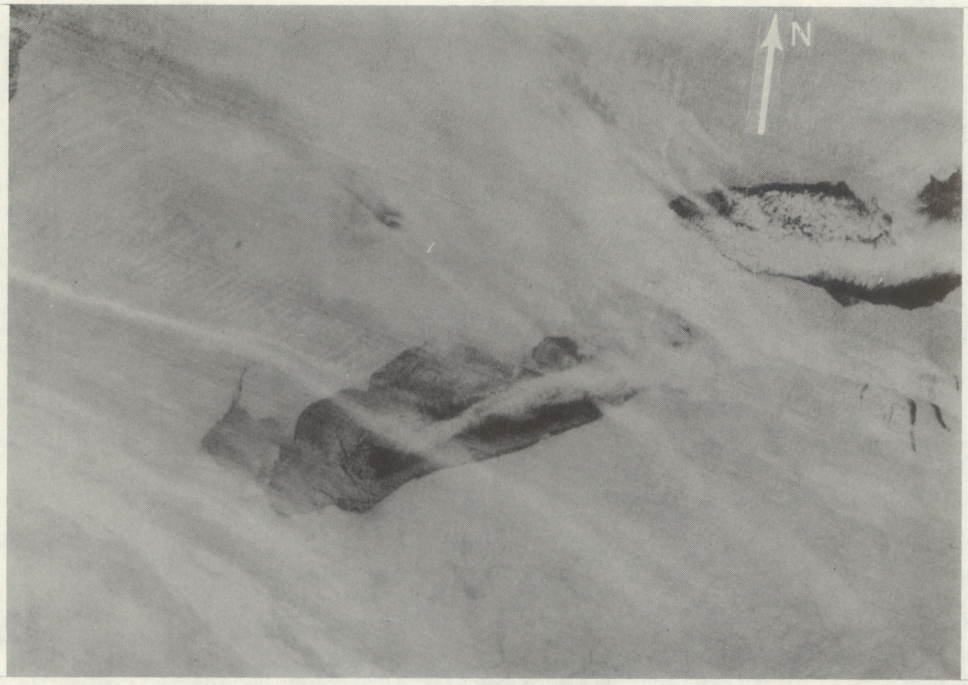


Figure 6.--Infrared image, orbit 1088, 1423 GMT, February 10, 1975.

