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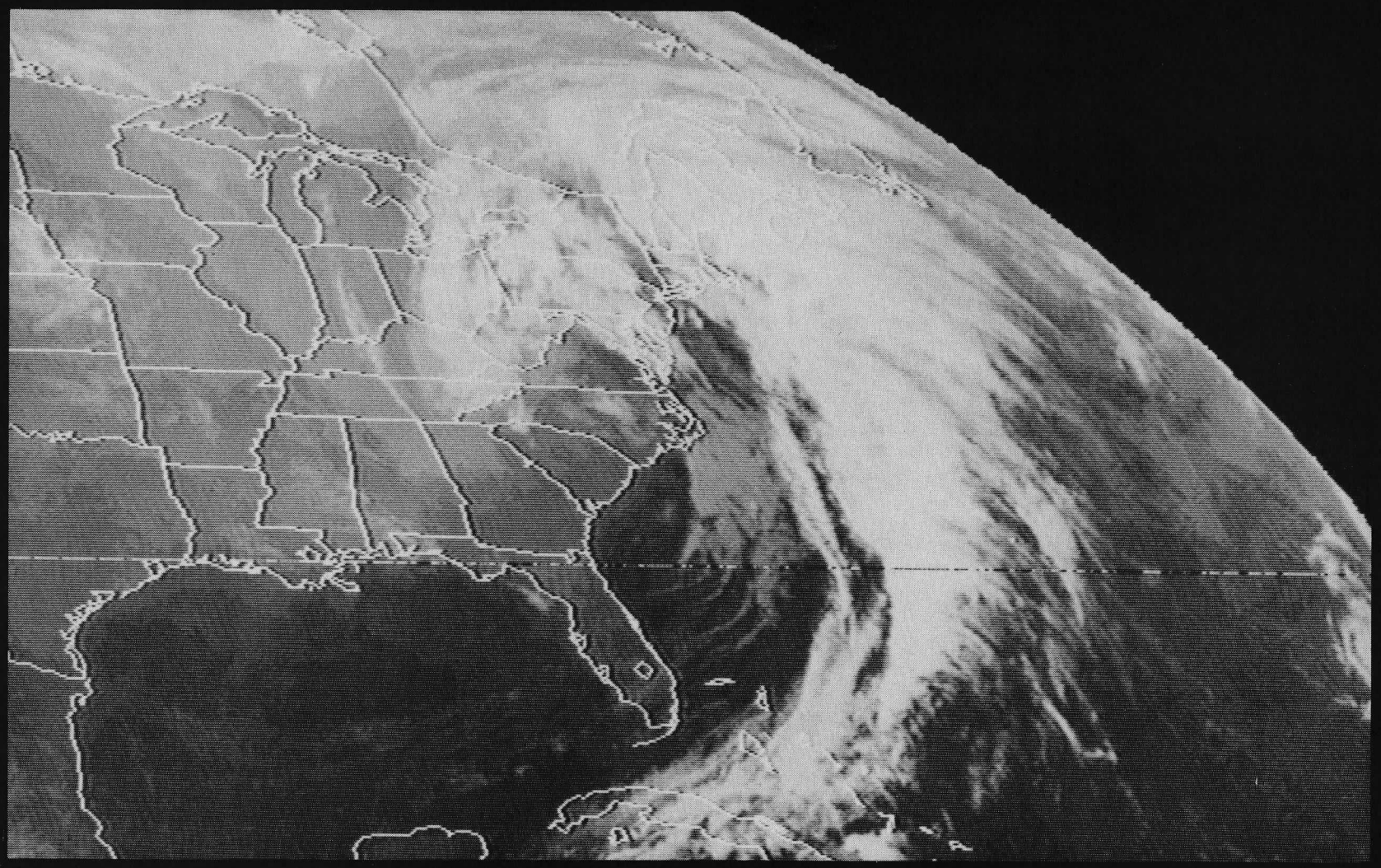
GOES IMAGERY FOR THE GENESIS OF ATLANTIC LOWS EXPERIMENT

GALE PERIOD: JANUARY 15 - MARCH 15, 1986



BY CHRISTOPHER VELDEN AND JANET PYEATT

SPACE SCIENCE AND ENGINEERING CENTER
UNIVERSITY OF WISCONSIN-MADISON

National Aeronautics and Space Administration Under Grant NAG 5-742

JULY 1987

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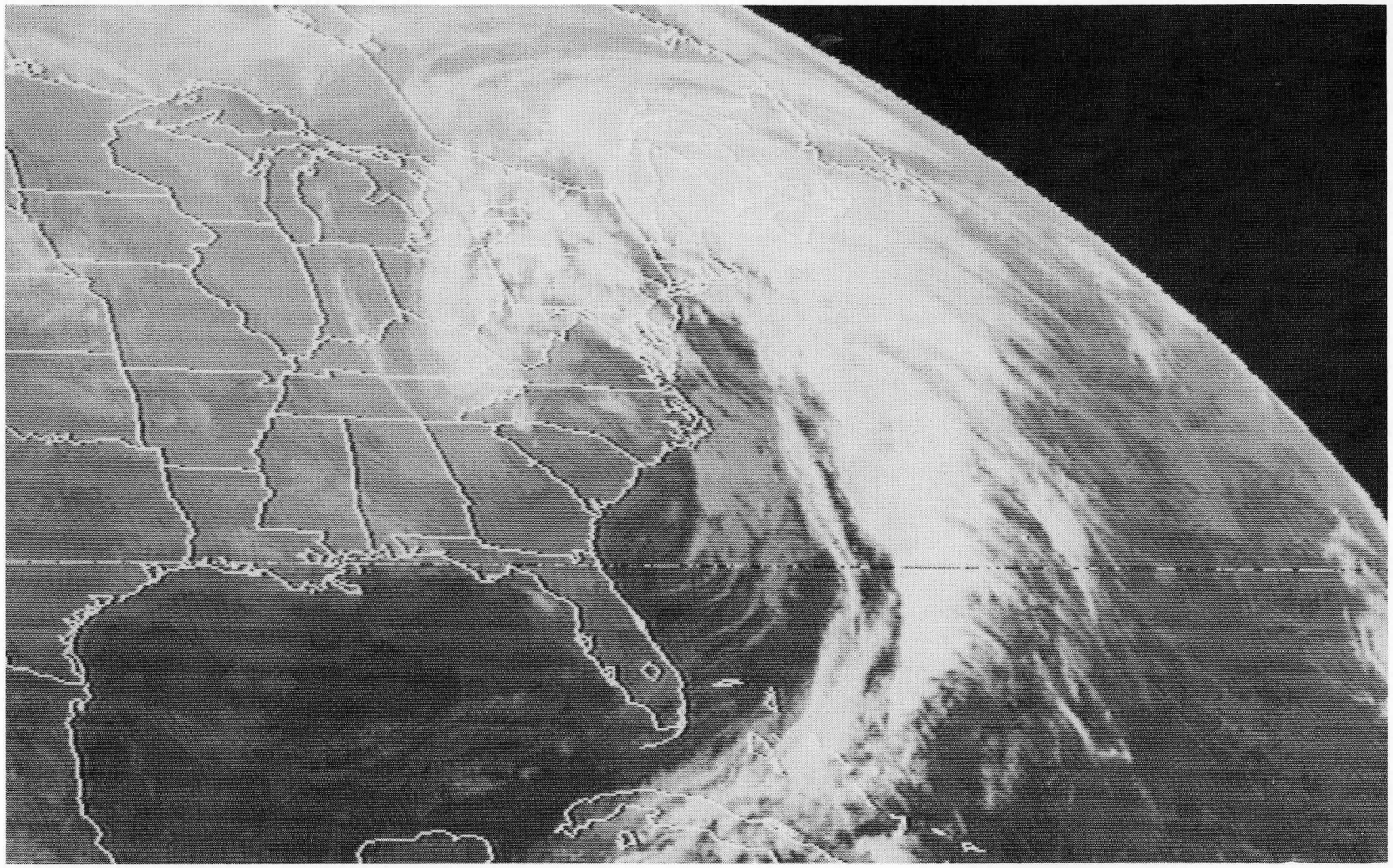

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GEOSTATIONARY SATELLITE IMAGERY
FOR THE GENESIS OF ATLANTIC LOWS EXPERIMENT

1. Introduction

The Genesis of Atlantic Lows Experiment (GALE) was conducted during January - March, 1986. Thirteen special observing periods were designated for intensive observations from both conventional and special GALE sources. An integral part of the experiment was GOES data which was collected and archived at the University of Wisconsin-Madison's Space Science and Engineering Center (UW-SSEC). This data was made available to the Raleigh, North Carolina GALE forecast office via a workstation remotely connected to the Man-computer Interactive Data Access System (McIDAS) at UW-SSEC where the data is archived on video cassettes.

There are several different types of meteorological data collected from GOES. Infrared (IR) imagery at 4 km resolution is available every half hour around the clock. High resolution (1 km) visible (VIS) data is available every half-hour during daylight hours. The IR and VIS data were occasionally available at 15 minute intervals during Rapid Interval Scan Operations (RISOP) mode (see Appendix). VISSR Atmospheric Sounder (VAS) observations include multi-spectral imagery available on a half hour basis (except from 02-08 GMT, when VAS data is not available). This data includes 8 km resolution water vapor imagery as well as several CO_2 absorption bands and window channels. Products and imagery which were derived by UW-SSEC from this basic raw data set are discussed in the Appendix.

