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SATELLITE OBSERVATION OF GREAT LAKES ICE - WINTER 1978-79

Washington, D.C.
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U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Earth Satellite Service

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SATELLITE OBSERVATION OF GREAT LAKES ICE - WINTER 1978-79

Jenifer L. Wartha-Clark

Washington, D.C.
October 1980

UNITED STATES
DEPARTMENT OF COMMERCE
Philip M. Klutznick, Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
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SATELLITE OBSERVATIONS OF GREAT LAKES ICE: WINTER 1978-79

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ABSTRACT. Ice conditions on the five Great Lakes and Lake St. Clair were monitored from satellite imagery. The formation, movement, and dissipation of lake ice were traced from December 1978 through May 1979. Wind speeds and directions were correlated with ice movement, and air temperatures were related to ice formation and decay.

INTRODUCTION

This report on the 1978-79 ice season on the Great Lakes monitors the development of ice from early December until May. Maximum extent of ice occurred simultaneously on all of the Great Lakes on February 17. Lake Ontario was approximately 80 percent ice covered, while normal maximum ice cover for this lake is only 25 to 35 percent. Since air temperatures ranged from less than 0°C to only 6°C during the first week in May, ice in Lake Superior persisted until at least May 12.

Local daily mean weather conditions for stations surrounding the lakes are used. Air temperatures at these stations are correlated with ice formation and degeneration; ice movement is a function of wind speed and direction.

DATA SOURCES

Satellites

Half the data were gathered by TIROS-N, the first in a series of NOAA's third-generation polar orbiting satellites. The primary sensor onboard is the Advanced Very High Resolution Radiometer (AVHRR). AVHRR is a four-channel scanning radiometer with resolution of 1.1 km at nadir. All TIROS-N data depicted are from AVHRR visible channel which is sensitive to energy between 0.55 and 0.9 μm. (The spectral interval of visible channel on subsequent satellites will be 0.58 - 0.68 μm.)

NOAA's other operational satellite, the Geostationary Operational Environmental Satellite (GOES), provided the other half of the data. The primary sensor onboard is the Visible and Spin Scan Radiometer (VISSR) which is sensitive to visible radiation between 0.55 and 0.75 μm and infrared radiation between 10.5 and 12.5 μm. Resolution for VISSR is 1 km in the visible and 8 km in the infrared. All GOES data are from the VISSR visible channel.

Other Sources

Local climatological data were observed at Chicago, Ill.; Alpena, Detroit, Flint, Grand Rapids, Marquette, and Sault Ste. Marie, Mich.; Duluth, Minn.; Buffalo, Rochester, and Syracuse, N.Y.; Cleveland and Toledo, Ohio; Erie, Pa.;

and Green Bay and Milwaukee, Wis. The Environmental Data and Information Service (EDIS) in Asheville, N.C., provided these data. Especially useful were the daily average air temperatures, and daily resultant wind speed and direction.

SUMMARY OF THE ICE GENERATION, MOVEMENT, AND DECAY

LAKE SUPERIOR ICE COVER: 1978-79

From November 19 to March 16, temperatures over Lake Superior were mostly below freezing. However, owing to excessive cloudiness ice was not detected until December 28 when it was observed in Nipigon Bay, Black Bay, and most of Thunder Bay. By January 5, ice was seen along the western perimeter of Whitefish Bay and along the shore from Duluth to the Apostle Islands. Eight days later on January 11, in spite of cloudy conditions, ice was visible from Duluth to the Apostle Islands, southward in Chequamegon Bay to Ashland, along the shore to the Keweenaw Peninsula, and along southern Keweenaw Bay to Munising. Whitefish Bay was 60-90 percent ice covered. Ice was discernible close to shore between Black and Nipigon Bays and Isle Royale. On January 13 the clouds receded, revealing offshore ice from Duluth to Isle Royale. A lead along the shore was induced by generally northerly winds of 7 to 9 knots at Duluth and Sault Ste. Marie on the 13th. Whitefish Bay was 100 percent ice covered on January 16, and ice appeared south of Isle Royale.

Figure 2, taken on January 18, was the most cloud-free image of Lake Superior up to that time. Whitefish Bay is still 100 percent ice covered. Additional ice (60-90 percent coverage) can be seen north of the fast ice and adjacent to shore between 47 and 47.5°N (see bathymetric chart of Lake Superior). Beaver and Chequamegon Bay ice had 90 to 100 percent concentration with refrozen leads along the north shore between Duluth and Pie Island, and between Ashland and the Apostle Islands. One week later on January 25, the previously observed lead in Chequamegon Bay had disappeared (fig. 3) and the lead east of Duluth along the north shore of Beaver Bay had diminished. Fast ice covered all of Beaver and Chequamegon Bays, between Thunder and Black Bays and north of Isle Royale, and along the southern coast of Keweenaw Bay.

Two weeks later on February 8, ice (fig. 5) between Isle Royale and the Keweenaw Peninsula had thickened and could be seen extending east of Nipigon Bay. On February 9, two new leads (fig. 6) appeared in a period of 1 day. One was located in the middle of the fast ice found in Beaver and Chequamegon Bays and appeared semicircular; the other was south of Isle Royale. Westerly winds at 8 knots observed at Duluth on February 9 may have forced the ice eastward, creating these leads. Owing to very low temperatures (-14 to -25°C) these leads (fig. 7) refroze by February 11. The next day, February 12, most of the lake was ice covered except for leads (fig. 8) along the eastern shore near Otter Head and from Michipicoten to Coppermine Pt. These leads were the result of easterly winds of 7 knots at Duluth from February 11-13 combined with northerly winds at 3 knots on February 12 and easterly winds at 6 knots on February 11 at Sault Ste. Marie. Ice in the eastern third of the lake was thinner than that in the remainder of the lake. Fast ice could be seen in Whitefish, Beaver, and Chequamegon Bays and along the south shore of Keweenaw, Black, Nipigon, and Thunder Bays as well as from Isle Royale to the north shore.

February 17 marked the peak extent of ice on Lake Superior as well as on the other Great Lakes for the year. Figure 10 shows that ice cover on the lake is near 100 percent. There are some possible leads and some frozen leads. Ice between Munising, Whitefish Point, and northward is 95 percent concentrated and thinner than on the rest of the lake. The next day, February 18, winds from the east-southeast at 8 knots moved this highly concentrated thin ice lakeward, creating leads (fig. 11) along the southern coast from Munising eastward to Whitefish Point. A lead can also be seen north of the Keweenaw Peninsula.

One week later on February 25 a wide lead (fig. 13) and many broken floes were discernible between Michipicoten and Whitefish Point. Frozen leads are east and west of Slate Island and parallel to the north shore fast ice between Nipigon Bay and Otter Head. There is also a very long lead along the north shore of Beaver Bay to the south side of Isle Royale and southward in the middle of Chequamegon Bay. Most of the western two-thirds of the lake is still 100 percent ice covered. Ice in the remaining eastern one-third is less concentrated, thinner, and sometimes occurs as broken floes.

Lake Superior was still heavily iced on March 6 (fig. 15). Beaver and Chequamegon Bays are covered with fast ice. The only lead apparent in either of these bays extends from just south of Isle Royale, northward to the coast and then westward along shore. East of Isle Royale a long lead extends from a point near Nipigon Bay to Keweenaw Peninsula to Munising. Many more leads can be seen throughout the middle section of the lake; the eastern part of the lake is cloud covered. On March 10, westerly winds (12 knots at Duluth and Sault Ste. Marie) transported ice eastward forming leads along the western shore of the Keweenaw Peninsula from Nipigon Bay to Isle Royale and from the north shore of Beaver Bay to the south shore of Chequamegon Bay just east of the Apostle Islands to Isle Royale.

The lead observed on March 10 (from north shore to Beaver Bay to south shore of Chequamegon Bay just east of the Apostle Islands) was again seen on March 16. Leads in Keweenaw Bay have widened significantly since March 6, and extend from Keweenaw Bay along the southern coast to Whitefish Point. Whitefish Bay as well as Thunder, Black, and Nipigon Bays are still covered with fast ice due to sustained low temperatures. Many leads and broken floes are prevalent throughout the middle and eastern portions of the lake. From Isle Royale to Nipigon Bay and clockwise to Michipicoten, ice is thin with only 30-60 percent coverage.

From March 17-22, temperatures rose above freezing. The reduction in ice cover is obvious (fig. 18 taken on March 27) in the eastern one-third of the lake where the depth is greatest (180 to 240 meters). During the next week only minimal change was detected in the southern half of the lake (fig. 19). On March 27 (fig. 18) leads were observed from the north shore of Beaver Bay eastward to Isle Royale and in Keweenaw Bay; these had significantly increased in size by April 6 (fig. 20).

Ice on Whitefish, Black, and Nipigon Bays was observed to deteriorate as temperatures rose above freezing on April 7. By April 30, Beaver and Chequamegon Bays still had extensive ice cover (fig. 21); however, there were many leads and the ice was not as concentrated (approximately 80 percent). Most of the eastern half of the lake was ice free. For the next 12 days, owing to high temperatures, the ice melted rapidly. On May 12 thin ice remained near Duluth and there were scattered floes in Chequamegon Bay. The three bays north of Isle Royale and Keweenaw Bays were ice free.

The ice season on Lake Superior began near December 28 and lasted until May 12, a full 135 days with maximum extent of 100 percent ice coverage occurring on February 17. The ice season was unusually long for Lake Superior.

LAKE MICHIGAN ICE COVER: 1978-79

Ice was detected in the southern and northern ends of Green Bay on TIROS-N satellite imagery of December 9. Air temperatures had been generally below freezing starting on November 20. Eighteen days later on December 27 most of Green Bay was covered (75 percent concentration) except over areas of more than 30 meters depth. Thin ice was also detected near Milwaukee and Chicago.

By January 3, fast ice covered all of Green Bay except for thin ice over the deeper areas. In addition thin ice formed from Port Washington along the western boundary to the southernmost tip of the lake. A thin lead was discernible on January 5 along the western coast of Lake Michigan in response to persistent 7- to 14-knot westerly winds during the preceding 4 days. A similar observation was made on January 8. Westerly winds beginning on January 2 had again pushed the ice offshore (fig. 1), creating a lead parallel to the shore from Milwaukee to Chicago. In fact, bands of ice interspersed with refrozen leads illustrate the following cycle characteristic of Lake Michigan ice: Ice forms along shore, westerly winds transport the ice offshore creating leads, leads refreeze, refrozen leads blow offshore, and so on. Sometimes this ice dissipates upon reaching deeper water.

The clouds finally moved away from the lake shore on January 11, exposing new ice areas along the eastern shore between Grand Rapids and St. Joseph and along the entire western boundary. Again the lead along the western shore (a result of westerly winds) was easily seen, and fast ice was visible from the Straits of Mackinac to Beaver Island. Green Bay was covered entirely by fast ice by January 16 and ice extended along the eastern shore from Gary to Big Sable Point.

The process of ice forming along the western shore, winds blowing the ice offshore creating leads, etc., continued with little net change in the extent of lake ice until February 10. By that date ice on the eastern boundary had become noticeably wider (37 km) and ice filled the surface area of Grand Traverse Bay. On February 11 and 12, 8-knot winds from the southeast and northeast, respectively, caused leads to form along the eastern shore. Ice then formed between Manitou Island and Beaver Island. Again on February 16 winds influenced the movement of the ice; this time it was northerly winds pushing the ice lakeward to create the leads along the north coast.

Maximum ice extent was observed on Lake Michigan (and the other Great Lakes) on February 17; the lake was almost entirely covered with ice of 95 percent concentration (fig. 10). The only possible ice-free area was in the central part of the lake, located east of Milwaukee and extending southward for 111 km. Sustained low temperatures dating from November 28 had contributed to the unusually extensive ice formation.

Northerly winds at 9 to 13 knots on February 24 moved ice from both the northern and western shores of Lake Michigan, concentrating the ice southward. Northeasterly winds at 13 to 21 knots on Feburary 25 then concentrated the central lake ice (fig. 13) southwestward creating leads along the northern shore, between Beaver and Manitou Islands, and along the eastern perimeter.

Air temperatures rose above freezing beginning March 1. By March 6 ice melting (fig. 15) could be observed along the eastern shore and westward across the lake and also along the southern and southwestern coasts. Westerly winds again transported ice offshore, creating leads along the western shore. The upper half of the lake was 70 percent covered by thick, 90 percent concentrated ice while the lower half was 50 percent covered by thinner, 60 percent concentrated ice.

High air temperatures in combination with westerly winds on March 14-16 melted the ice (fig. 17) in the lower half of the lake except for a thin band of fast ice between St. Joseph and Muskegon and compressed the ice eastward in the upper half of the lake. Green Bay was still covered by fast ice.

On March 27 fast ice (fig. 18) still persisted along one section of the lower east coast, in Grand Traverse Bay, between Beaver Island and the Straits of Mackinac, and in Green Bay. Very thin ice covered part of the northern half of the lake, but the lake interior was mostly less than 30 percent ice covered.