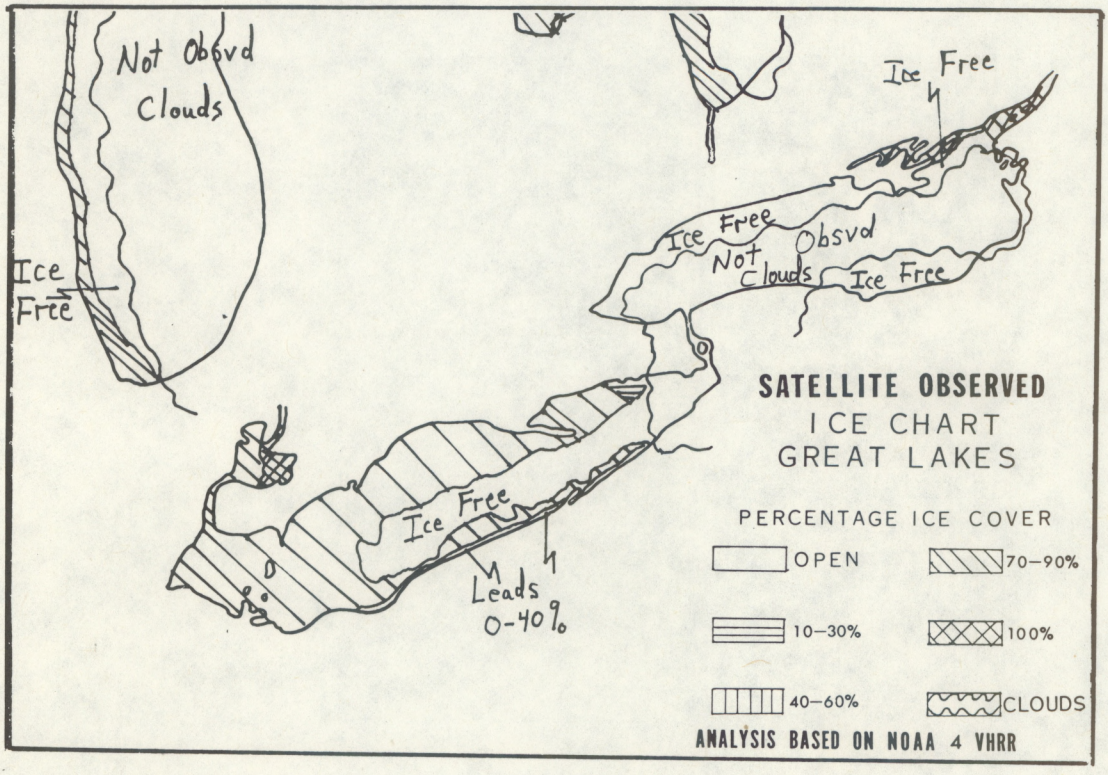


Figure 7.--A portion of the satellite ice chart for the Great Lakes, prepared from NOAA-4 imagery of February 8-10, by the Environmental Products Group.

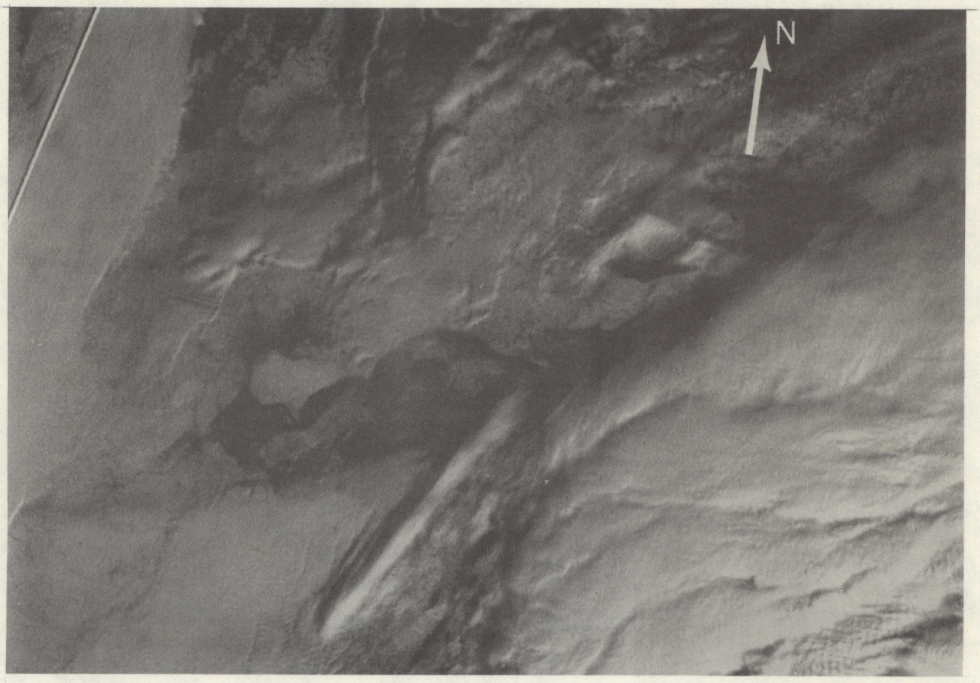


Figure 8.--Visible image, orbit 1113, 1418 GMT, February 12, 1975.


Figure 9.--Visible image, orbit 1126, 1515 GMT, February 13, 1975.