This atlas is to be used as a reference for the evolution of cloud conditions and features during GALE events. Obviously, with the large volume of satellite data collected during this 60-day period, not all of the imagery is included in this atlas. However, a representative subset which hopefully captures evolving features and structures has been assembled here for qualitative assessment by GALE researchers as they examine the quantitative data collected during GALE.

Three types of GOES imagery are presented here. The water vapor imagery is shown at approximately four-hourly intervals (except during the period 02-08 GMT and during RISOP modes, when it is not available) during the entire 60-day GALE period (January 15 - March 15, 1986). The darker areas in this imagery depict very dry or subsidence regions in the mid-troposphere (700-200 mb), while the lighter areas indicate relatively moist areas. The bright areas are clouds. This imagery is intended to show the large scale scenario and also depicts synoptic features which may not be readily apparent in conventional satellite imagery. IR window imagery is presented at four-hourly intervals during and immediately surrounding IOPs, and is centered on the GALE region. Visible imagery at 2 km resolution is included at hourly intervals during daylight hours and covers a limited area centered on the GALE special observation network. This imagery shows greater detail and mesoscale features.

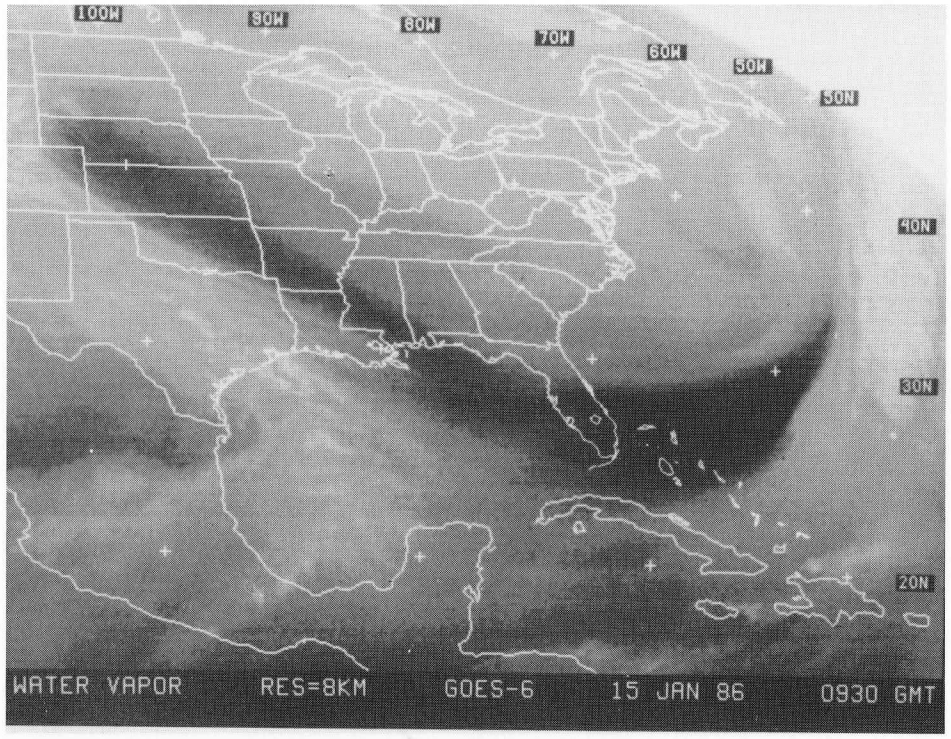
A brief, non-technical satellite synopsis is given before each IOP, summarizing features observed from the imagery during the IOP. Additional use was made of a videotape depicting the satellite data in animation, the GALE Field Program Summary, and the Weather

Service Forecasting Handbook No. 6 (Satellite Imagery Interpretation for Forecasters) in preparing these summaries.

Computer tapes containing the complete GOES data set in digital format are available from UW-SSEC. A video cassette has also been produced from the same imagery included in this atlas, complete with McIDAS color enhancements and animated loops. This cassette is available through GDC at Drexel. More information on satellite data available during GALE can be found in the Appendix and also in the GALE Data Users Guide.