The most prominent change from March 27 to April 3 was the ice degeneration (fig. 19) between Beaver Island and the Straits of Mackinac. Ice in the entrance to Green Bay had also begun thawing. By April 10, the ice in Grand Traverse Bay was reduced to 60 percent concentration along the extremities with ice-free conditions in the central portion. Melting continued at the mouth of Green Bay over the deep (greater than 30 meters) water. By April 18, Grand Traverse Bay was ice free and thin (30 percent concentrated) ice remained between Beaver Island and the Straits of Mackinac. Fast ice still covered all of Green Bay but showed dissipation at the mouth of the Bay. Finally on April 27, the lake was nearly ice free except for small areas in Green Bay.

The ice season on Lake Michigan began on December 9 and ended near April 27, a total of at least 140 days, with maximum ice extent occurring on February 17.

LAKE HURON ICE COVER: 1978-79

Air temperatures at Sault Ste. Marie, Flint, and Alpena were mostly below freezing after November 19. On December 10, ice was scattered in the North Channel of Lake Huron. Five days later on December 15 ice was also detected adhering to the eastern shore of Saginaw Bay and later grew westward toward the western shore of Saginaw Bay and along the southern end near Bay City on December 17, in response to the sustained low temperatures. By December 28, the lower half of Saginaw Bay was 90 percent ice covered while the upper part was about 50 percent covered with thin ice. Ice appeared along the northern shore of Georgian Bay and covered about 75 percent of the surface of North Channel. The 25 percent ice-free area was located over the deepest part (greater than 30-60 meters) of the North Channel.

Eleven days later on January 8, along the eastern shore of Georgian Bay fast ice was observed adjacent to a lead, possibly refrozen, adjacent to offshore ice. North Channel, as well as the southern half of Saginaw Bay, was 100 percent covered with fast ice. Westerly and southwesterly winds on the 8th-10th pushed the offshore ice in Georgian Bay against the eastern shore, narrowing the lead seen on the 8th. These winds also pushed the ice from Harbor Beach to Port Huron out into the lake, causing a lead. Ice now extended along the shore from Saginaw Bay counterclockwise to the Saugeen Peninsula and across to the south side of the Islands separating the main lake from the North Channel. Clouds still obscured the center of the lake so the ice conditions there were not known.

By January 18, the northern half of Georgian Bay was covered with 90-100 percent concentrated thick broken floes (fig. 2). Ice south of Manitoulin Island widened. Two weeks later on February 2, Saginaw Bay and Georgian Bay were 90 percent ice covered. Open water existed only in the center of the lake in a circular area of approximately 130 km radius. The remainder of the lake was ice covered. On February 9, ice south of Manitoulin Island extended southward to 75 km. On February 11, leads (fig. 7) between the fast ice along the eastern shore and offshore ice north of Harbor Beach developed due to the influence of south, east, and southeast winds at 3 to 7 knots, transporting ice (fig. 8) south of Manitoulin Island and Saugeen Peninsula. This lead (fig. 9) quickly froze the next day due to sustained low temperatures.

Two days later on Feburary 17, Lake Huron's ice cover peaked at 95 percent concentration. Two refrozen leads (fig. 10) generally parallel to the eastern shore probably formed in response to 3- to 11-knot easterly winds during the period February 13-15. Fast ice encircled the entire lake and completely covered the North Channel, Straits of Mackinac, and the lower half of Saginaw Bay. Low temperatures were prevalent throughout January and February.

Winds from the south at 4 to 11 knots on the 20th pushed the ice northward from Goderich clockwise to Pt. Huron, Harbor Beach, northern Saginaw Bay, and Sturgeon Point, creating a lead parallel to the shore. Then on February 24-26 northerly winds moved the ice south of Manitoulin Island and in northern Georgian Bay southward, creating leads along the shore.

By February 27, ice (fig. 14) had blown from the western side of Saugeen Peninsula and south of Manitoulin Island so that a lead about 75 km wide was opened. Winds from the south and southwest on March 5 and 6 pushed the lake ice (fig. 16) northward and northeastward from Harbor Beach to Goderich, causing wide leads parallel to the fast ice along the shore. The rest of the lake was cloud covered.

Temperatures were above freezing (1-9°C) on March 3-5 and again on March 13. Winds from the west averaged 12 knots on March 14-15. In the satellite image acquired on March 16, there are leads (fig. 17) along the entire western perimeter and west bank of Georgian Bay caused by the westerly winds and temperatures that were sporadically above freezing prior to March 16. North Channel and the southern half of Saginaw Bay were still covered with fast ice although Saginaw bay ice was thinning.

By March 27 ice (fig. 18) had decreased in the northern part of Georgian Bay and the previous lead along the west coast of Georgian Bay had disappeared.

Ice can be seen clustered along the eastern shore from Goderich and northward to the Saugeen Peninsula and from Presque Isle parallel to the 60- and 120-meter bathymetric contours. With the exception of a lead in the central portion of the lake, Saginaw Bay was still covered with fast ice. Open water can be seen in northern Saginaw Bay and south of Manitoulin Island to south of the Saugeen Peninsula. Ice in North Channel was still 100 percent concentrated but thinning.

Ice in Saginaw Bay (fig. 19) had decreased rapidly by April 3 and ice in Georgian Bay was much thinner than previously observed on March 27. By April 10, the ice had dissipated in Georgian Bay and only some fast ice remained along the eastern coast. By April 17, this fast ice had also melted. Only North Channel and along the western border of Saugeen Peninsula still contained fast ice. By April 18, most of the lake was ice free except North Channel, which finally thawed by April 28.

Ice began forming in Lake Huron on December 10 and lasted until April 28, a total of 139 days with maximum extent of 95 percent concentration occurring on February 17.

LAKE ST. CLAIR ICE COVER: 1978-79

Ice was discerned on satellite imagery of December 15 in the northeastern portion of Lake St. Clair. Winds from the west and southwest from December 9-15 had compressed the ice against the northeastern shore. Thirteen days later, on December 28, fast ice appeared along the southern shore and thin, 75 percent concentrated ice occupied the remainder of the lake surface. By January 11, Lake St. Clair was 100 percent ice covered.

The Detroit River connecting Lake St. Clair to Lake Erie has current speeds as high as 6 knots which hinder the growth of ice. Even though Lake St. Clair is still 100 percent frozen, the Detroit River (fig. 2) is discernible and probably ice free.

Lake St. Clair remained 100 percent ice covered until March 11, a period of almost 2 months. Air temperatures rose above freezing on February 27 and remained there except for March 10-12 and 15. This resulted in ice thawing in southern Lake St. Clair at the mouth of the Detroit River (fig. 17, March 16).

Rapid melting occurred during the next 11 days in response to generally high temperatures until, on March 27, less than 30 percent ice coverage remained (fig. 18). By April 3, only sedimentation (fig. 19) can be seen in Lake St. Clair. The lake is ice free.

The ice season on Lake St. Clair commenced December 15 and ended on March 27 with maximum coverage (100 percent) from January 11 through March 11. Since this lake is shallow and has a large surface area to depth ratio, it freezes quickly and thaws early in the season.

LAKE ERIE ICE COVER: 1978-79

Satellite imagery of December 15 showed thin ice in the shallow western end of Lake Erie. Temperatures had been generally below freezing from November 26 except for December 3-8 when temperatures at the stations surrounding the lake rose to 2-7°C. By December 23, the thin ice in the western basin east of Kelleys and Pelee Islands had grown to a width of approximately 55 km. Ice thickened during the 5-day period between December 23 and December 28.

A brief warming trend took place between December 30 and January 1, temperatures ranging from 3° to 9°C. The rest of January was seasonably cold with temperatures as low as -16°C. By January 11 ice in the basin west of Pelee and Kelleys Islands and in the eastern basin adjacent to Buffalo had become 100 percent concentrated. In addition, 70-100 percent concentrated thin ice was discernible through light clouds over the remainder of the lake except in the deep area (45 to 60 meters) east of Long Point.

Pelee and Kelleys Islands form a barrier to eastward ice movement. In response to westerly winds, ice is typically separated into two areas divided by a lead at the island obstruction. Figure 2 is a satellite image acquired on January 18. The wind impact on the ice is noticeable. Westerly and southwesterly winds at 4 to 13 knots have moved the two ice areas eastward, creating leads nears Toledo, east of the island barrier, and along the north shore from Point Pelee to an area east of Long Point.

From January 25 through February 5 winds were generally from the west and southwest and temperatures remained well below freezing. Because of the westerly wind influence over the previous 12 days, the leads mentioned in figure 2 also appear in figure 4 taken on February 5. Three ice areas instead of two are now visible. The eastern basin contains two distinct ice areas--one, which is 100 percent concentrated, adhering to the southern and eastern shores, and another of 75 percent concentrated ice between the islands and the north shore extending through Long Point. Refrozen leads are also discernible.

Six days later on February 11, three long leads (fig. 7) could be seen between Cleveland and Erie extending to the north shore. In addition the area east of Long Point now had 90 percent concentrated ice. The leads between the two ice areas and from Toledo to the Detroit River had disappeared.

Winds from the north, northeast, and east at 4 to 13 knots from February 13-17 have moved the ice (fig. 10 observed on February 17) at the previously observed lead near Erie westward, crowding the ice against the island barrier. The entire lake is 90 to 100 percent ice covered.

From February 21-24 temperatures ranging from -1 to 8°C, combined with northeasterly winds at 14 to 19 knots on February 25-26, caused thin but concentrated ice (fig. 14) to melt from Pt. Pelee to Long Point and also moved this ice westward so that wide leads appeared from Pt. Pelee to Long Point.

Figure 16, a satellite image acquired on March 7, illustrates a dramatic change in ice conditions on Lake Erie. A wide lead now appears on the southern shore but the lead observed on February 27 has disappeared. Winds generally from the south at 4 to 17 knots have compressed the ice northward against the shore, closing the previously observed north shore leads. During the past 7 days temperatures had remained above freezing (1° to 9°C). The ice seemed thinner than it was on February 27, in response to the higher temperatures.

Again on March 16 the wind direction and intensity influenced the ice movement. Westerly winds from March 11 to 16 at 9 to 17 knots pushed the ice (fig. 17) eastward, creating wide leads from Toledo to the Detroit River, east of the island obstruction, and east of Long Point, once more obliterating the leads discerned in the February 27 image along the southern shore. The area east of Long Point is ice free and the area east of the island barrier is approximately 60 percent concentrated and very thin.

On March 17-25 temperatures ranged from 2° to 18°C and contributed to the dissipation of the lake ice. On March 27 the lake is ice free (fig. 18) except along the shore from Cleveland to Buffalo. In just 7 days the lake ice rapidly degenerated from 90 percent areal coverage of 90 to 100 percent concentration to 20 percent areal coverage of 80 percent concentration.

One week later on April 3, only the familiar ice plug (fig. 19) at Buffalo remains. The ice plug melted slowly over a period of 26 days until it finally disappeared on April 29.

The ice season on Lake Erie lasted from December 15 until April 29, a total of 136 days, with maximum extent of ice occurring on February 27 with a greater than 95 percent concentration.

LAKE ONTARIO ICE COVER: 1978-79

In spite of generally below freezing air temperatures at Rochester and Syracuse since December 10, Lake Ontario remained ice free until January 9. One week later on January 16, 90 percent concentrated ice was detected in the shallow (less than 30 meters) area east of the Prince Edward Peninsula. By January 18, the ice east of Prince Edward Peninsula (fig. 2) had become 100 percent concentrated. In addition, thin ice (90 percent concentrated) developed south and west of Prince Edward Peninsula. Northwesterly winds of 11 knots on January 18 then moved the ice west of Prince Edward Peninsula out into the lake, producing a lead along the north shore.

Clouds covered Lake Ontario from January 22 through January 30, and did not totally clear up until February 3. Temperatures had remained below freezing for the entire month except for January 24-28 when temperatures were between 0° and 3°C. This lake has a small surface area to depth ratio, resulting in slow ice formation; (the entire water column must be cooled to 0°C before ice can form at the surface). Even so, by February 3 more ice had formed in response to the sustained low temperatures. Thin ice grew along the western shore north of Oswego. Ice previously observed west of the Prince Edward Peninsula had dissipated or had been compressed against the eastern shore by the predominantly westerly winds from January 27-February 3. By February 9 ice extended from Prince Edward Peninsula westward to near Toronto. Just 2 days later on February 11 ice could be seen from Prince Edward Peninsula across to Rochester on the south shore except west of Oswego over the deep (210 meters) water (fig. 7).

The satellite image acquired on February 17 (fig. 10) depicts unusually heavy ice cover on all the lakes. Lake Ontario is approximately 80 percent covered by ice, mostly 80 percent concentrated, excluding the ice-free area south of Toronto and possibly the area between Rochester and Oswego where the lake surface is obscured by thin clouds.

Ice locations as observed on February 20 had changed in response to 2- to 3-knot winds from the south reported at Rochester on the 19th and 20th and 0.4- to 4-knot winds from the east reported at Syracuse. A wide lead (fig. 12) had been generated from Niagara Falls east to Oswego. The ice has an approximate 90-percent concentration.

By February 27 ice (fig. 14) had dissipated in response to somewhat higher air temperatures (1° to 4°C on February 22-24). Ice concentration had been reduced to about 30 percent in the western half of the lake. The eastern half was cloud covered.