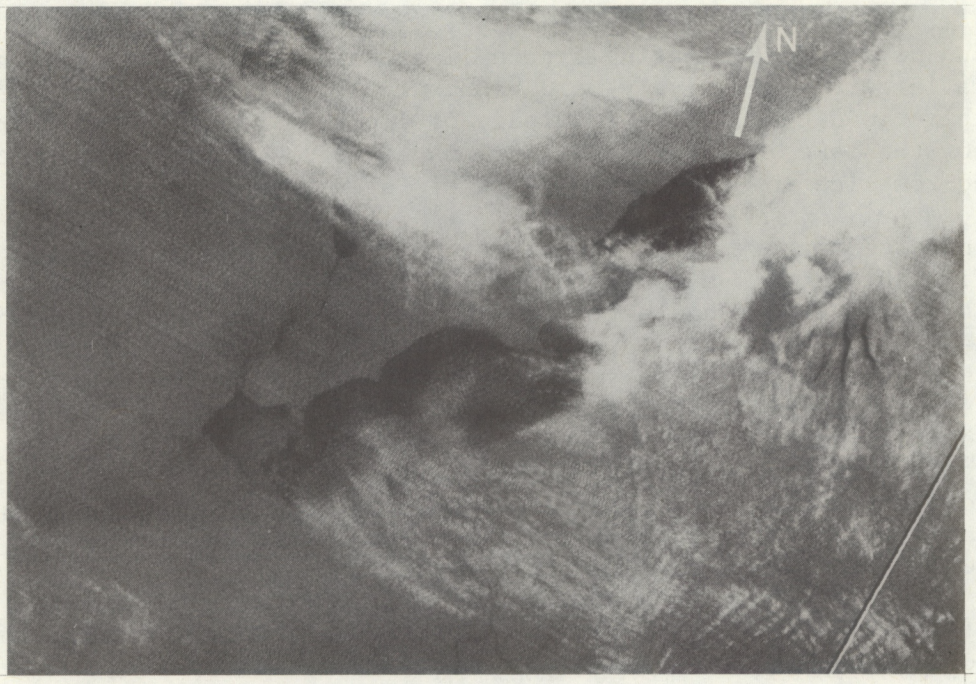


Figure 10.--Infrared image, orbit 1126, 1515 GMT, February 13, 1975.

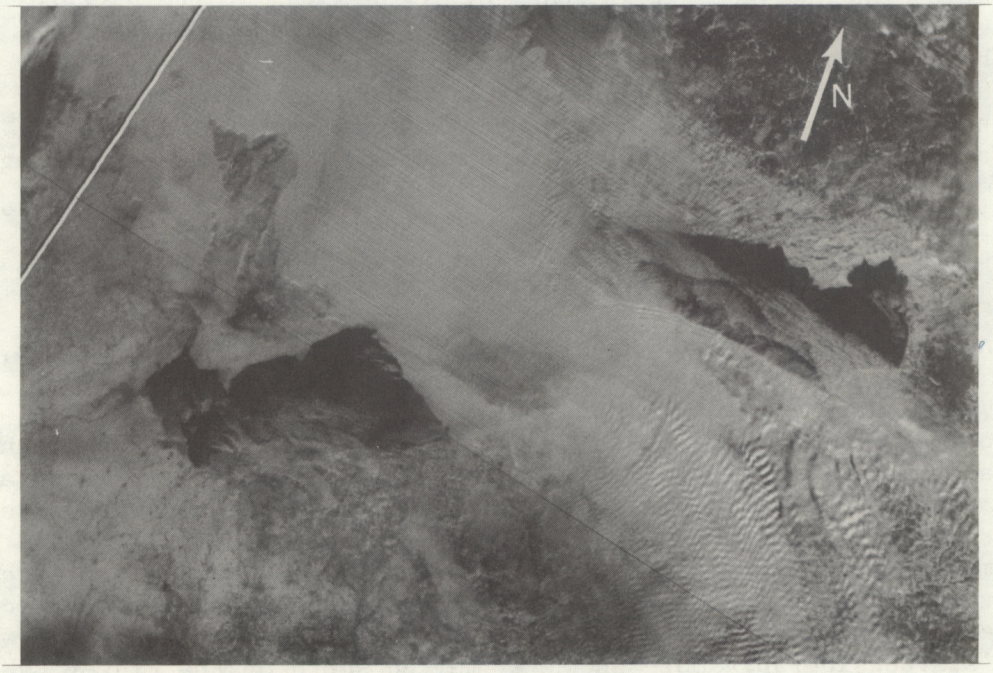


Figure 11.--Visible image, orbit 1138, 1414 GMT, February 14, 1975.

The wide band of clouds dominating figure 11 appears in the figure 12 infrared image as a large and relatively cold band. Nearly all of Lake Erie is obscured by this cloud band. Some knowledge of ice conditions in the extreme western half of the lake is available; there is a nearly solid pack of ice in that area, and some ice is breaking up south of Pelee Point.