2. Acknowledgments

Our thanks go to the UW-SSEC McIDAS operators, especially Dee Wade and Ann LaForce, for handling the collection and archiving of the raw satellite data that is reproduced here. Paul Menzel is to be commended for his efforts toward insuring that the comprehensive GALE satellite data set was scheduled and received. Thanks are extended to Robert Fox for use of the McIDAS facilities in this effort. The encouragement and financial support (NASA grant NAG5-742) from Drs. William Smith, Louis Uccellini and James Dodge were essential to the production of this atlas. The photographic material and reproduction was handled by the UW Photographic Media Center and the manuscript by Laura Beckett. A special thanks to Terri Gregory and Tony Wendricks for their technical assistance in preparing this atlas.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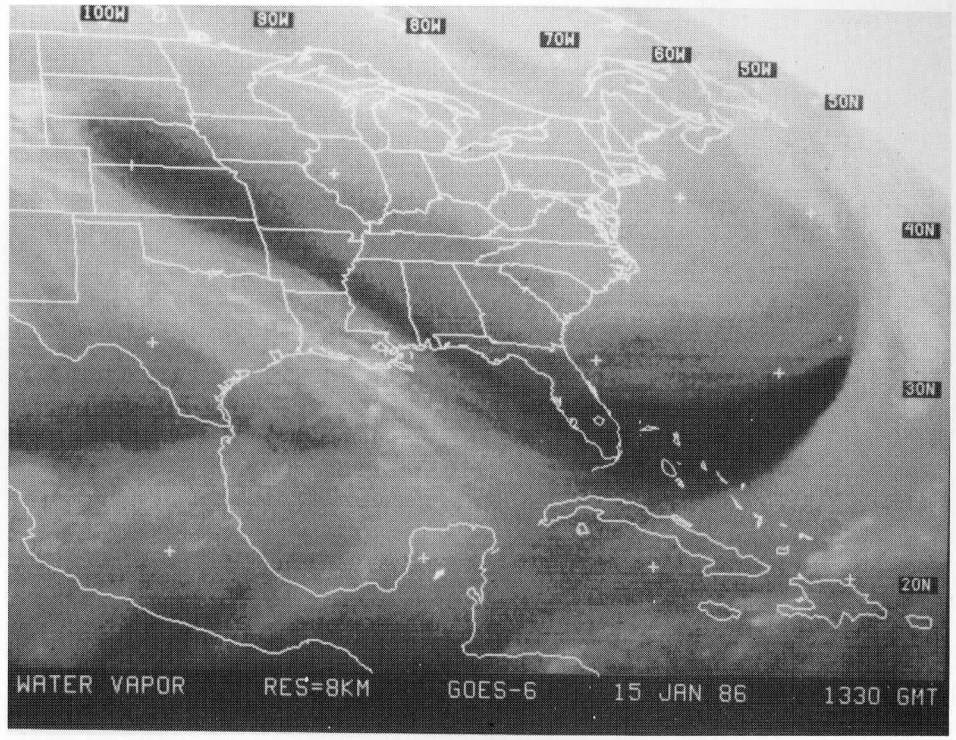
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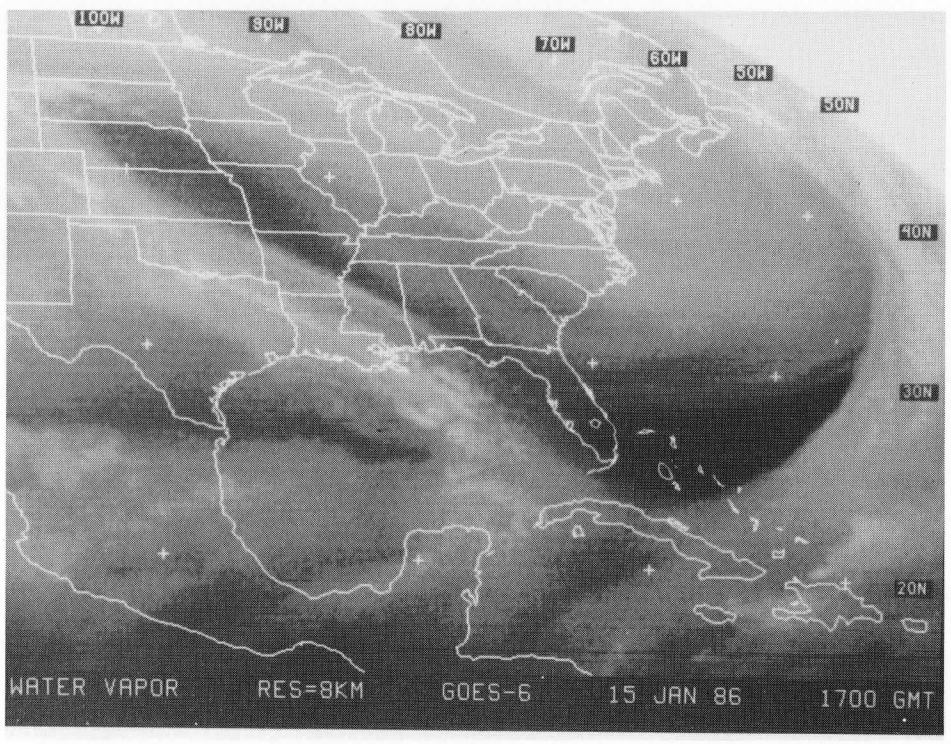
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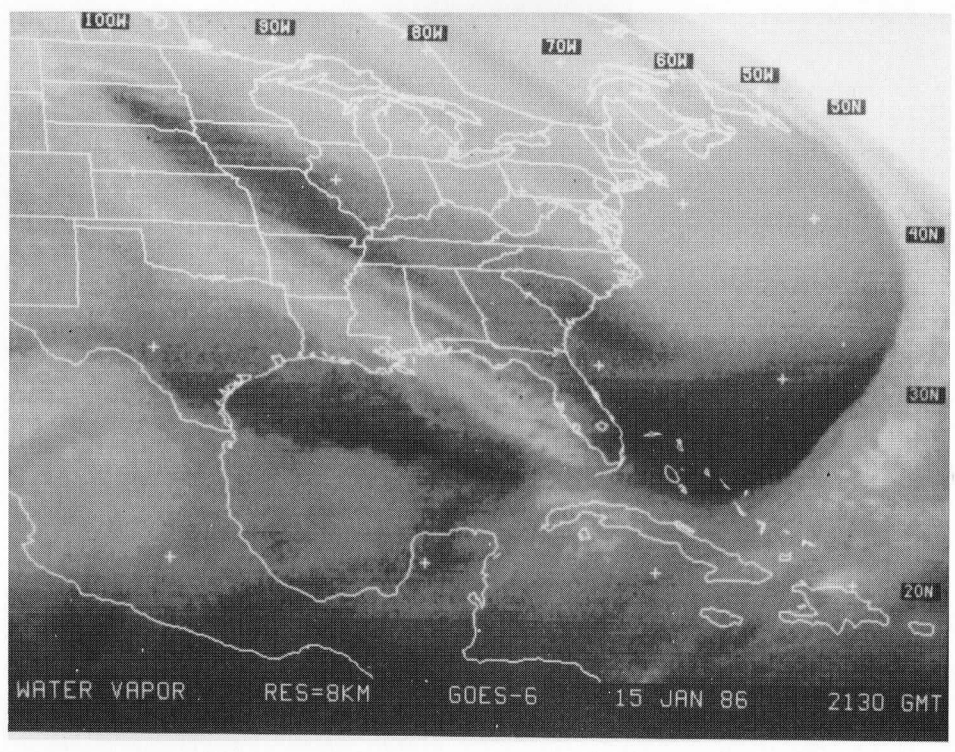
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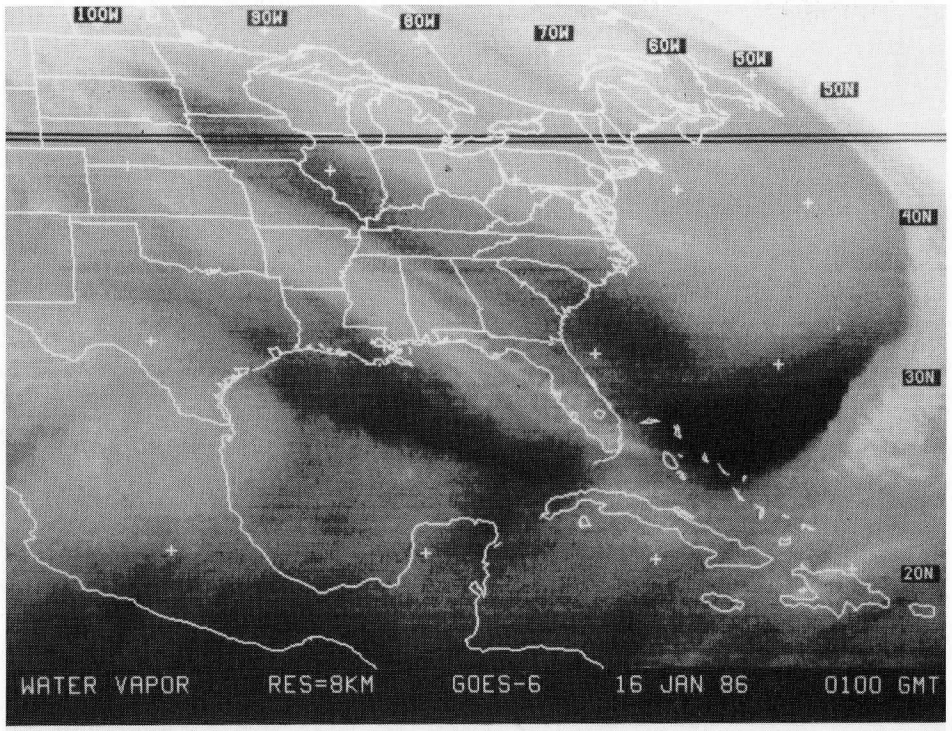
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IOP #1 - Upper Level Cyclogenesis Onshore / Coastal Wave
January 18 - January 20

Satellite Synopsis

Water Vapor

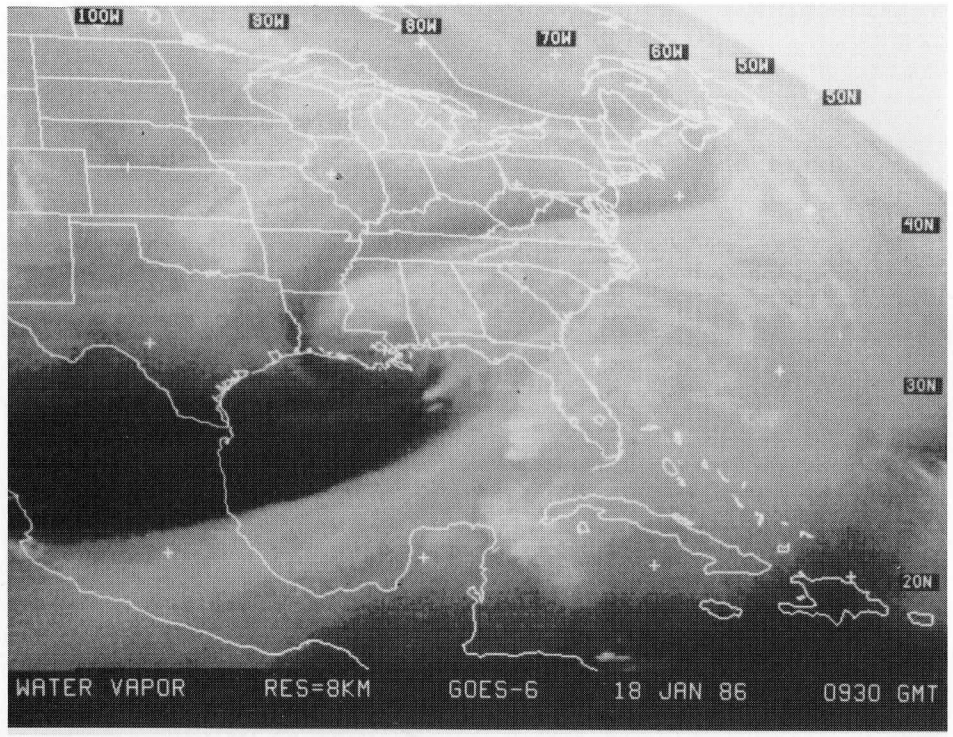
- Circulation center very apparent on the 18th near New Orleans, moves to New England and weakens by the 19th, 00 GMT.
- Intense dry band exists over the Gulf of Mexico region during the entire IOP.
- Short wave drops in from northern plains signified by a weak dry pattern. This wave amplifies on the 19th over Tennessee and wraps up over North Carolina, before heading northeast to near Cape Cod by 00 GMT on the 21st. A donut-like pattern of subsidence near the center of this circulation is evident, associated with tropopause folding around 00 GMT on the 20th.

IR

- Circulation center evident on the 18th in Alabama moves northeast into Virginia as it dissipates.
- Strong increase in convective clouds off the southeast coast on the 19th, moves into New England by the 20th.
- Large comma cloud pattern develops with trough on 20th.
- Negative tilt of trough becomes apparent from cirrus on 19th-20th.
- Increase in convection in cold air PVA southeast of Cape Cod late on the 20th.