Ice then melted rapidly. On February 28 fast ice remained only in the western basin near Hamilton and in the northeastern basin east of Prince Edward Peninsula. Scattered floes were adrift. Ice persisted east of Prince Edward Peninsula until March 20 owing to westerly winds concentrating the ice against the shore. The rest of the lake was ice free.

Lake Ontario was entirely ice free on March 27 (fig. 18). The ice season commenced on January 9 and ended on March 27, a total of 78 days, with maximum ice extent of 80 percent coverage occurring on February 17.

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REFERENCES

NOAA, Environmental Data and Information Service, National Climate Center, Climatological Data for the following 16 selected stations from November 1978 through April 1979: Chicago, Ill.; Alpena, Detroit, Flint, Grand Rapids, Marquette, and Sault Ste. Marie, Mich.; Duluth, Minn.; Buffalo, Rochester, and Syracuse, N.Y.; Cleveland and Toledo, Ohio; Erie, Pa.; and Green Bay and Milwaukee, Wis.

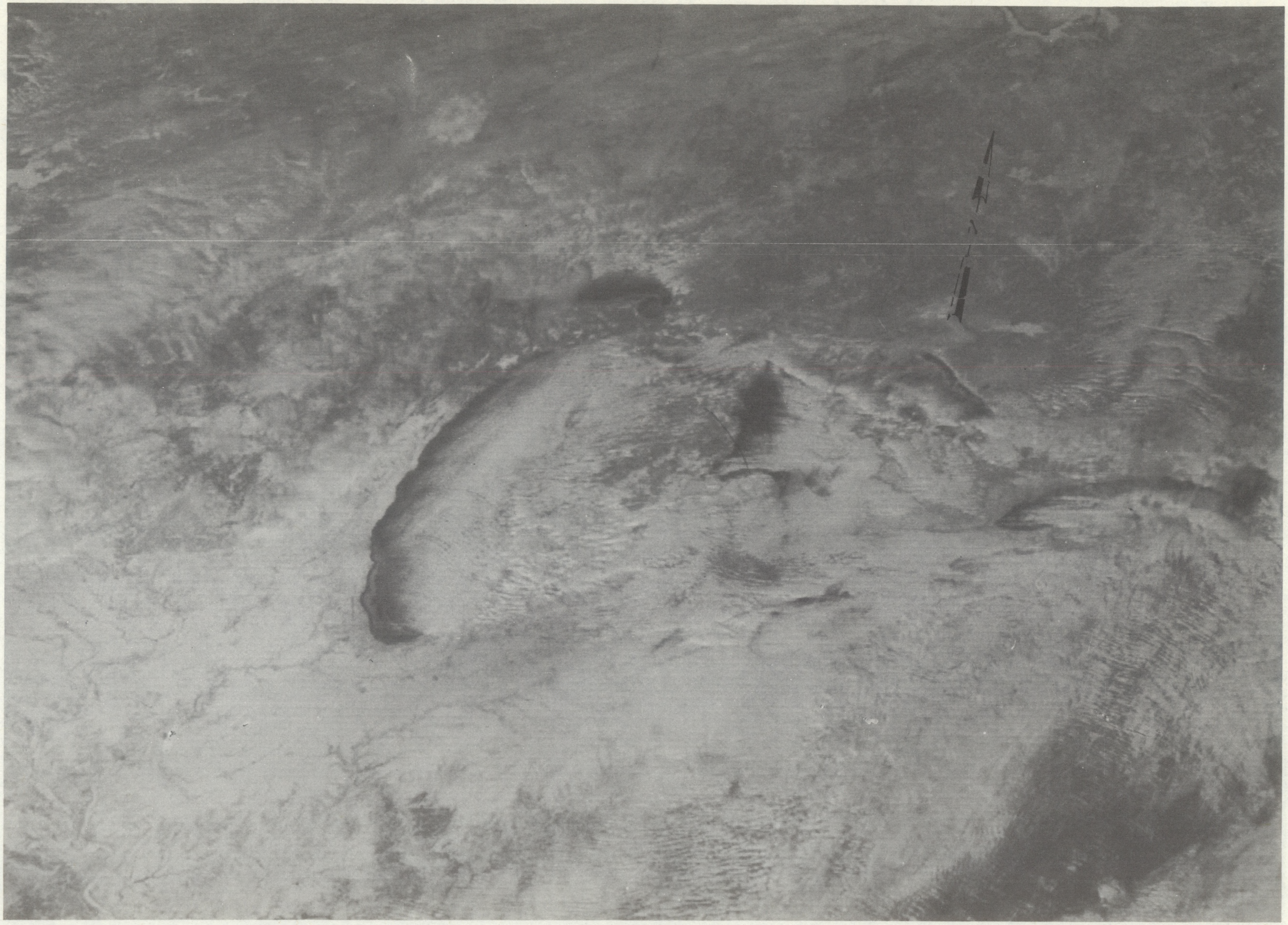

Figure 1.--GOES VISSR (visible) image for 8 January 1979.

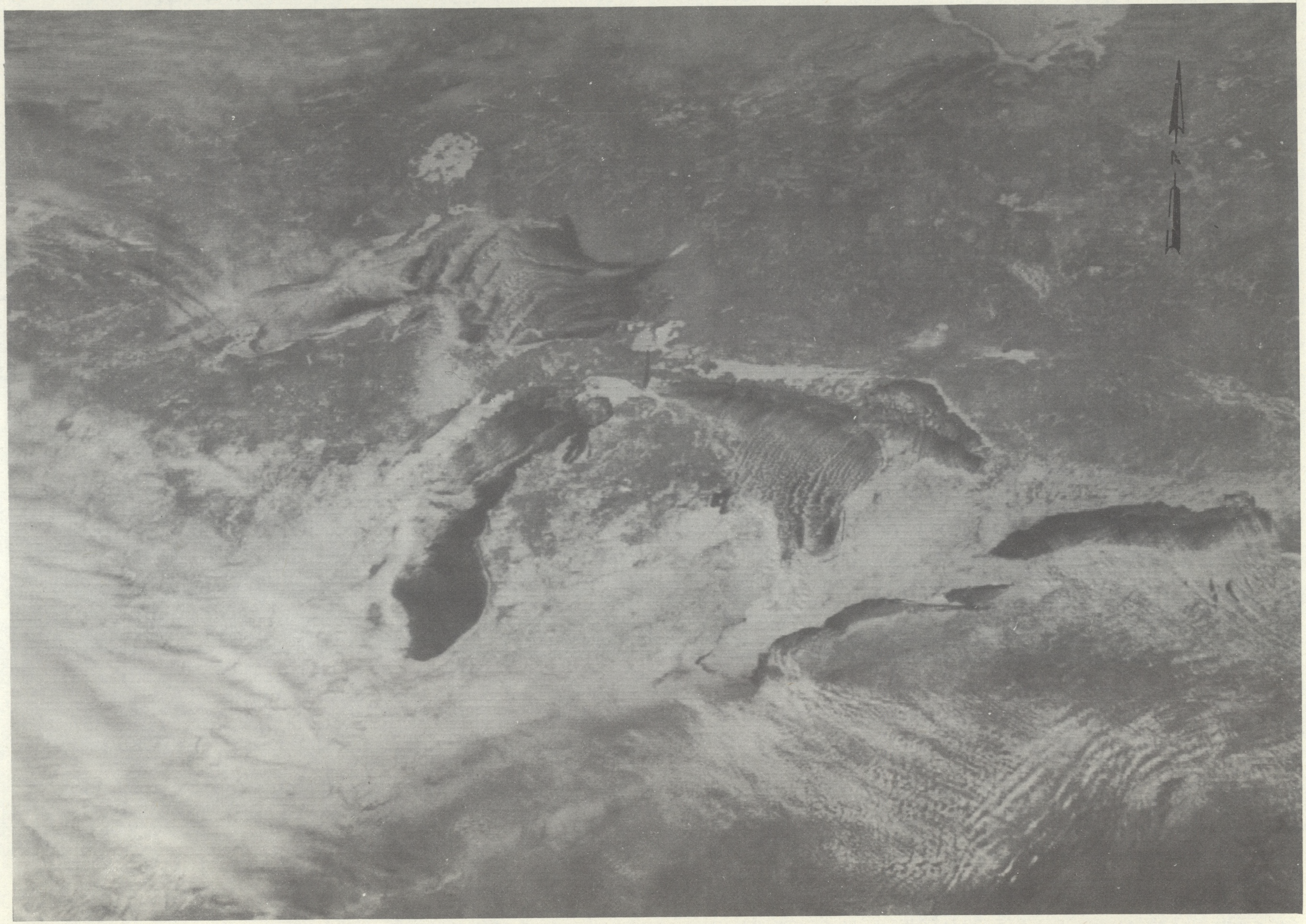

Figure 2.--GOES VISSR (visible) image for 18 January 1979.

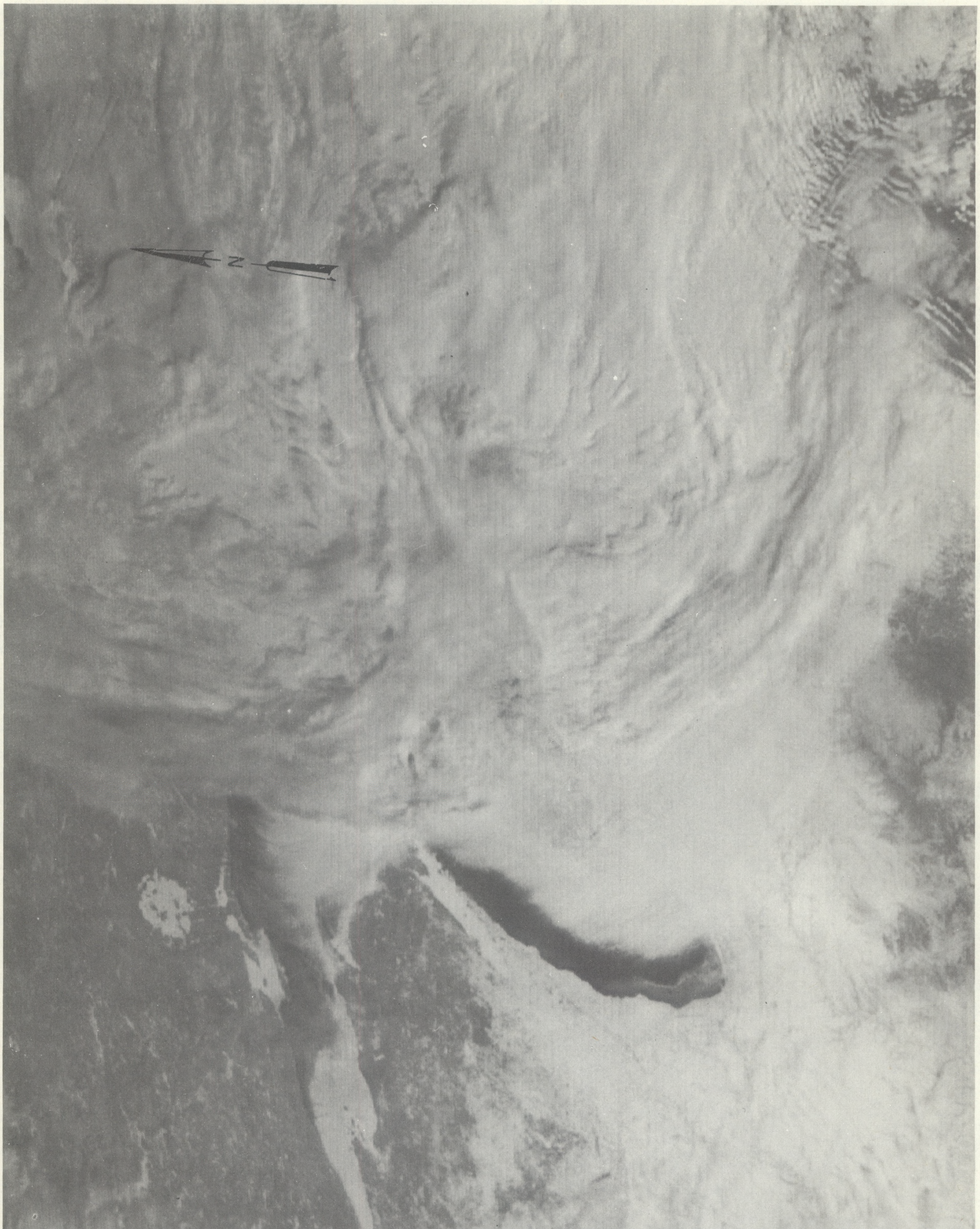

Figure 3.--GOES VISSR (visible) image for 25 January 1979.

Figure 4.--GOES VISSR (visible) image for 5 February 1979.