Nighttime infrared imagery allows 12-hourly coverage of the Great Lakes. This image (fig. 13) reveals a complete opening in the cloud cover over Lake Erie several hours after sun has set. An extensive layer of ice extends over much of the lake. The only large area of open water is at the eastern end; small open areas can be seen at the western end. Lake St. Clair appears to be about 80 percent ice covered. Small patches of ice can be detected at the southern tip of Lake Huron. The temperatures at 0000 GMT were just below freezing, ranging from 25°F at Erie to 32°F at Toledo. Winds from the southwest at 10 knots appear to have broken the ice into large floes and leads; it no longer is a solid covering. The ice in Lake St. Clair has been pushed to the northeastern shore by the southwesterly winds.

This image (fig. 14), obtained on the morning after that of figure 13, shows an excellent cloud-free view of Lake Erie. Detail and structure of the ice pack can be easily seen in this visible channel image. Much of the ice appears thin (less reflective) and fragmented. The air temperatures around the lake have risen: Toledo and Cleveland reported 40°F, Erie 35°F, and Buffalo, 36°F. These higher temperatures undoubtedly contributed toward the ice breakup. The main pack has moved away from the southern shore, leaving a thin line of ice adjacent to the shore. A solid pack of ice remains at the eastern end of the lake near Buffalo. Winds near the lake are from the southwest at 10 knots and have remained so since the night before. Almost all of Lake St. Clair is heavily ice covered, while just a small area of Lake Huron's southern tip has ice. The snow cover around Lake Erie has melted to the southwest, another indication of rising temperatures. A pronounced warming trend set in on February 16, bringing temperatures in northern Ohio to 10° to 12°F above normal. High temperatures in Ohio on the 17th ranged from 47°F in the northwest to 70°F in the south. Only traces of snow remained on the ground around Lake Erie and western Lake Ontario by the 24th.

Figure 15 shows a portion of the satellite ice chart for the Great Lakes, prepared from NOAA-4 visible imagery of February 12-21, 1975.

This image of Lake Erie (fig. 16) shows the ice much less reflective than in figure 14 and more difficult to locate. The ice was evidently present as a very thin layer. Using a visible image alone in this situation makes ice determination very difficult or ambiguous. Only the simultaneous IR image (fig. 17) permits a reasonably confident interpretation. Some thicker patchy ice can be detected in the southwestern end of the lake; clouds are apparent over the eastern third. The temperatures at the time the image was taken were in the low 20's. Considerably more snow has melted south of the Finger Lakes in New York since February 21 (fig. 14). A decrease in the ice cover of Lake St. Clair is evident. The week preceding March 9 was characterized by temperatures 3° to 5° lower than average, and snow showers south of the Great Lakes. On the 10th, snow depths around Lake Erie ranged from a trace to over 5 inches.

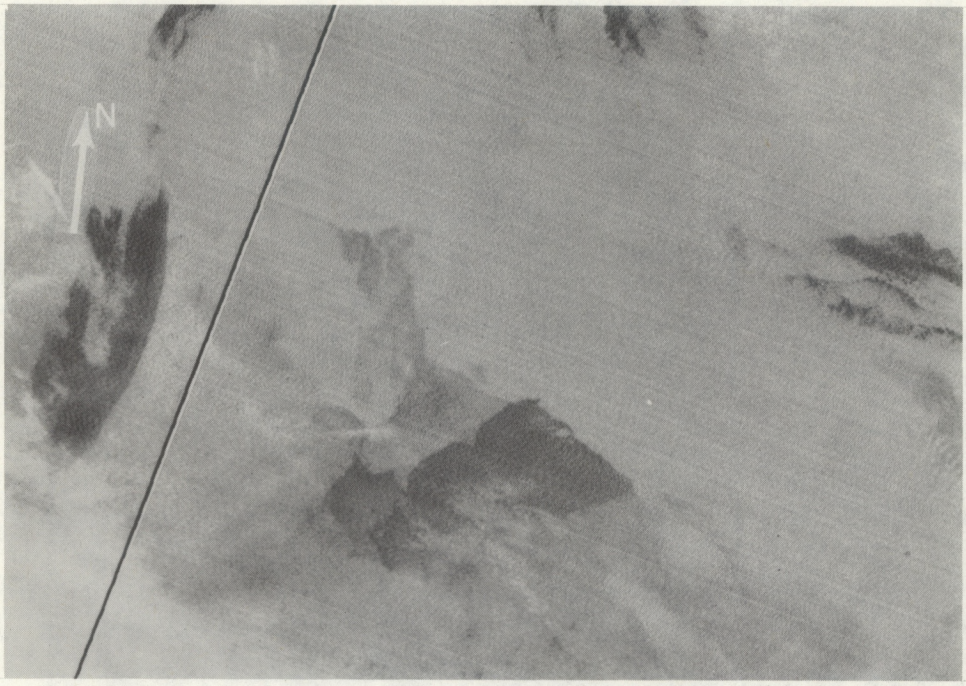


Figure 12.--Infrared image, orbit 1138, 1414 GMT, February 14, 1975.