Visible

- 19th, thunderstorms over the Gulf Stream (rope cloud).
- 19th, frontal convective line in Carolinas.
- 20th, banding of low level clouds over Atlantic off the Carolinas associated with cool, westerly winds.
- 20th, mountain-induced wave clouds in western Virginia, West Virginia and North Carolina.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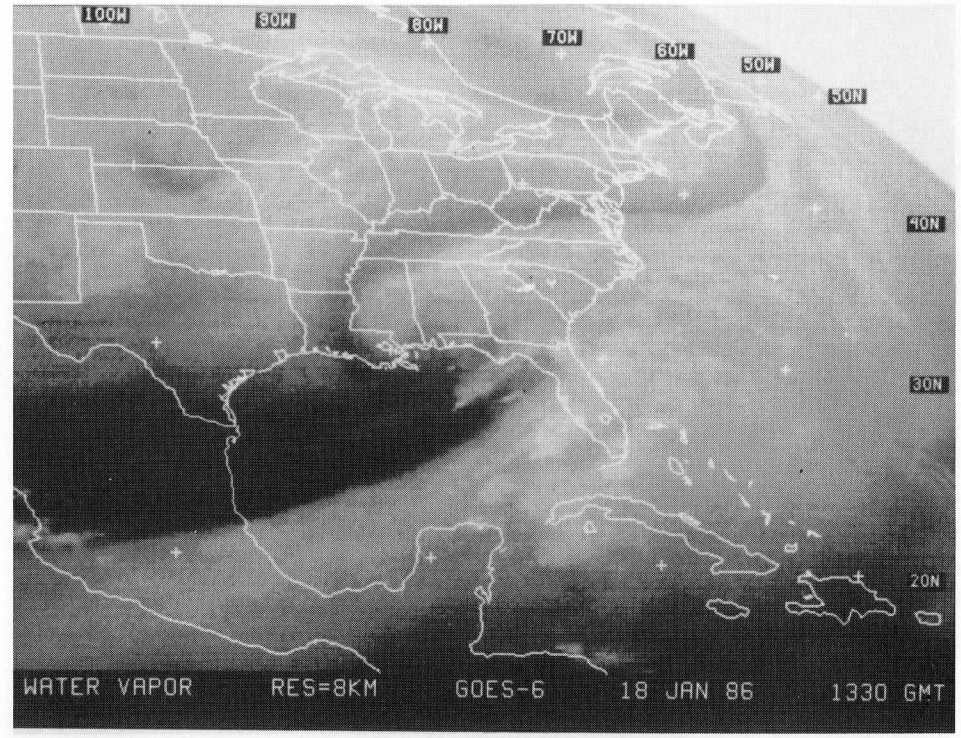