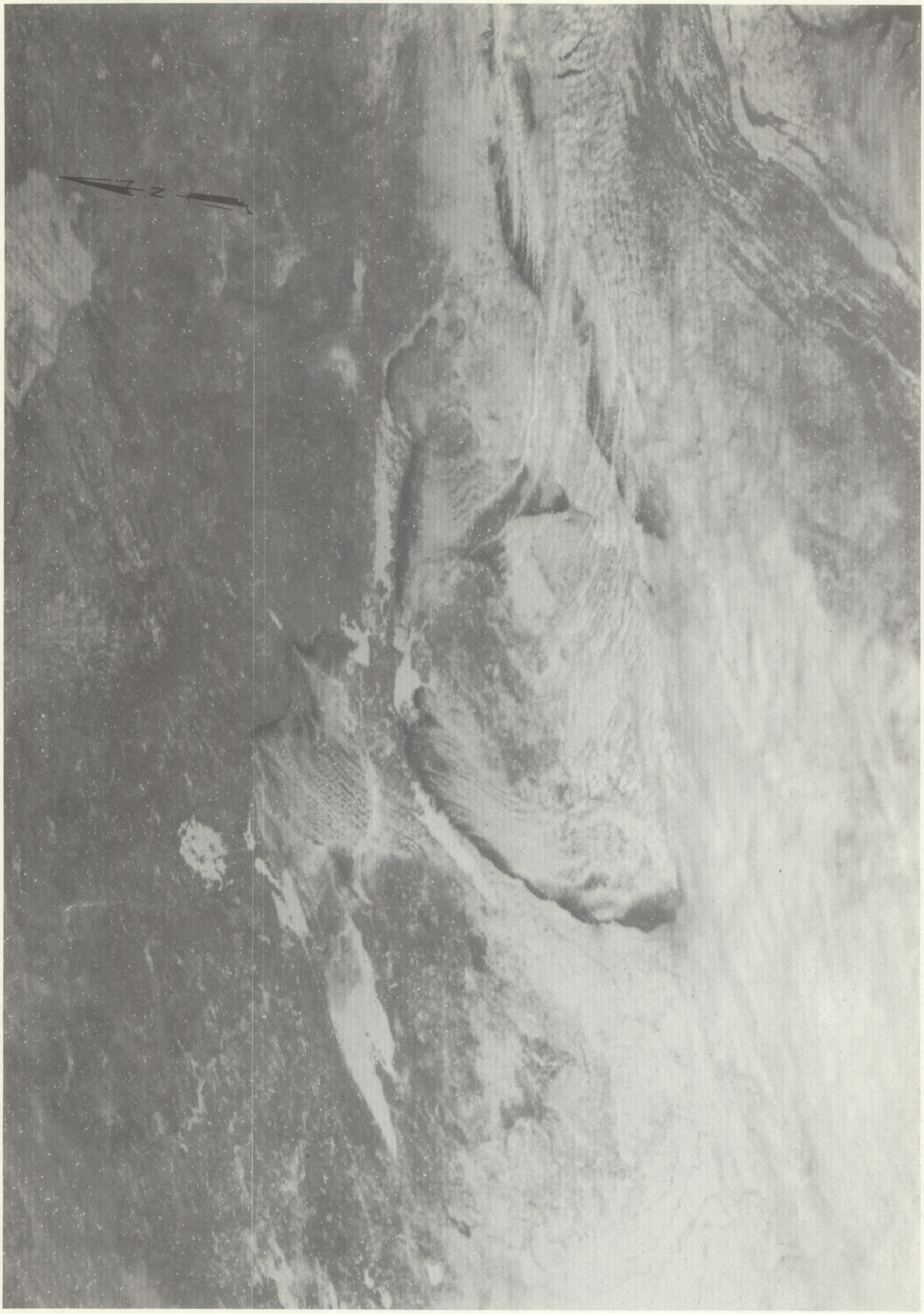

Figure 5.--GOES VISSR (visible) image for 8 February 1979.

Figure 6.--GOES VISSR (visible) image for 9 February 1979.

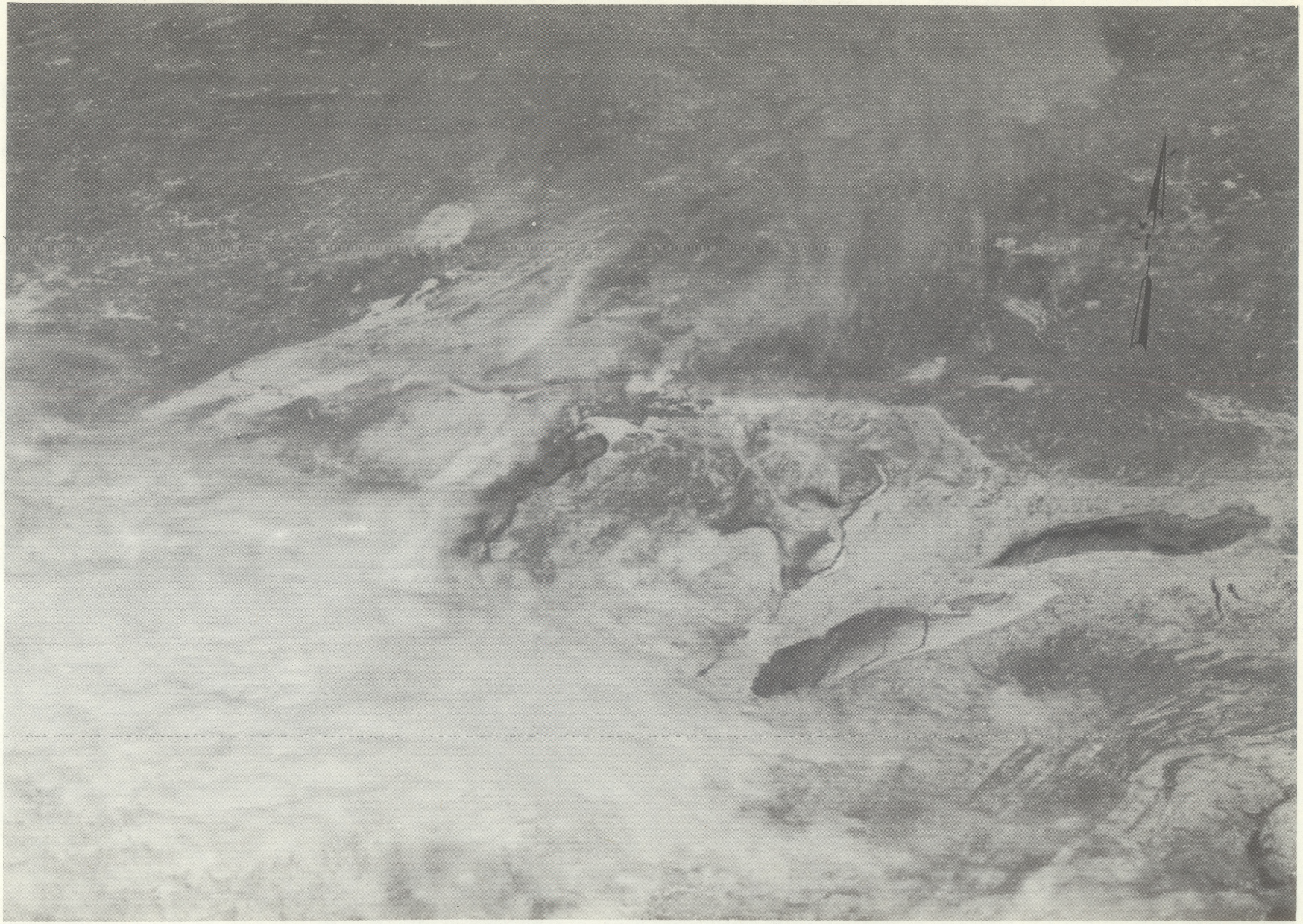

Figure 7.--GOES VISSR (visible) image for 11 February 1979.

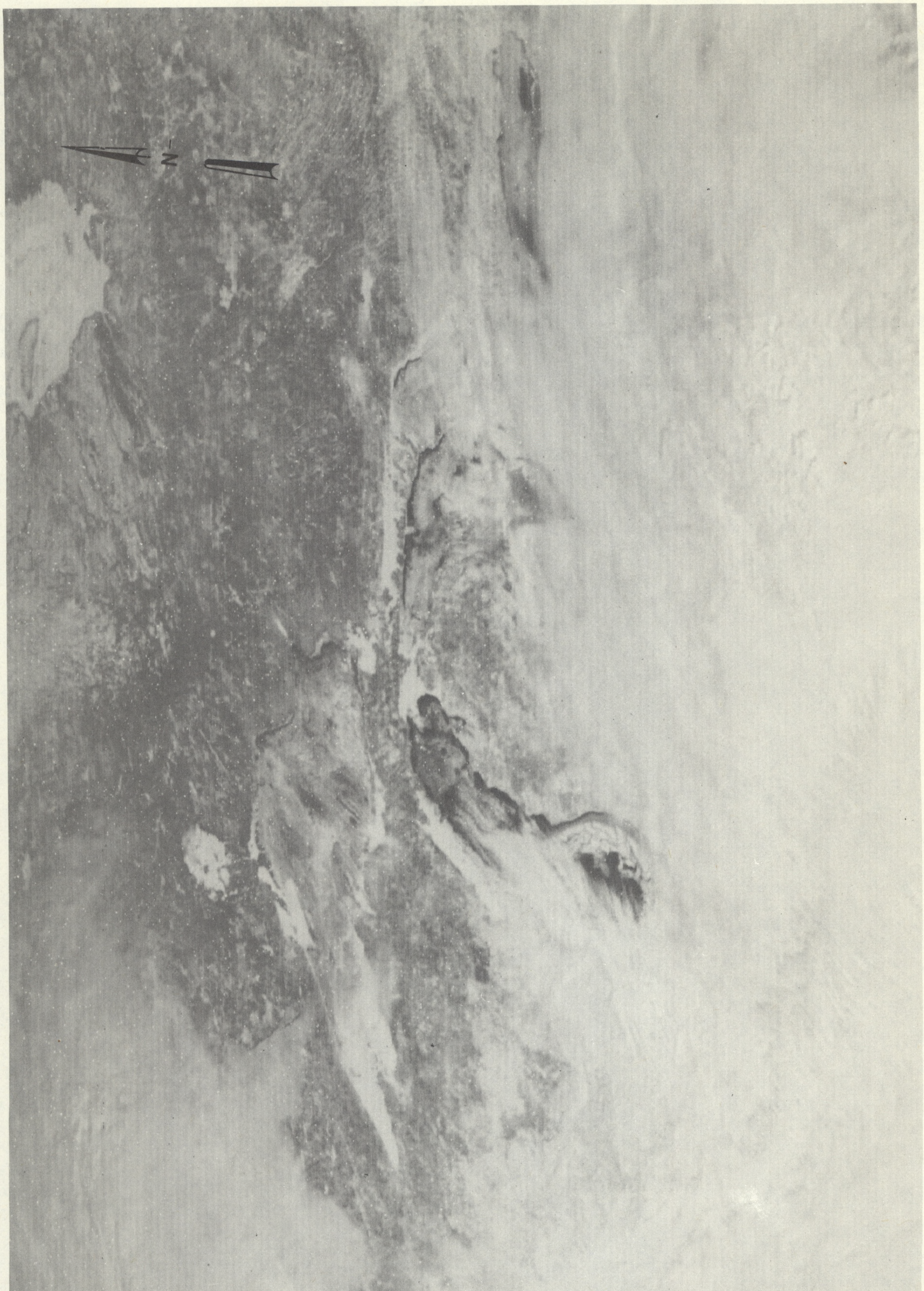

Figure 8.--GOES VISSR (visible) image for 12 February 1979.

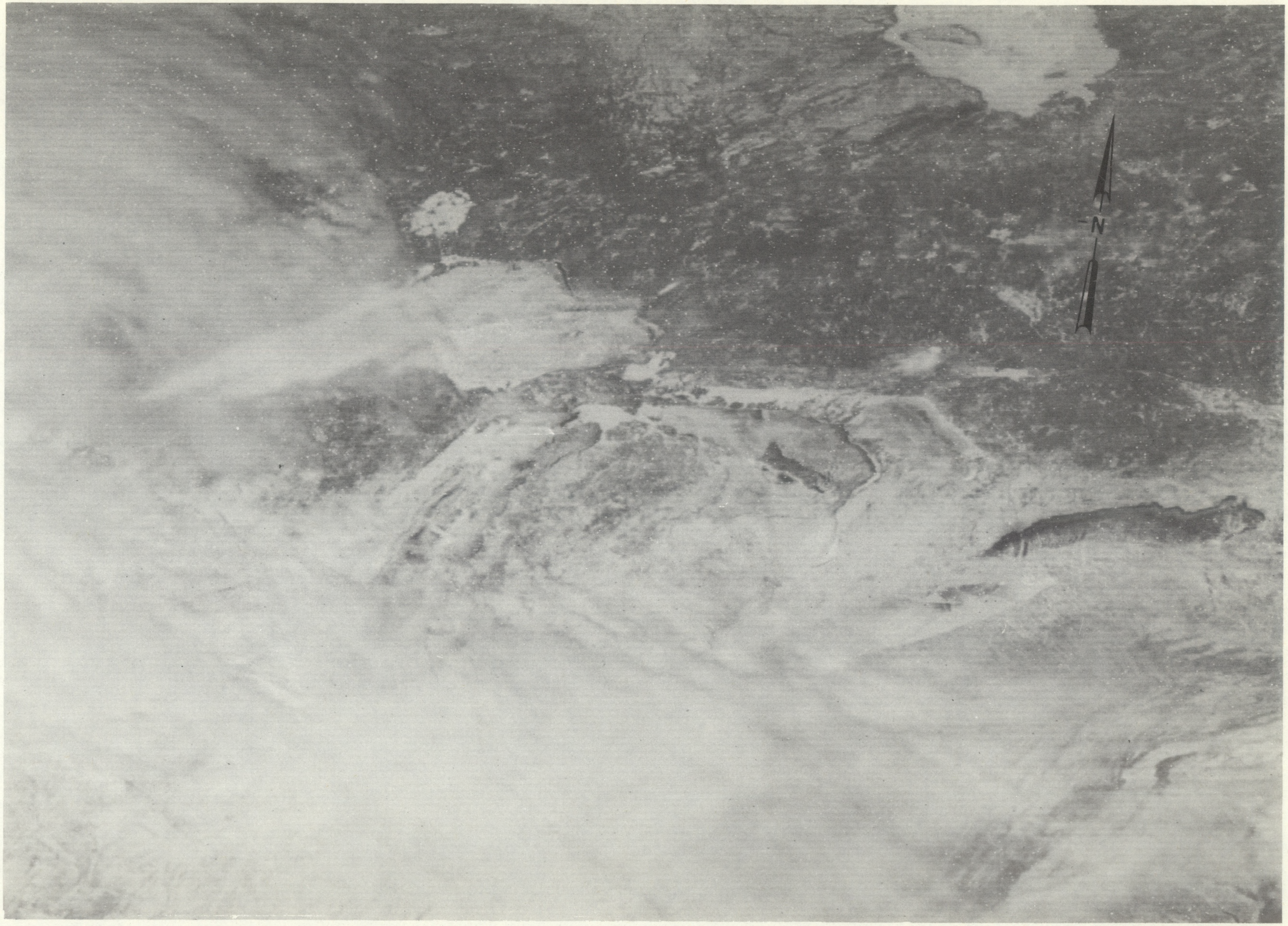

Figure 9.--GOES VISSR (visible) image for 13 February 1979.