Figure 13.--Infrared image, orbit 1219, 0057 GMT, February 21, 1975.


Figure 14.--Visible image, orbit 1226, 1455 GMT, February 21, 1975.

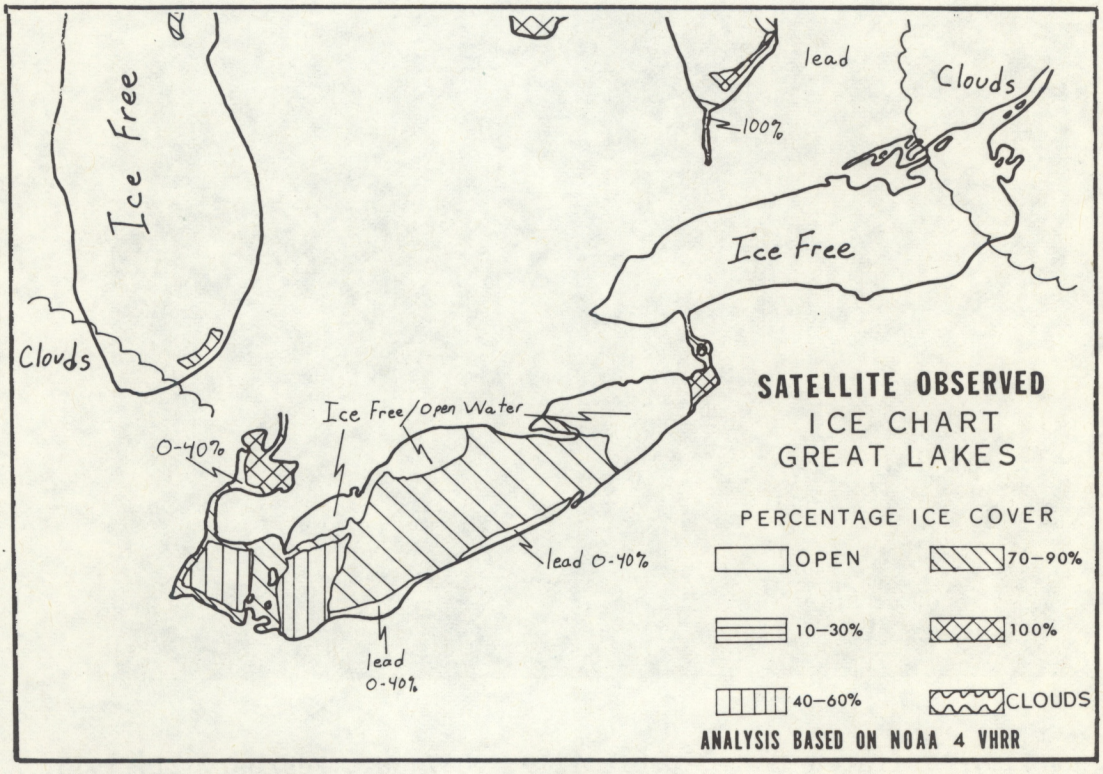


Figure 15.--A portion of the satellite ice chart for the Great Lakes prepared from NOAA-4 imagery of February 12-21, 1975.


Figure 16.--Visible image, orbit 1426, 1414 GMT, March 9, 1975.

Figure 17, the simultaneous infrared version of the scene given in figure 16, reveals, in spite of the scan lines and noise, that Lake Erie is nearly 100 percent covered with a thin ice layer. Temperatures around the lake are in the low 20's, thus causing the ice layer to form. Cloud cover in the area and over Lakes Erie, Ontario, and Huron can be seen more clearly than in figure 16. Thermal patterns due to topography can be seen in western New York and Pennsylvania. The dendritic pattern of river valleys and folded topography of the northern Appalachian Mountains is recognizable in the lower right corner of the image.