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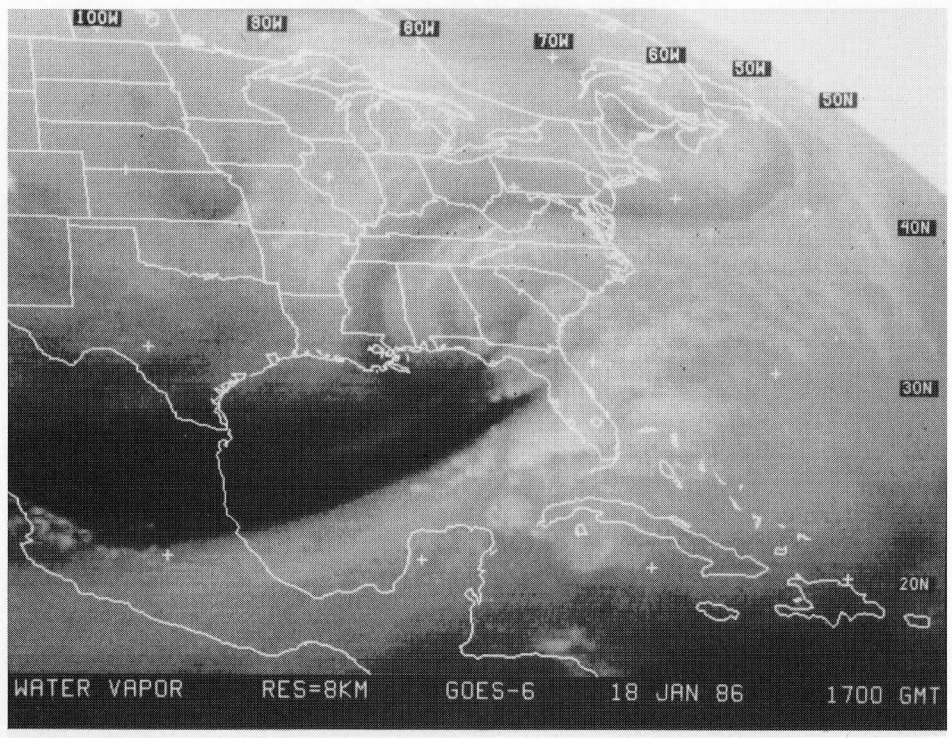
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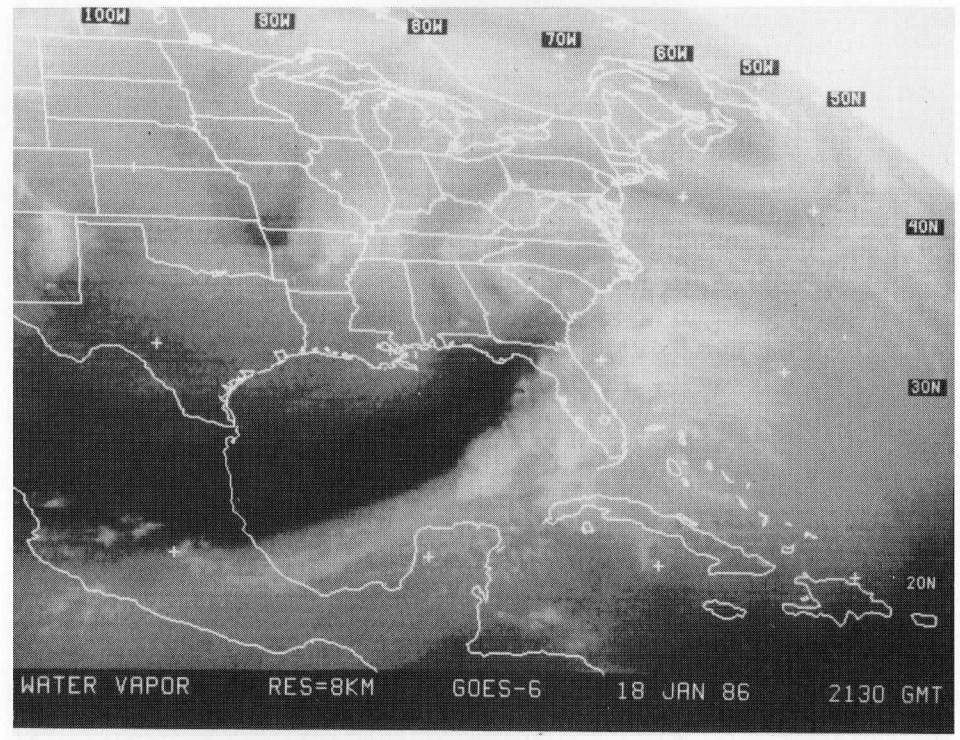
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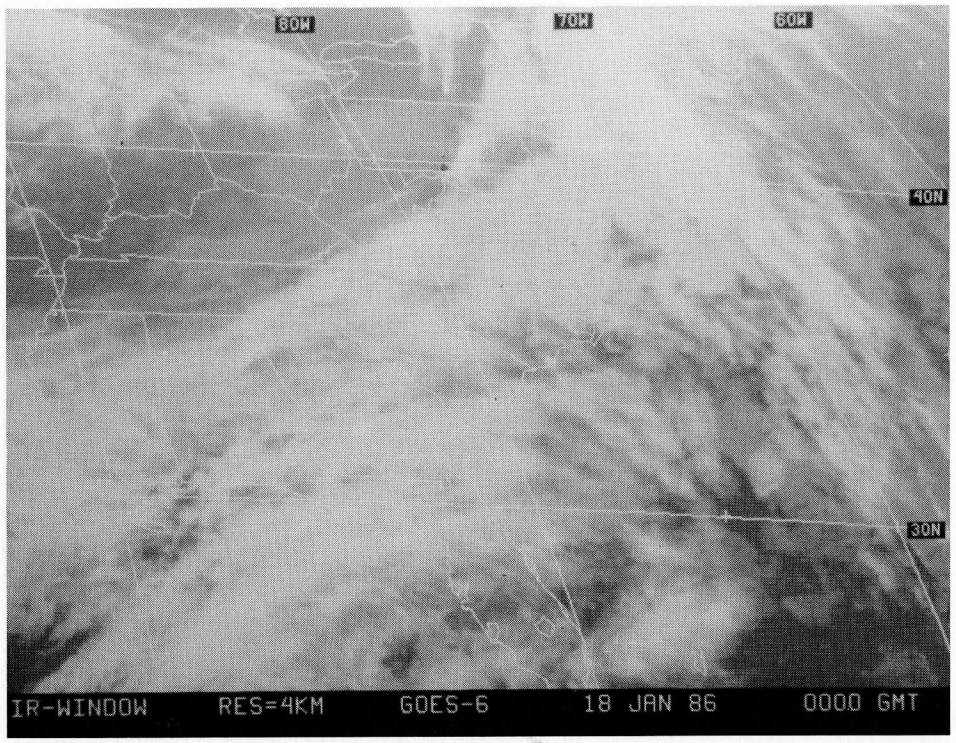
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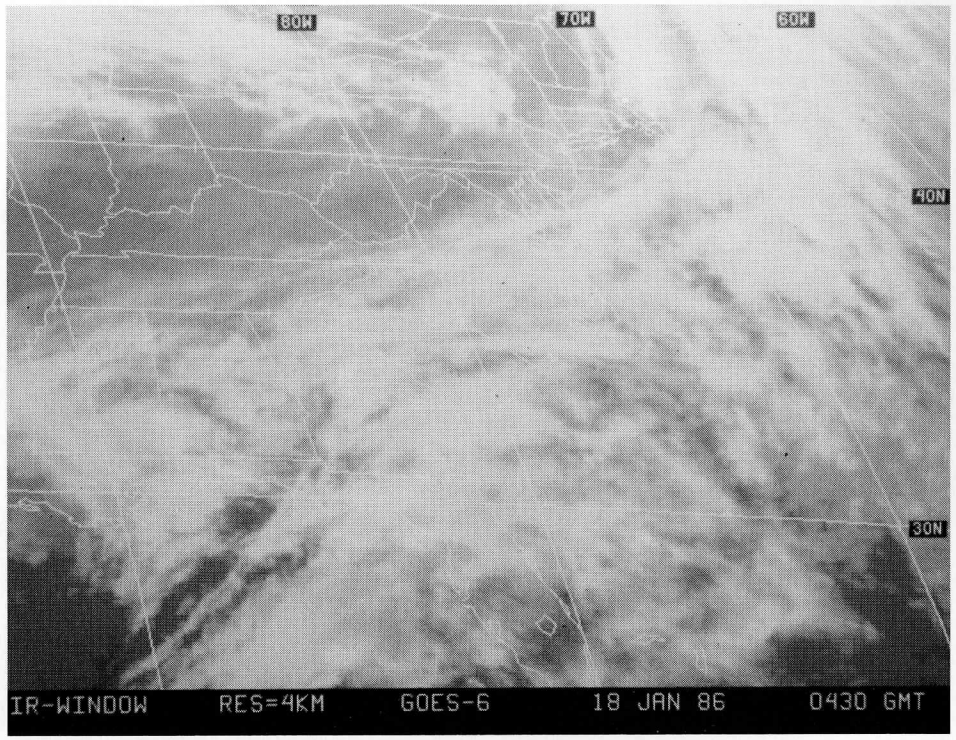
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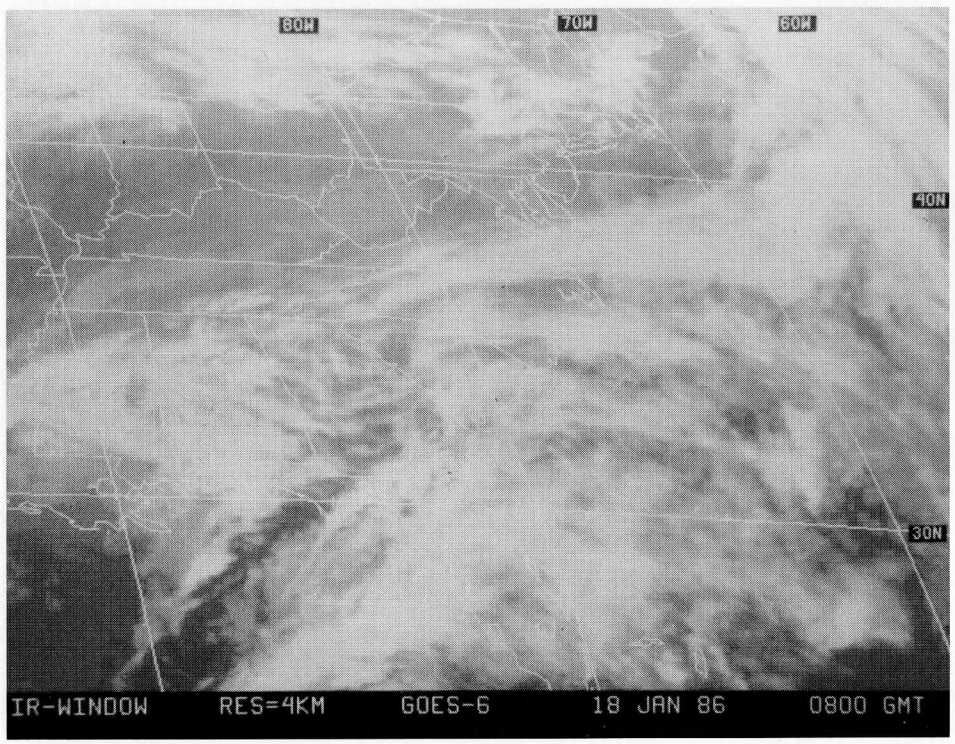