Figure 10.--TIROS-N AVHRR (visible) image for 17 February 1979.

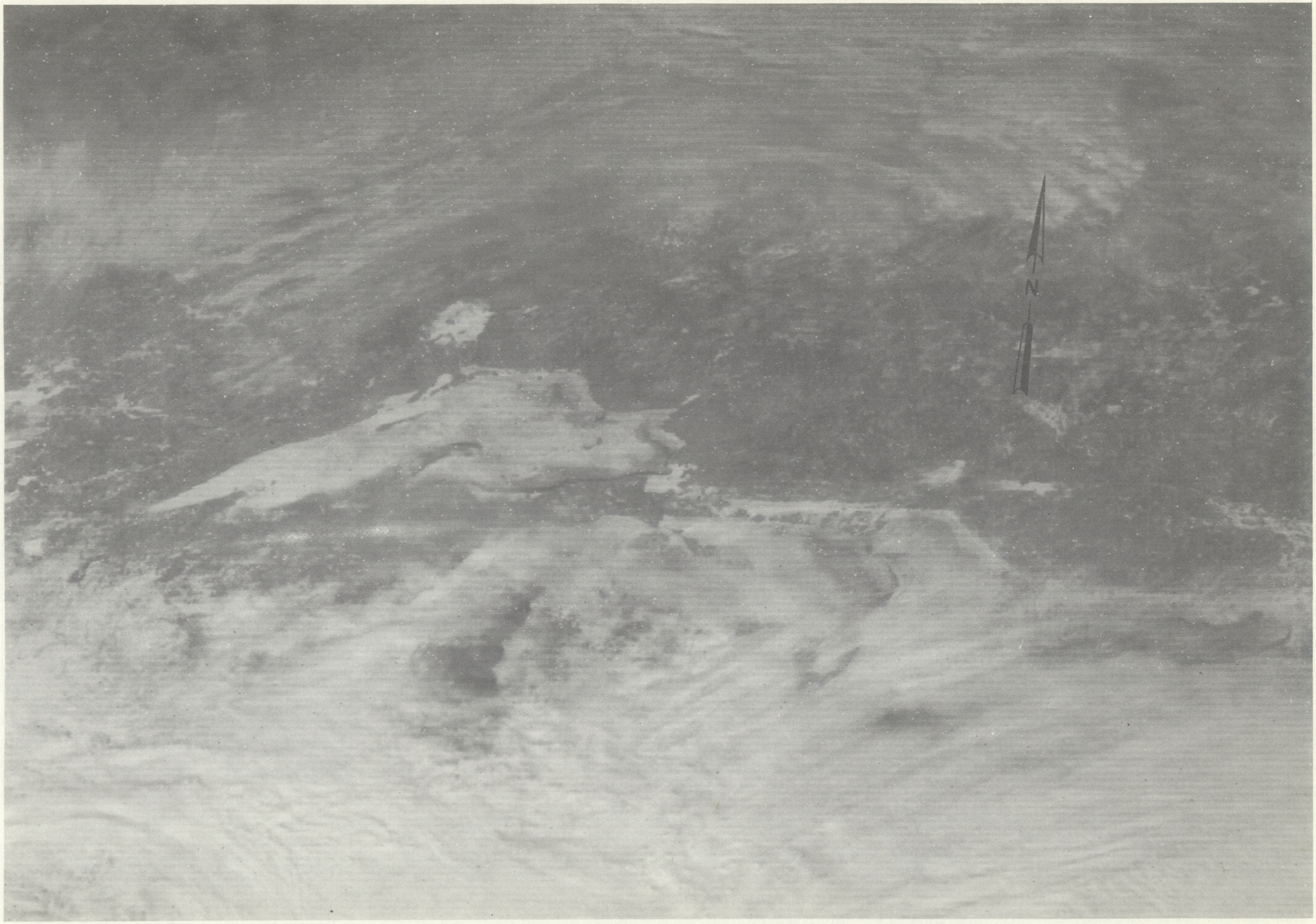

Figure 11.--GOES VISSR (visible) image for 18 February 1979.

Figure 12.--TIROS-N AVHRR (visible) image for 20 February 1979.

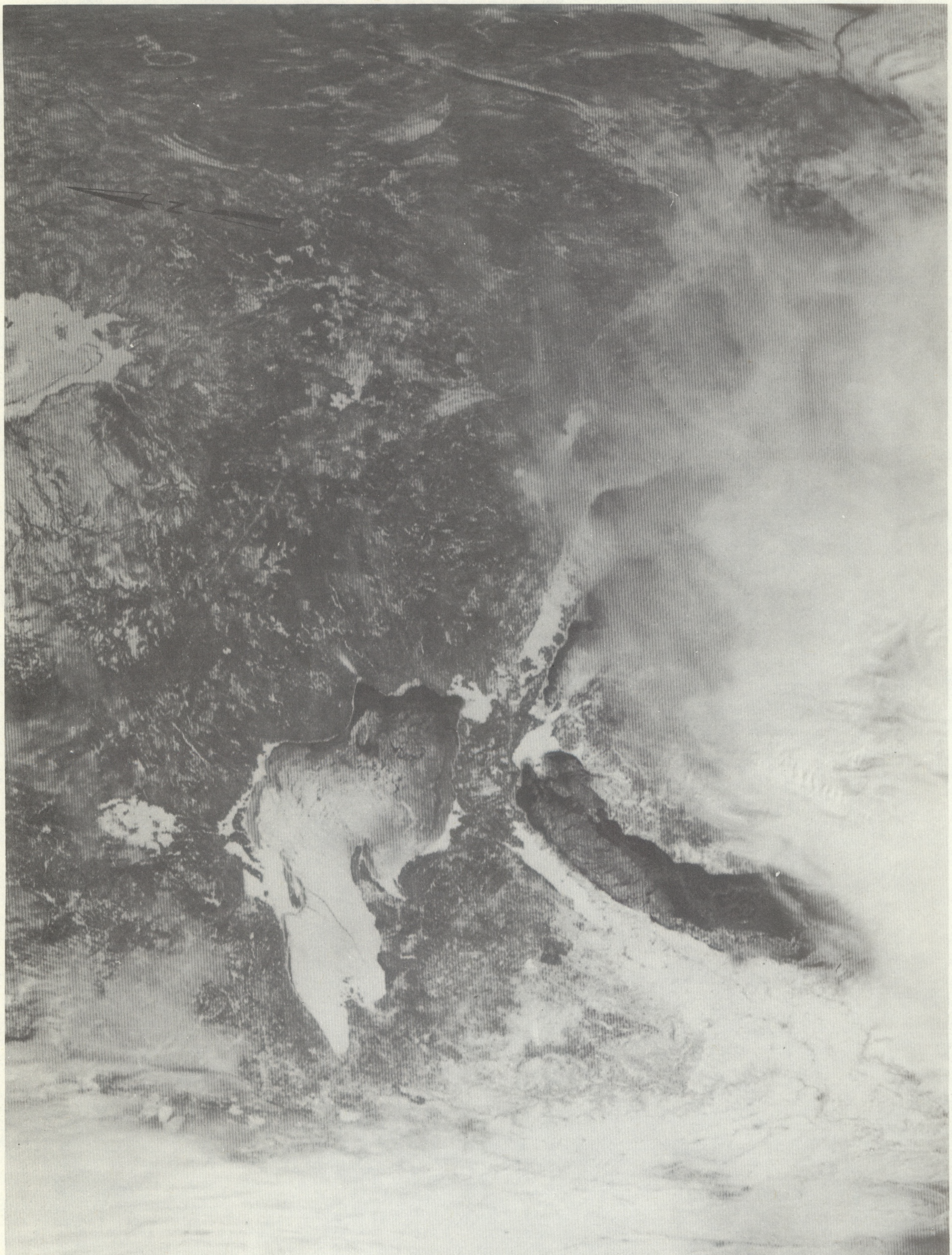

Figure 13.--TIROS-N AVHRR (visible) image for 25 February 1979.

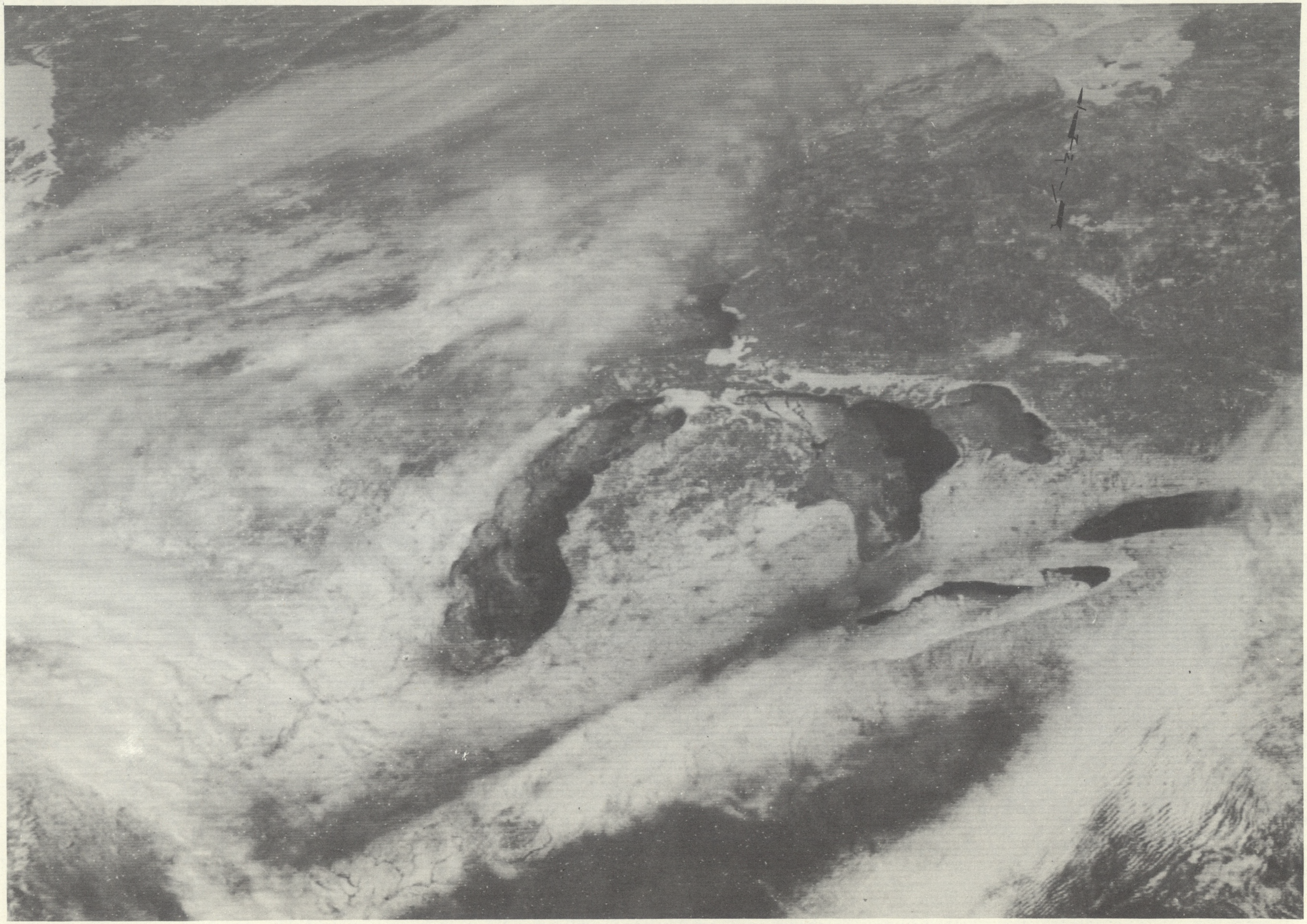

Figure 14.--GOES VISSR (visible) image for 27 February 1979.