The last image in the collection (fig. 18) shows that most of the ice in Lake Erie, except for a few areas of broken ice along the southern and western shores, has melted. The ice along the southern shore has moved off into the lake under the influence of winds. All stations around the lake report winds from the south or southeast at 15 to 20 knots. The temperatures at the time of satellite overpass are indicative of melting ice conditions: Buffalo 41°, Erie 44°, Cleveland 47°, and Toledo 49°F. Much of the snow cover around Lake Erie has also melted. Some upland snow remains south of Lake Erie and north of Lake Ontario. A heavy layer of clouds covers the center of Lake Huron and nearly all of Lake St. Clair. Much thinner clouds cover a portion of Lake Ontario. The week preceding March 18 was characterized by lower than normal temperatures. A Canadian cold air mass dominated the Central Plains and extended its influence to the vicinity of Lake Erie, keeping temperatures 1° to 5°F below normal.

## CONCLUDING REMARKS

The ability of the NOAA-4 to provide repeated, synoptic surveillance of large-scale ice conditions in Lake Erie and vicinity has been demonstrated. Another purpose of this paper was to compile a set of satellite images illustrating the formation and dissipation of ice in Lake Erie. By regularly compiling such documentation of ice behavior, ice forecasters may more accurately predict ice conditions in future years.

Cloud conditions often severely limit the usefulness of the satellite for surface viewing. Twice daily coverage, though, increases the likelihood of obtaining partly or completely cloud-free scenes. Information can occasionally be gathered through the partly transparent clouds that appear in the visible band imagery.

VHRR imagery from the NOAA satellites are received at the NESS headquarters in Suitland, Maryland, within a few hours following the satellite pass. This rapid receipt of data permits near real-time analysis of ice conditions. Imagery is also mailed on the day it is acquired to individuals and organizations requiring knowledge of ice conditions in the Great Lakes. Further information on the availability of Great Lakes ice imagery and analyses can be obtained from the Chief, Environmental Products Group, NOAA/NESS, S126, Washington, D.C. 20233.

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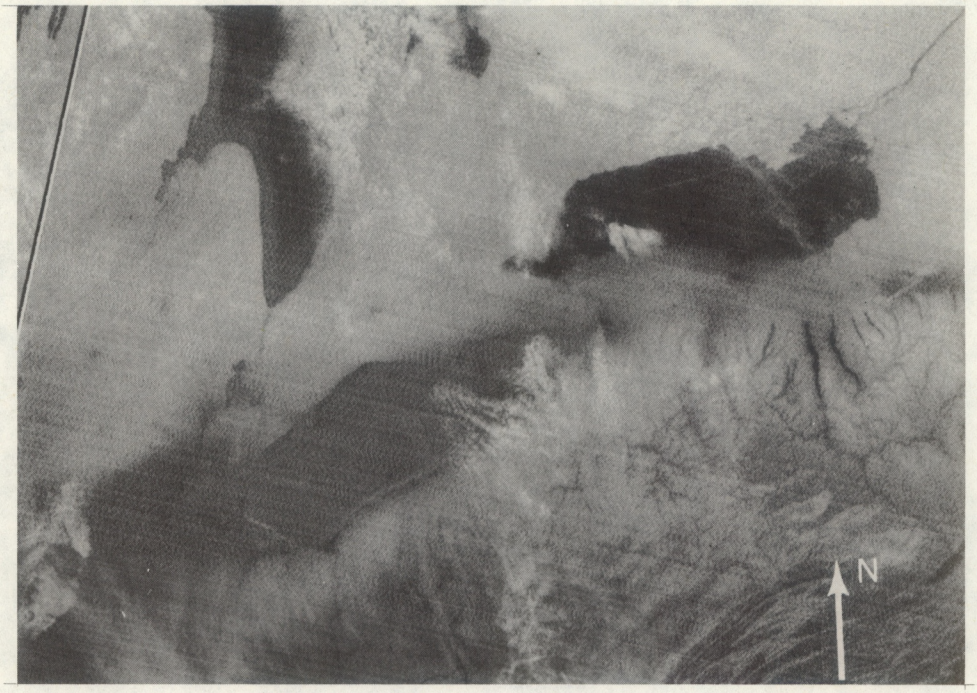


Figure 17.--Infrared image, orbit 1426, 1414 GMT, March 9, 1975.


Figure 18.--Visible image, orbit 1539, 1450 GMT, March 18, 1975.

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