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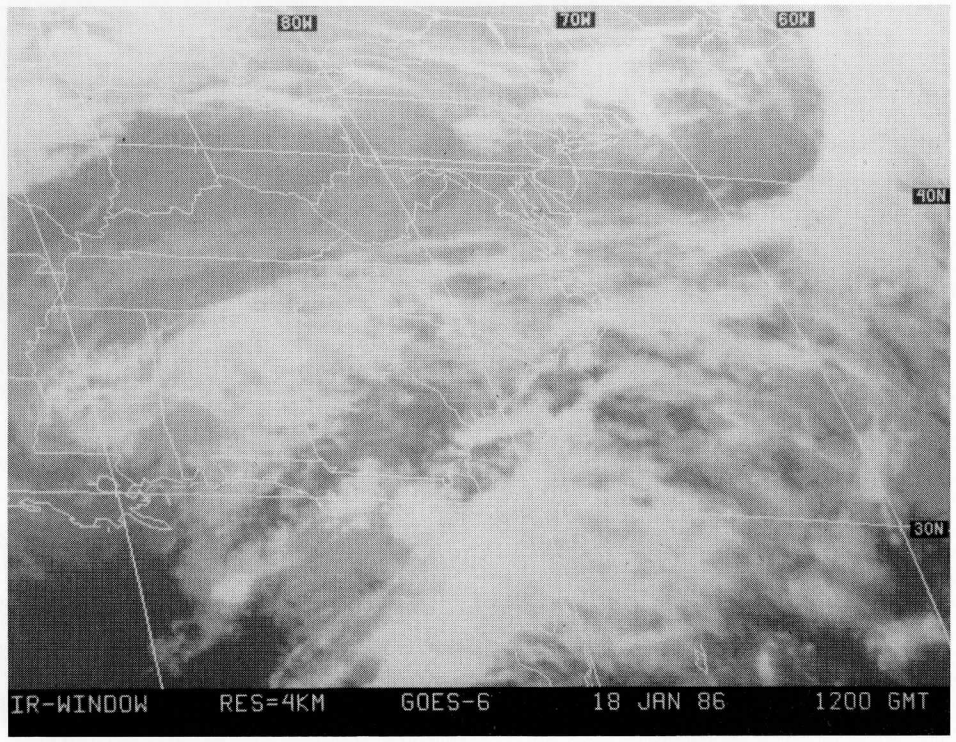
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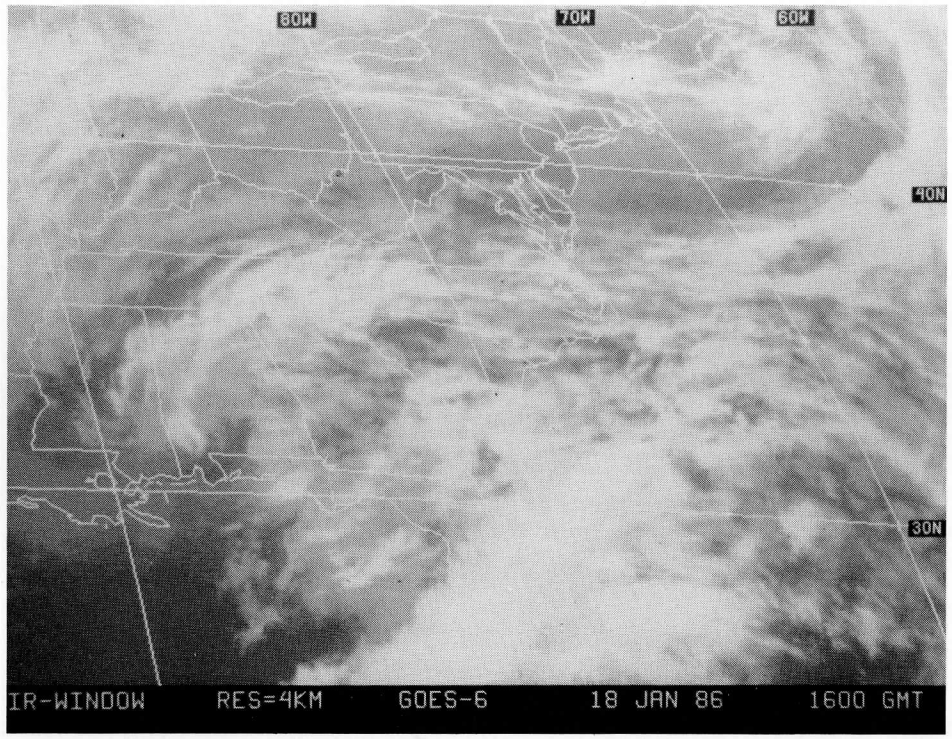
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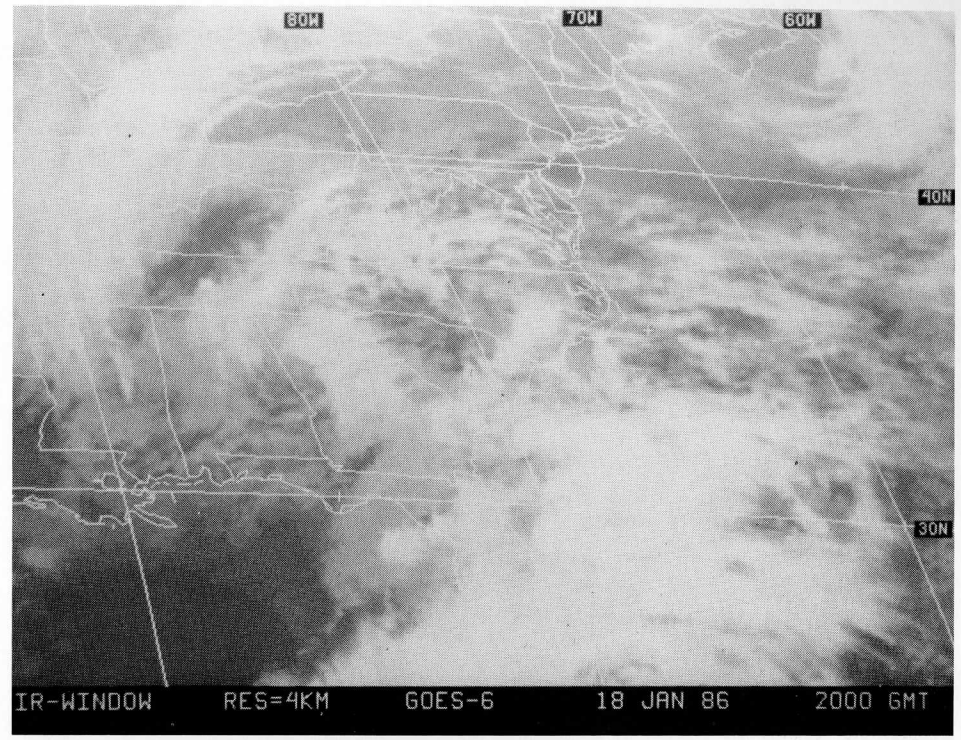
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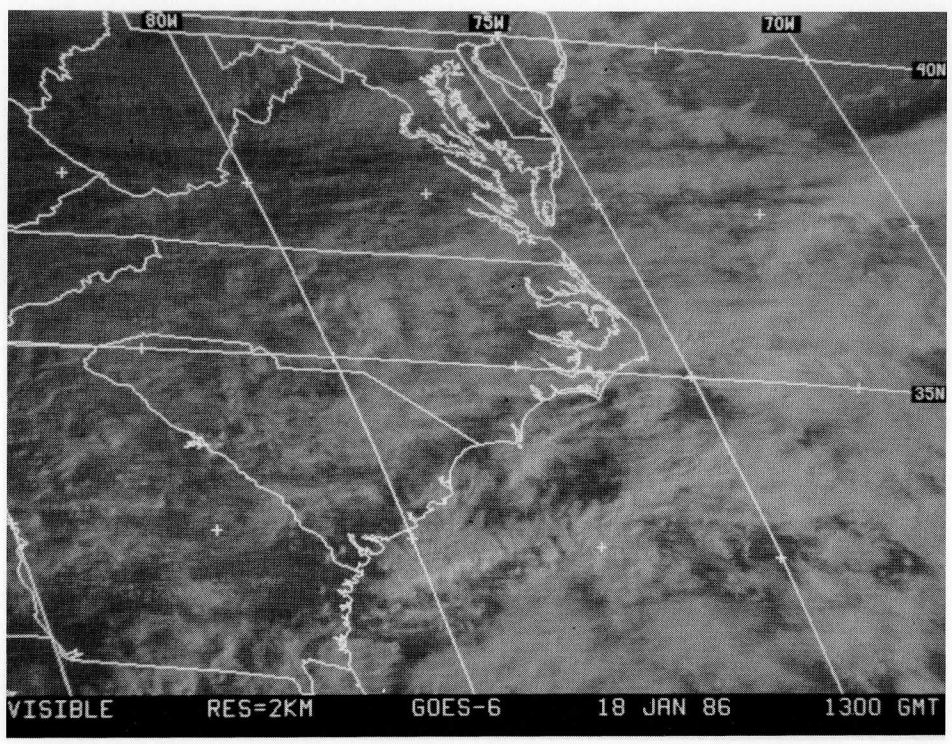
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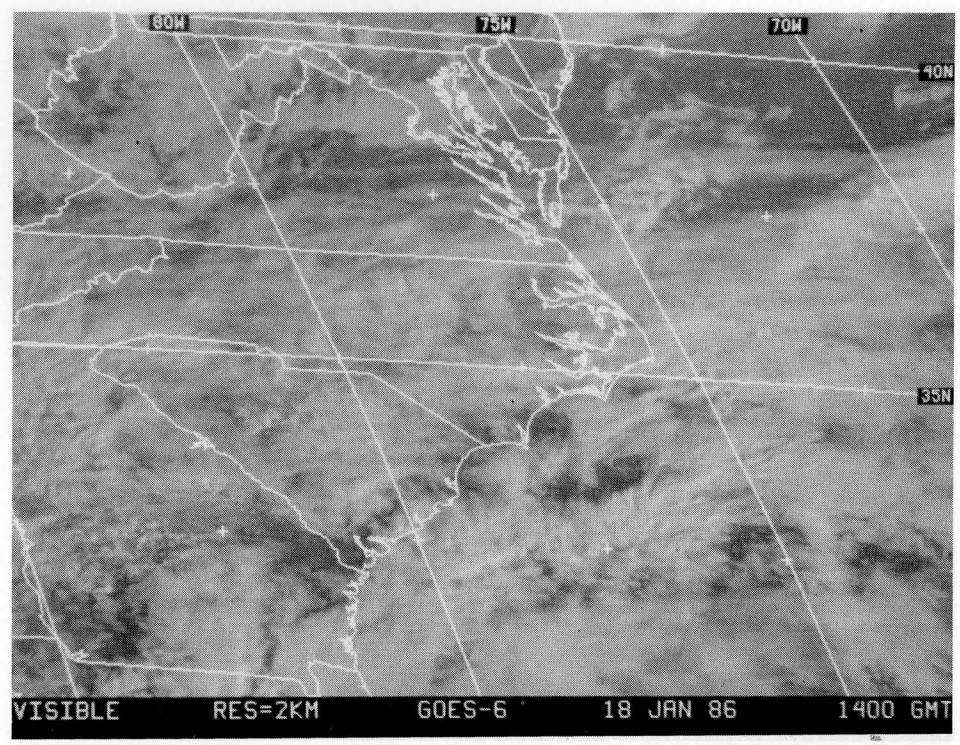