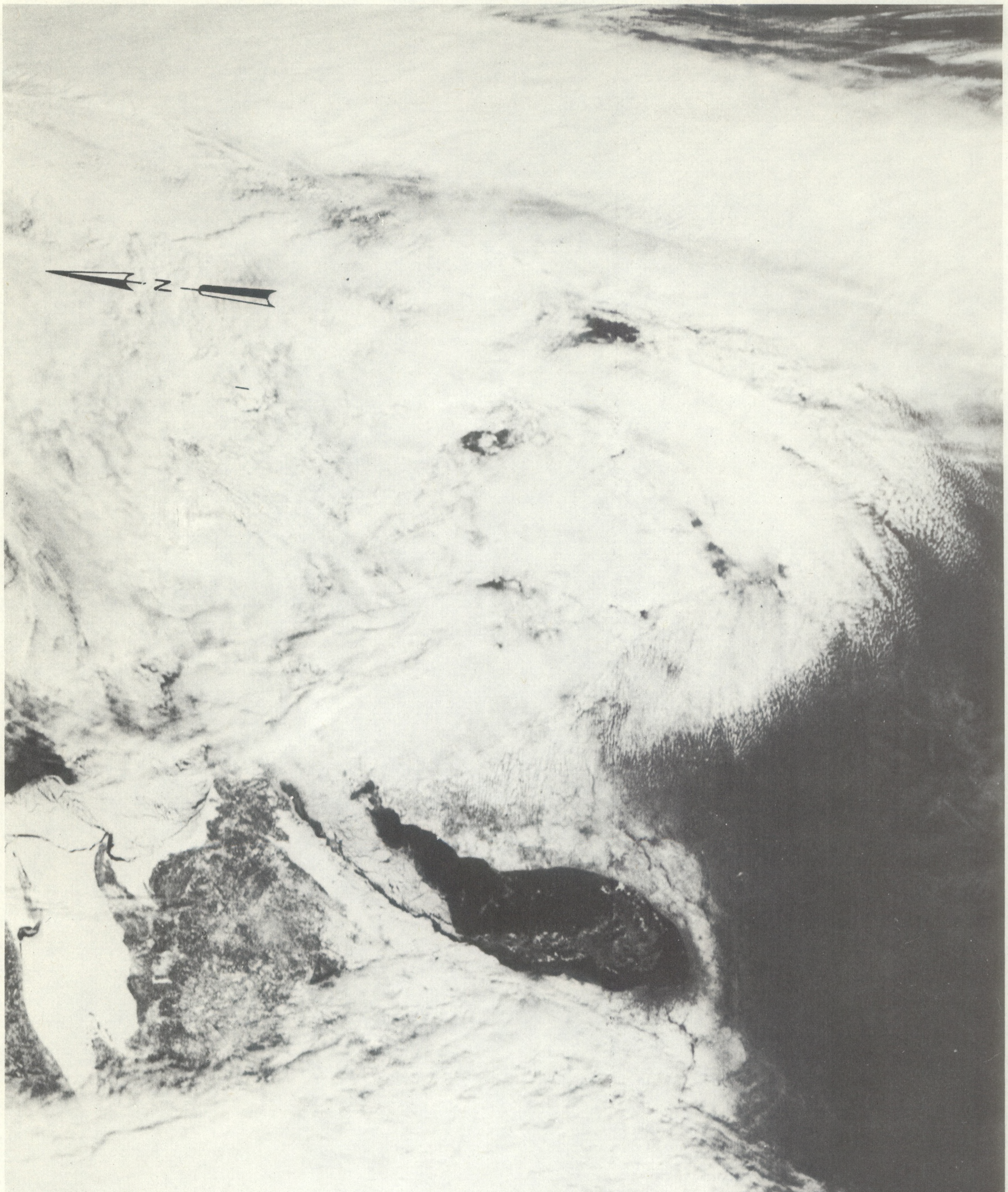

Figure 15.--TIROS-N AVHRR (visible) image for 6 March 1979.

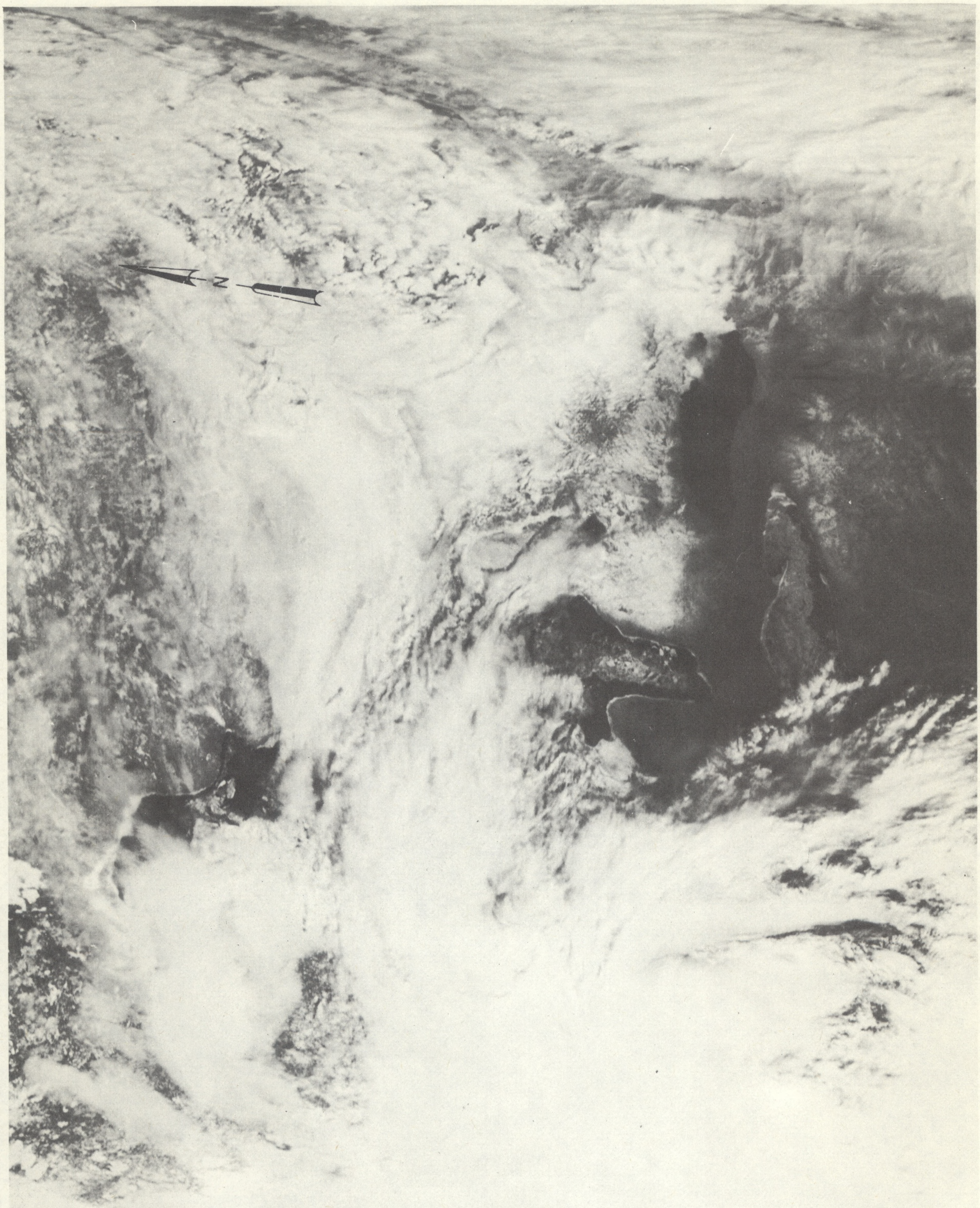

Figure 16.--TIROS-N AVHRR (visible) image for 7 March 1979.

Figure 17.--TIROS-N AVHRR (visible) image for 16 March 1979.

Figure 18.--TIROS-N AVHRR (visible) image for 27 March 1979.

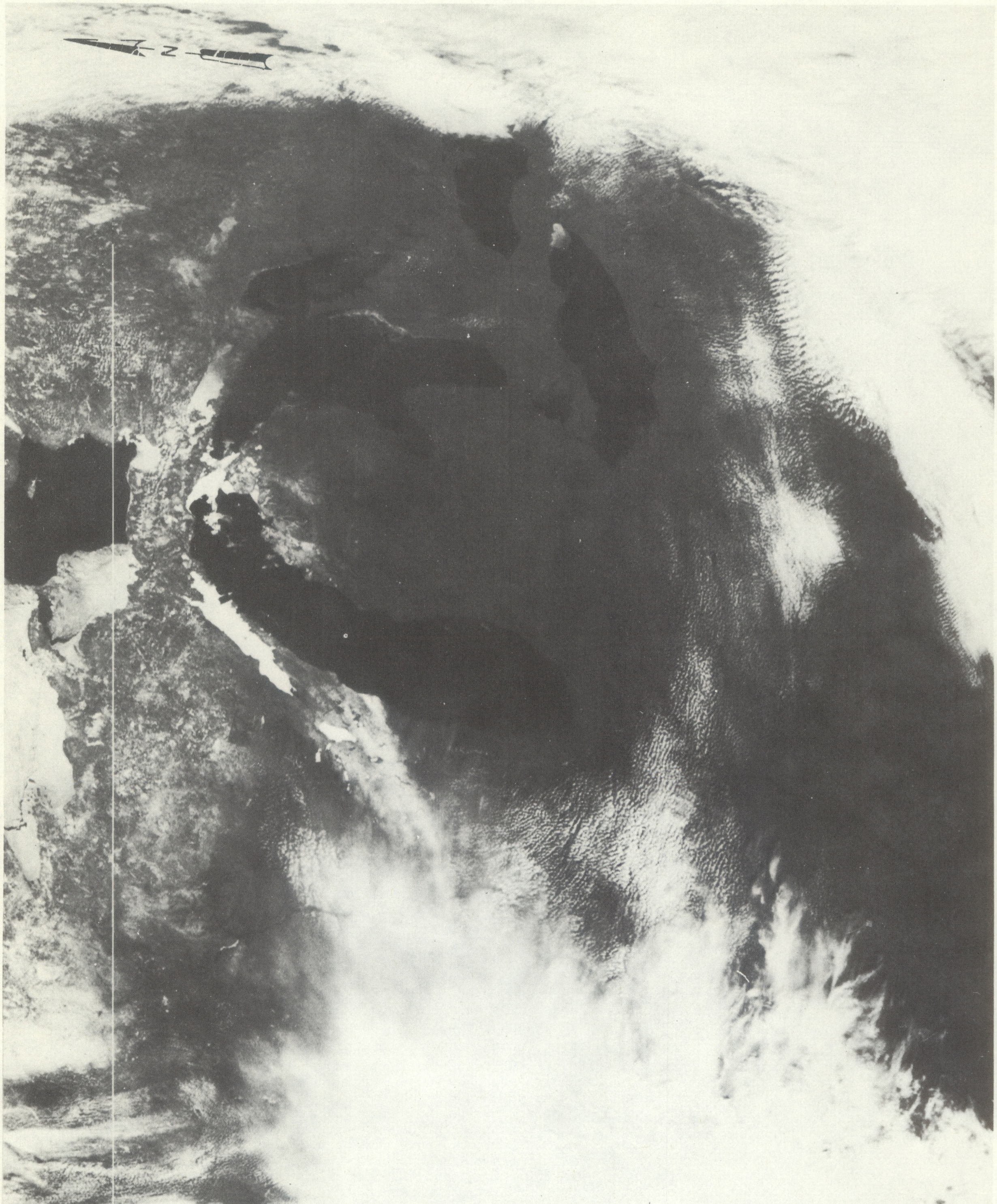

Figure 19.--TIROS-N AVHRR (visible) image for 3 April 1979.

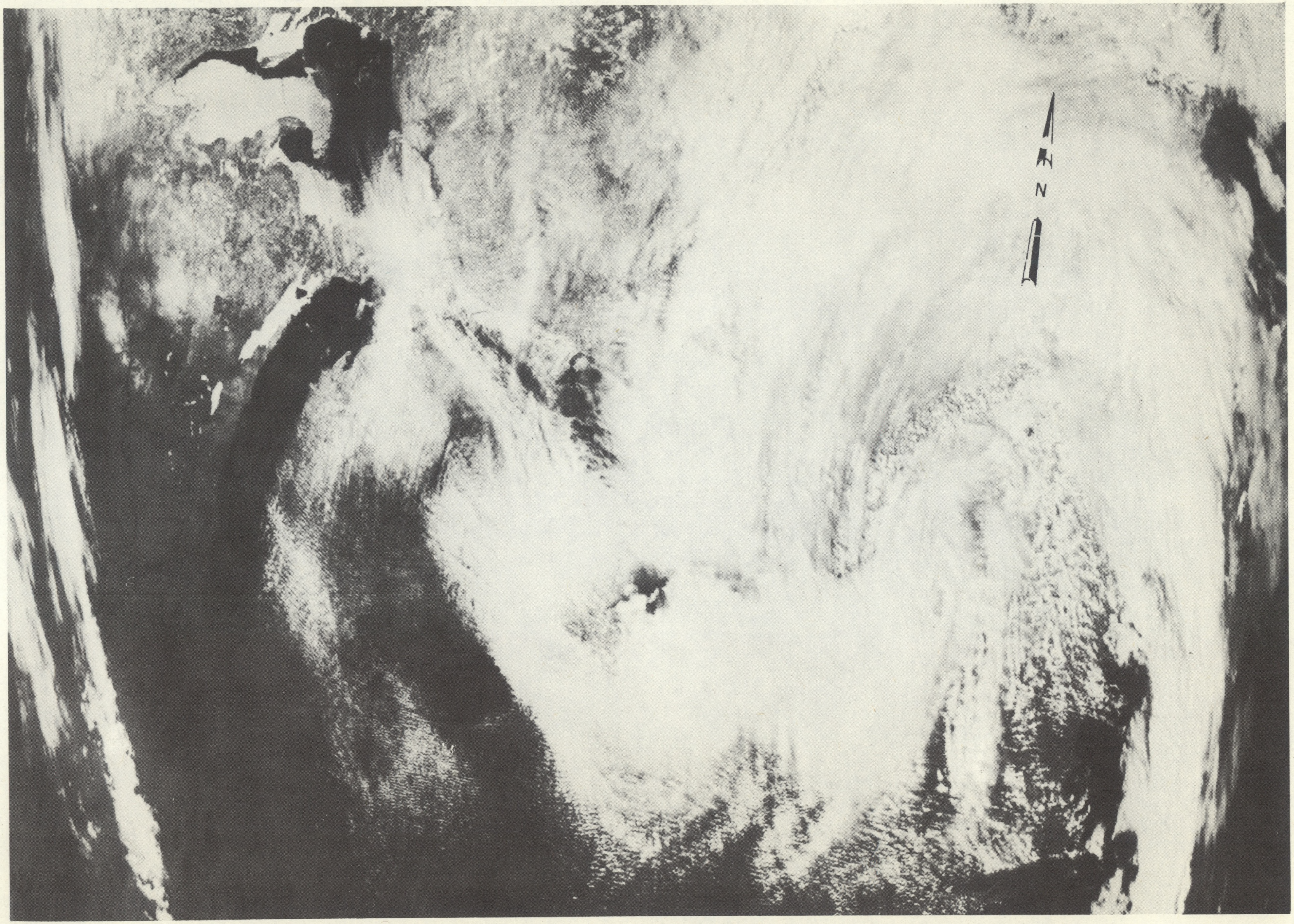

Figure 20.--TIROS-N AVHRR (visible) image for 6 April 1979.

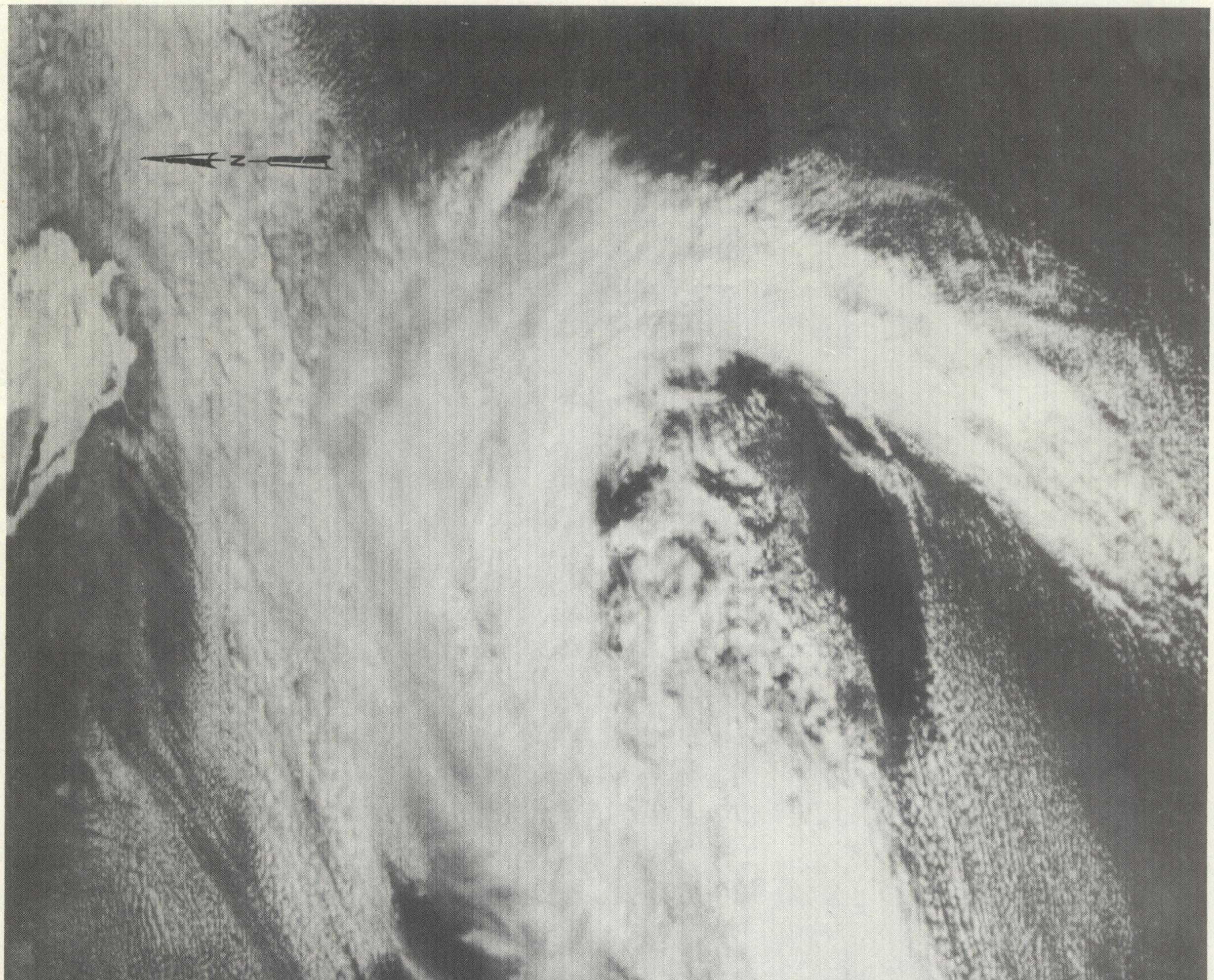

Figure 21.--GOES VISSR (visible) image for 30 April 1979.

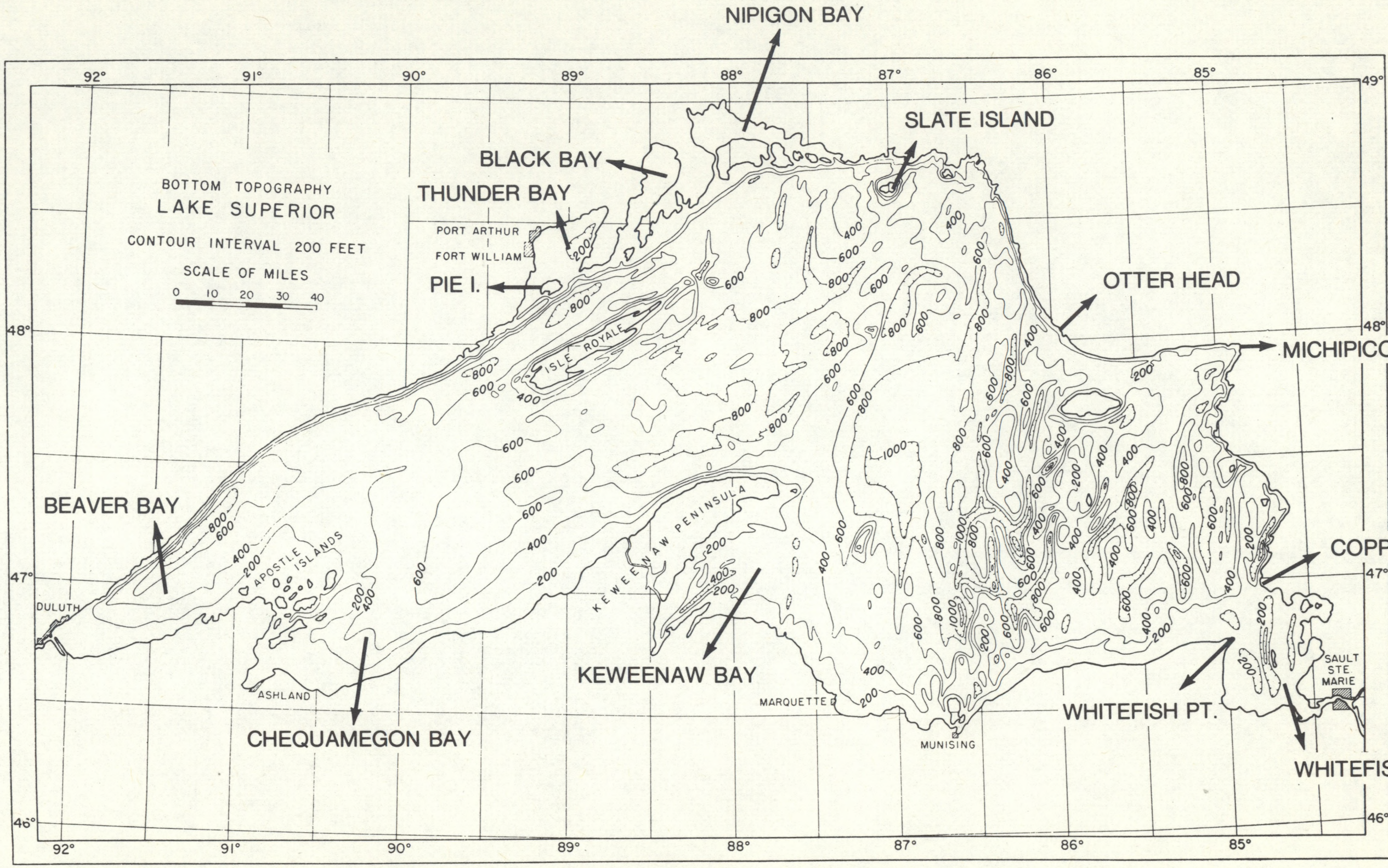

Figure 22.--Bathymetric and geographic location chart for Lake Superior.

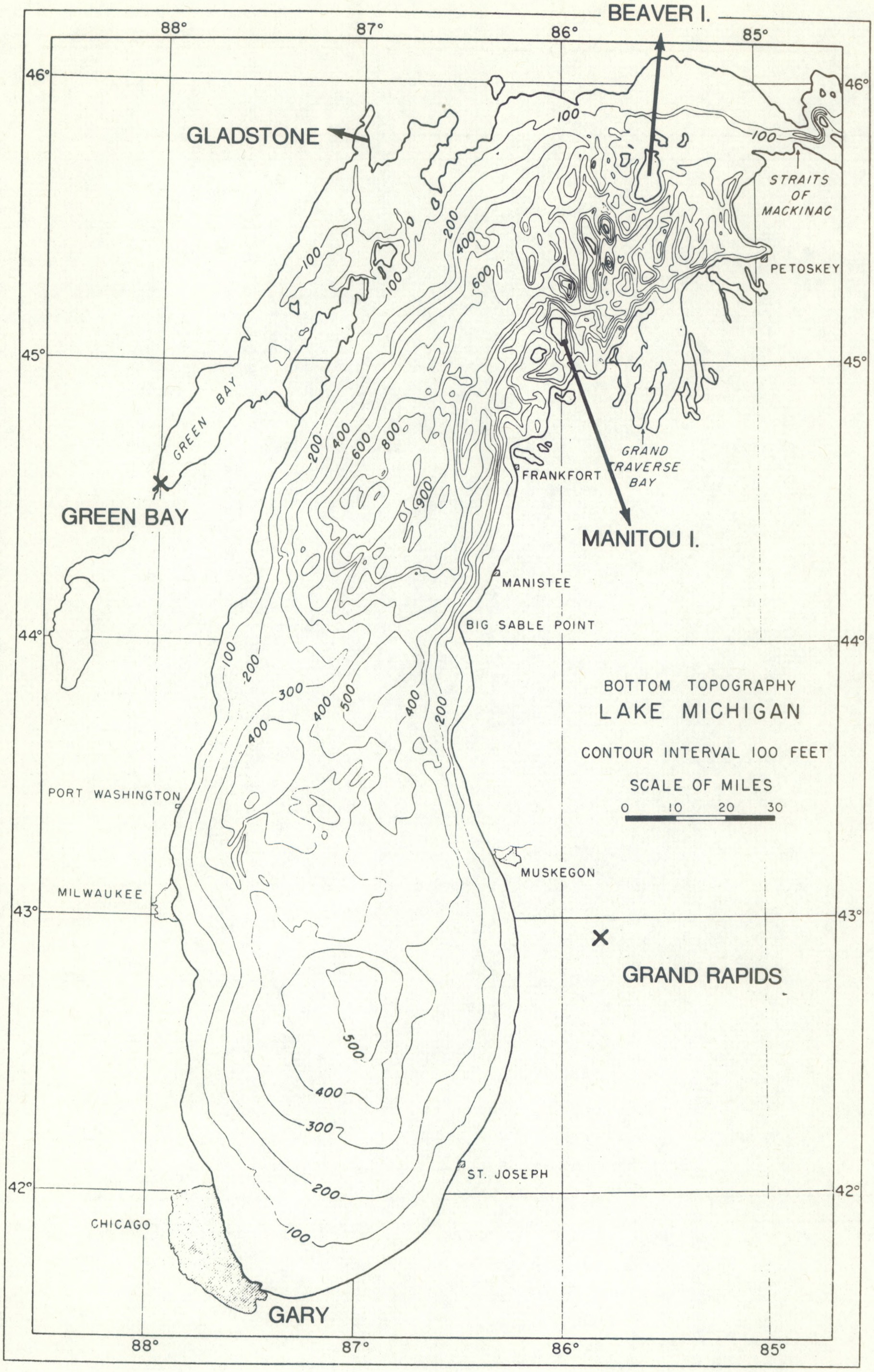

Figure 23.--Bathymetric and geographic location chart for Lake Michigan.