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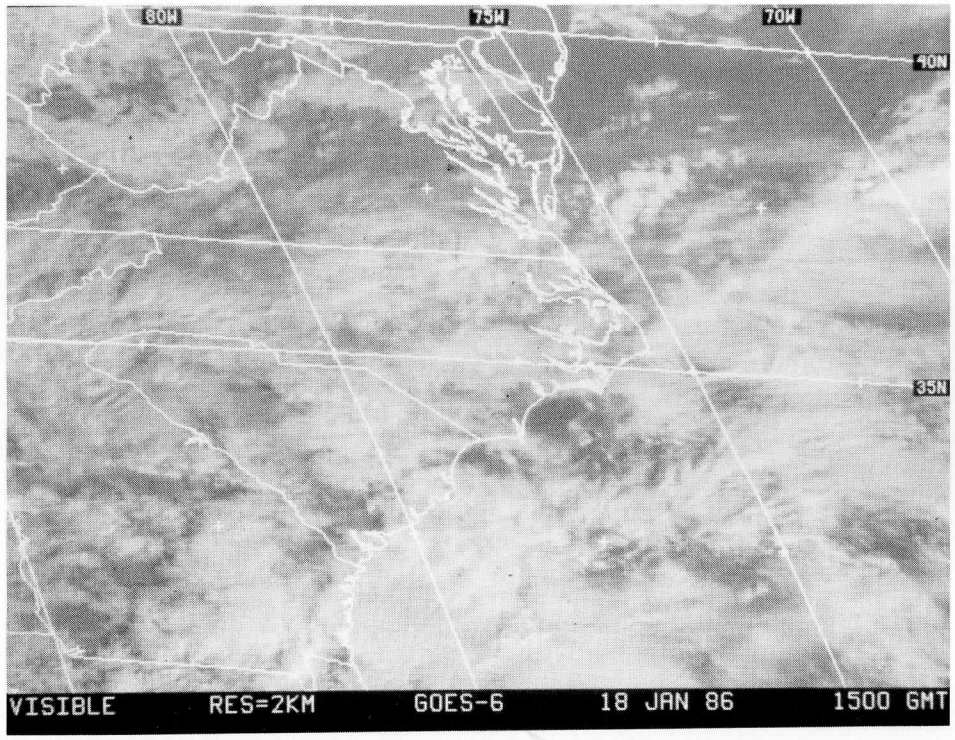
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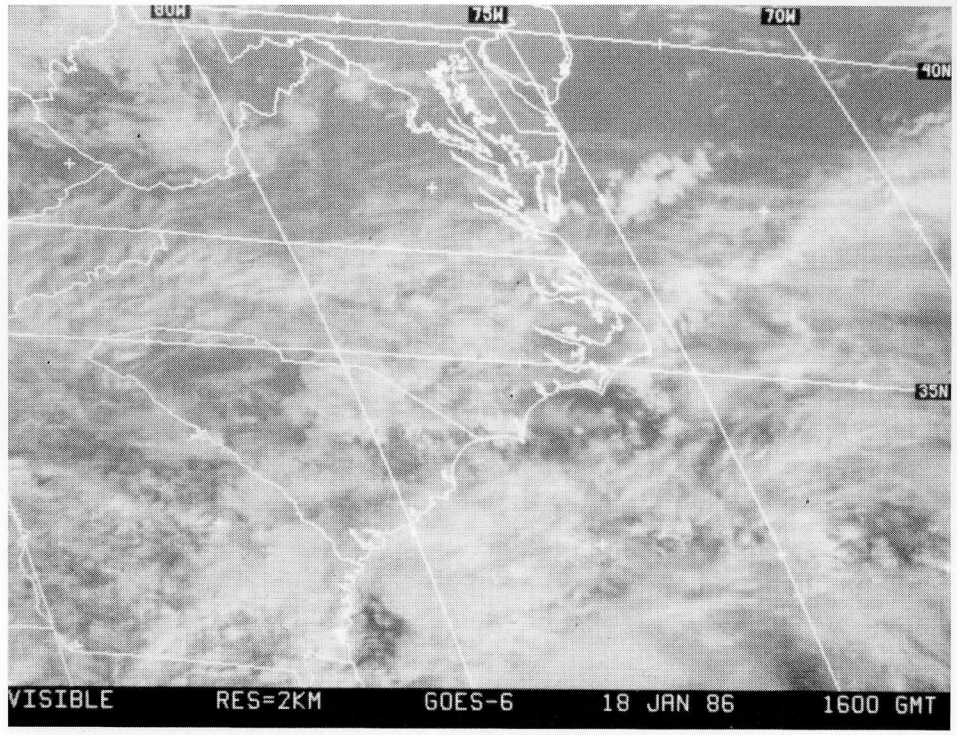
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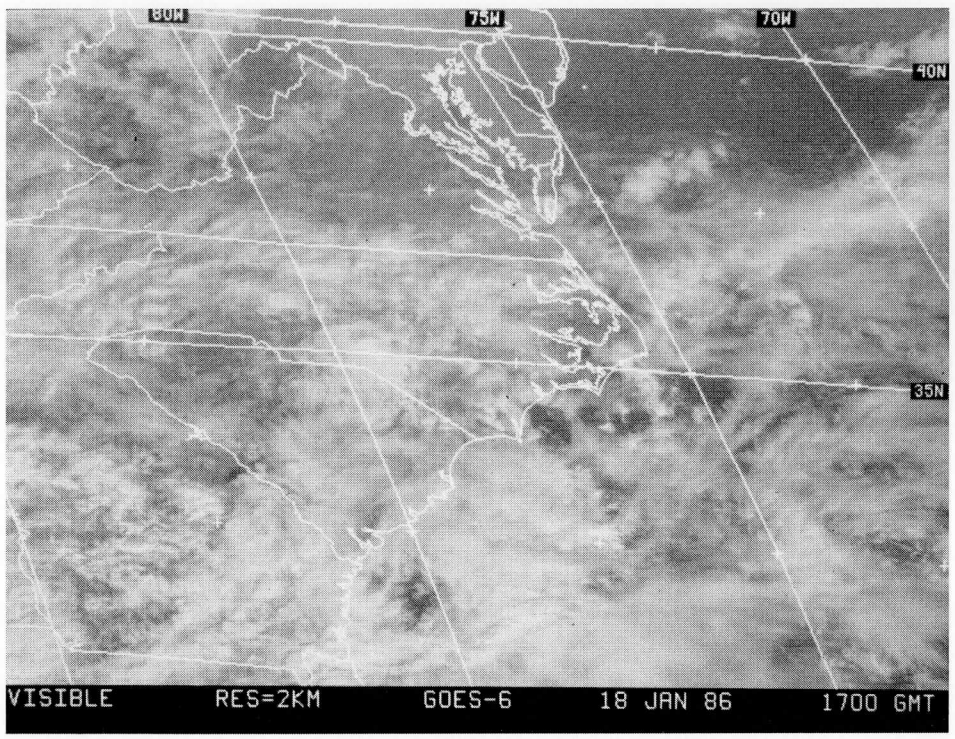
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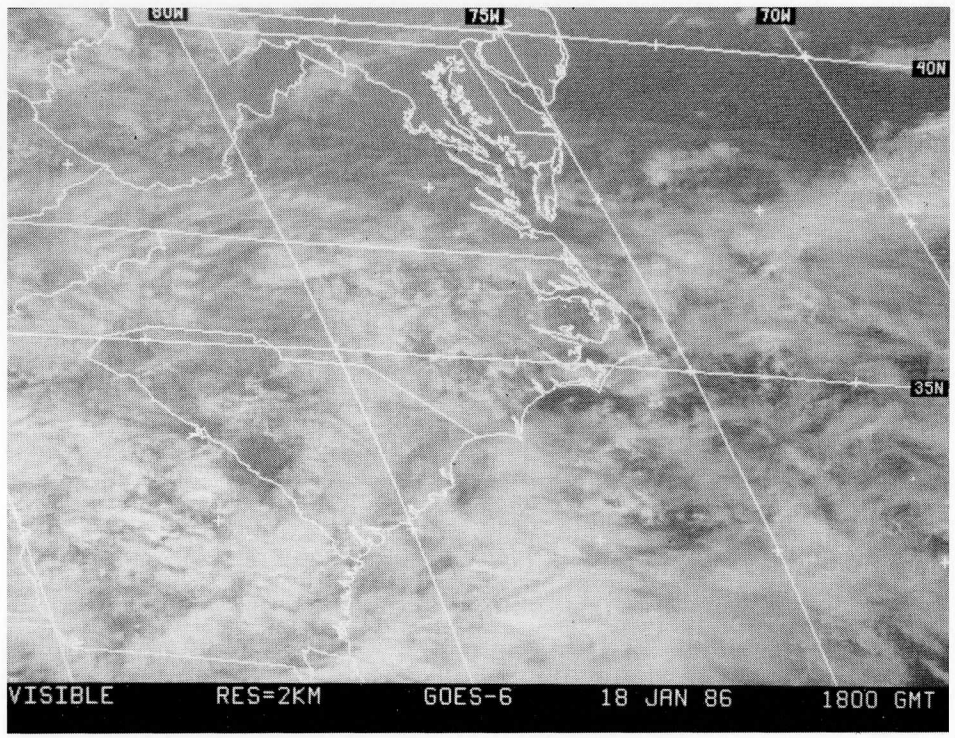
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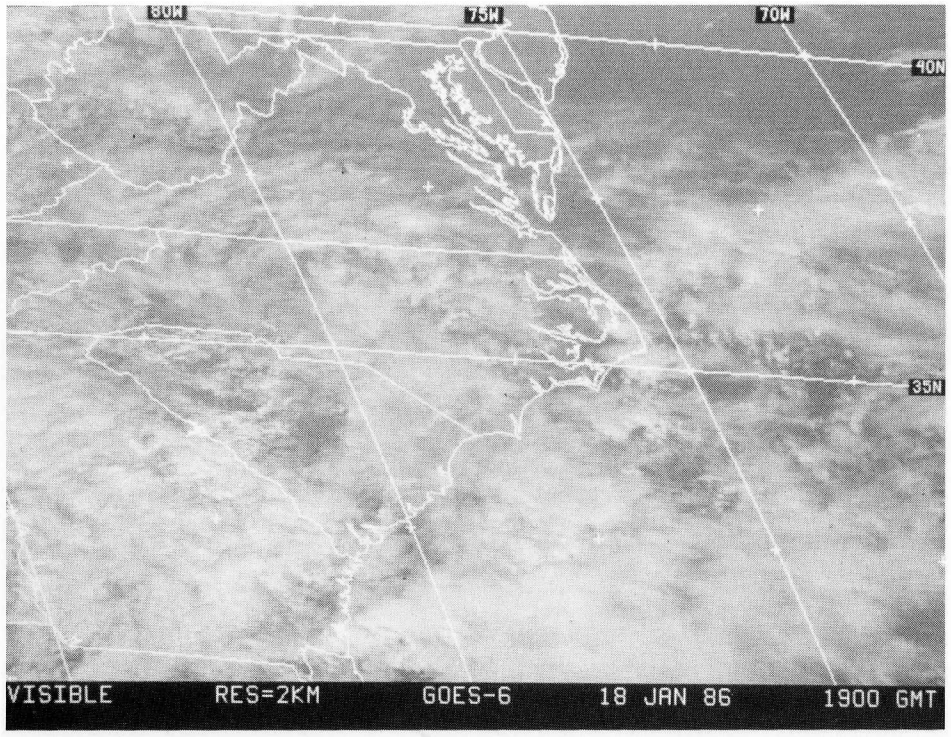