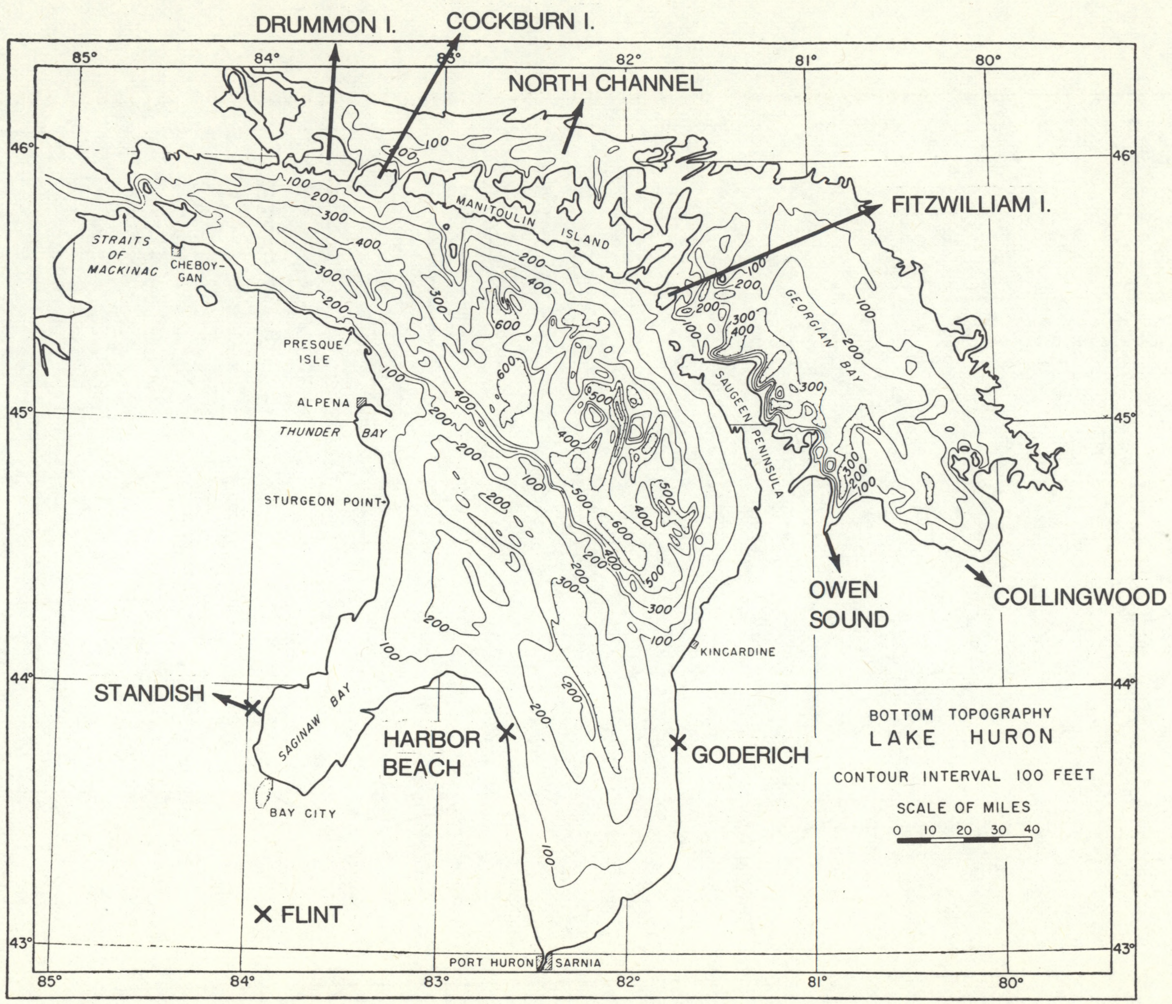

Figure 24.--Bathymetric and geographic location chart for Lake Huron.

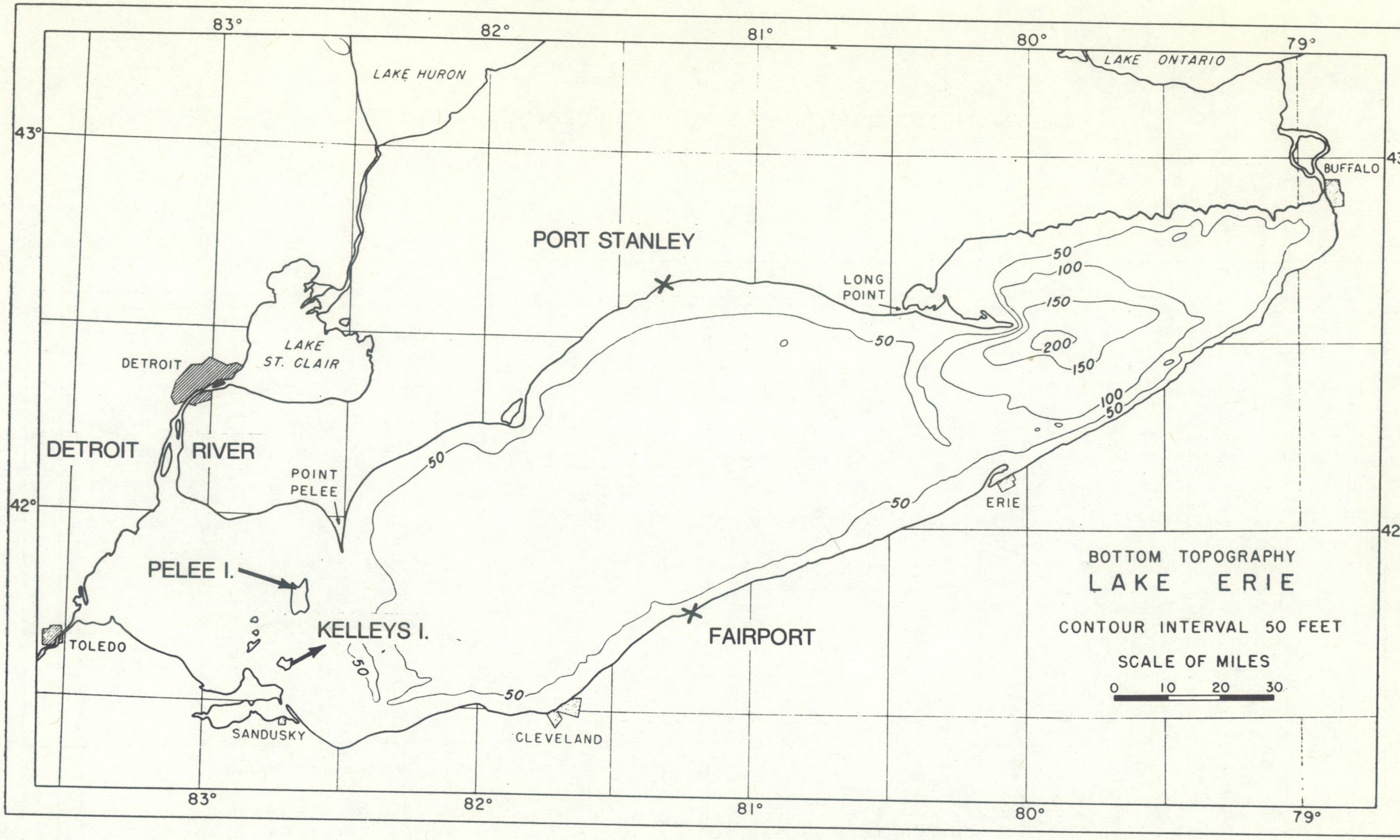

Figure 25.--Bathymetric and geographic location chart for Lake Erie and St. Clair.

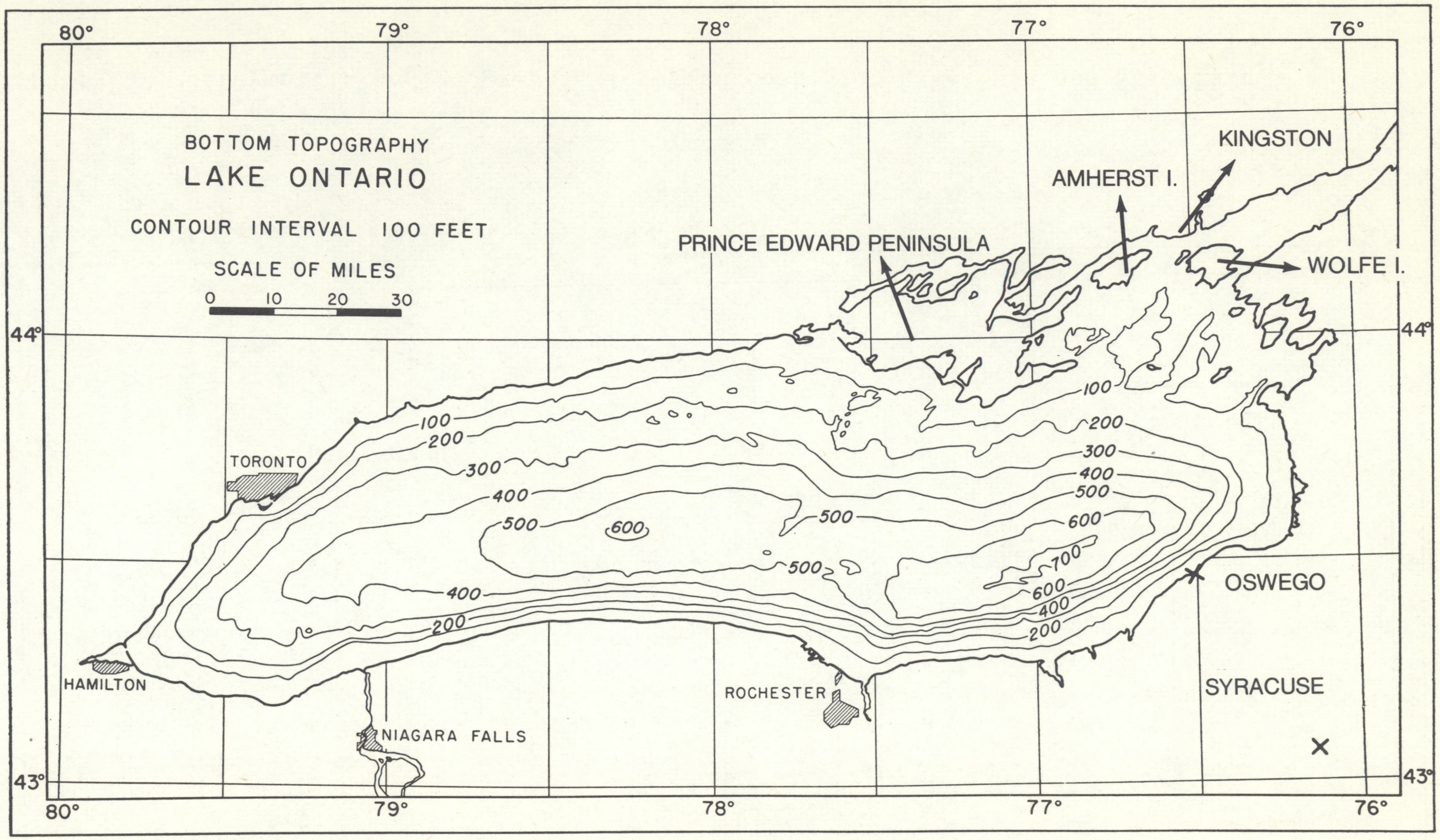

Figure 26.--Bathymetric and geographic location chart for Lake Ontario.

(Continued from inside front cover)

NESS 87 Atlantic Tropical and Subtropical Cyclone Classifications for 1976. D. C. Gaby, J. B. Lushine, B. M. Mayfield, S. C. Pearce, K.O. Poteat, and F. E. Torres, April 1977, 13 pp. (PB-269-674/AS)

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NESS 109 Catalog of Products, Third Edition. Dennis C. Dismachek, Arthur L. Booth, and John A. Leese, April 1980, 130 pp.

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