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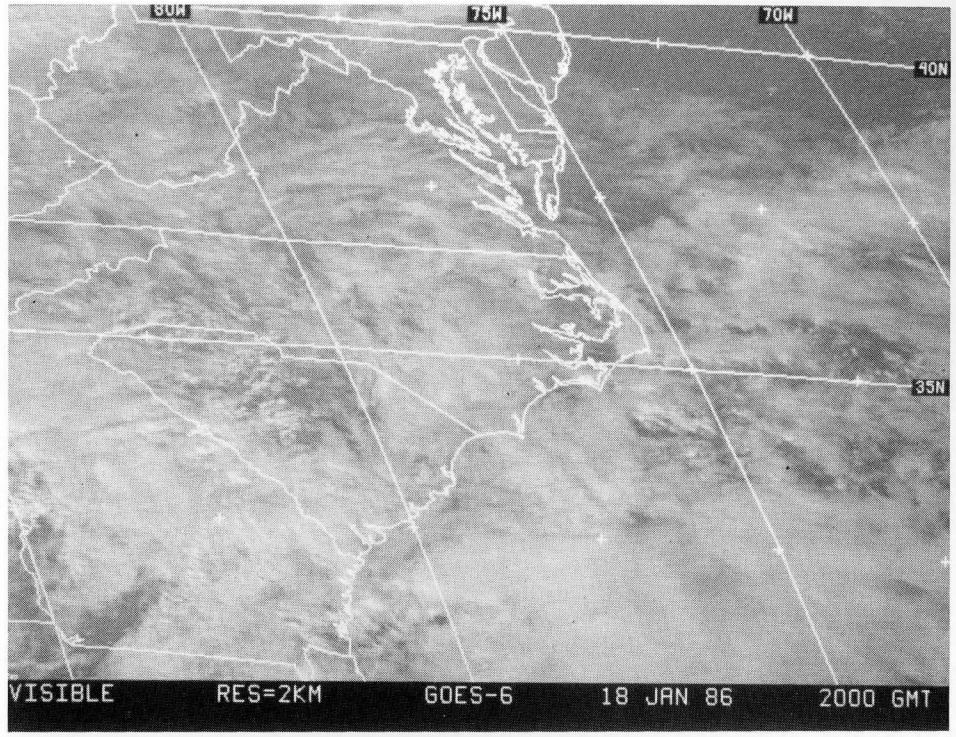
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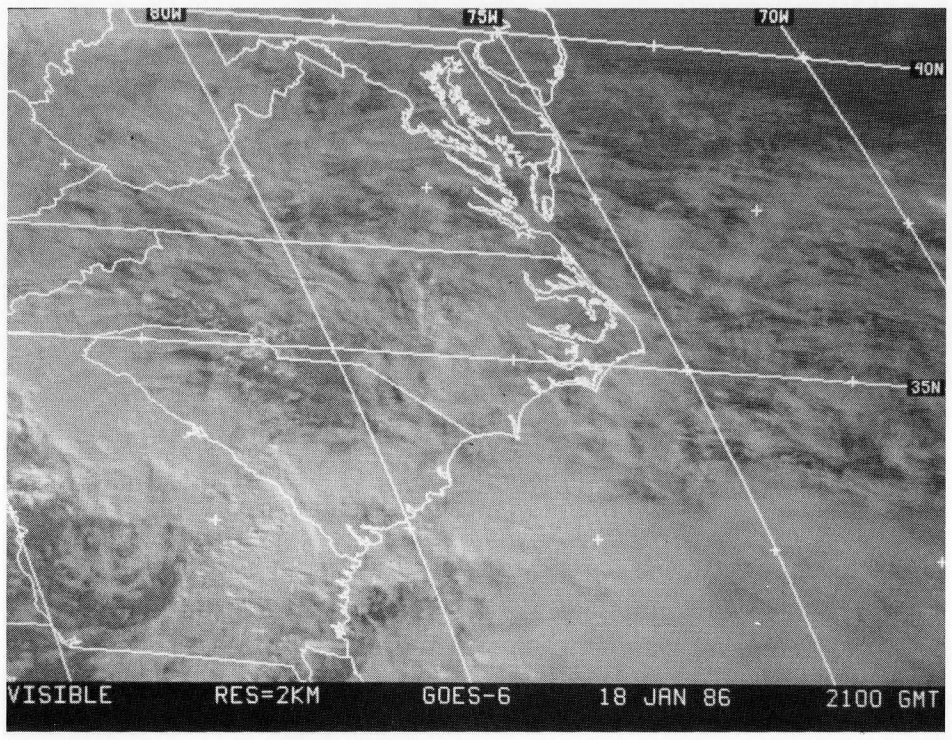
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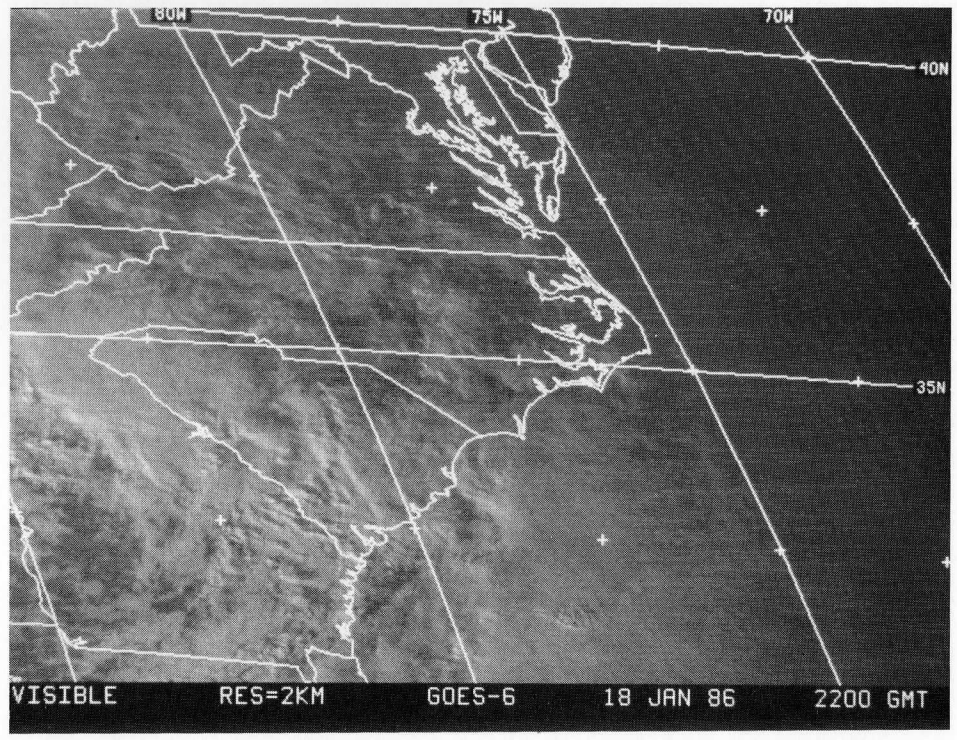
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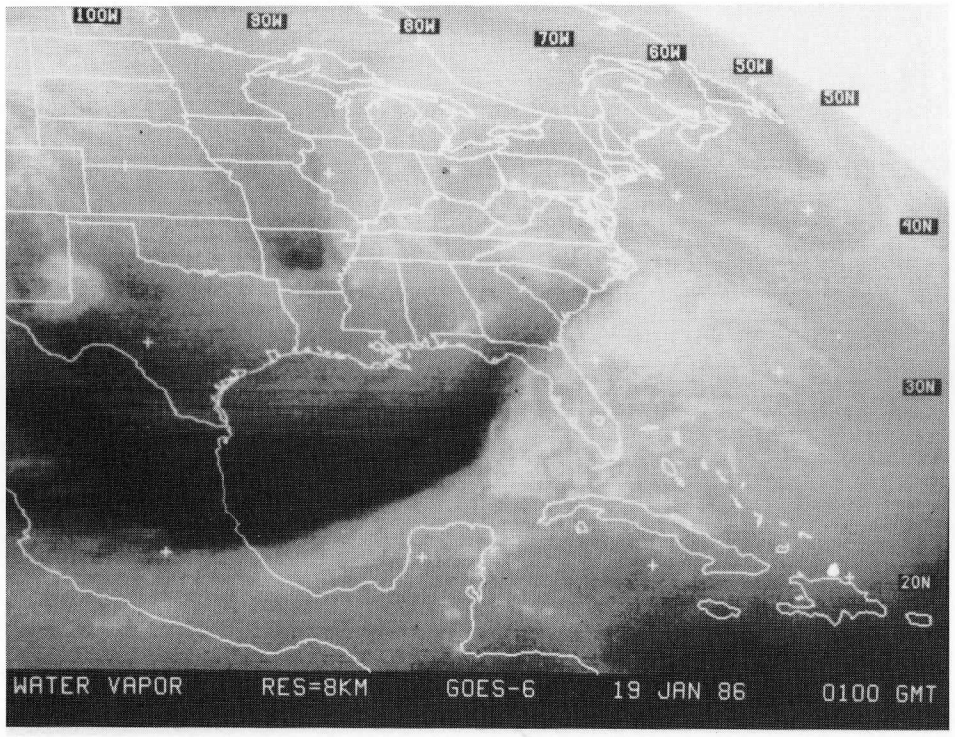
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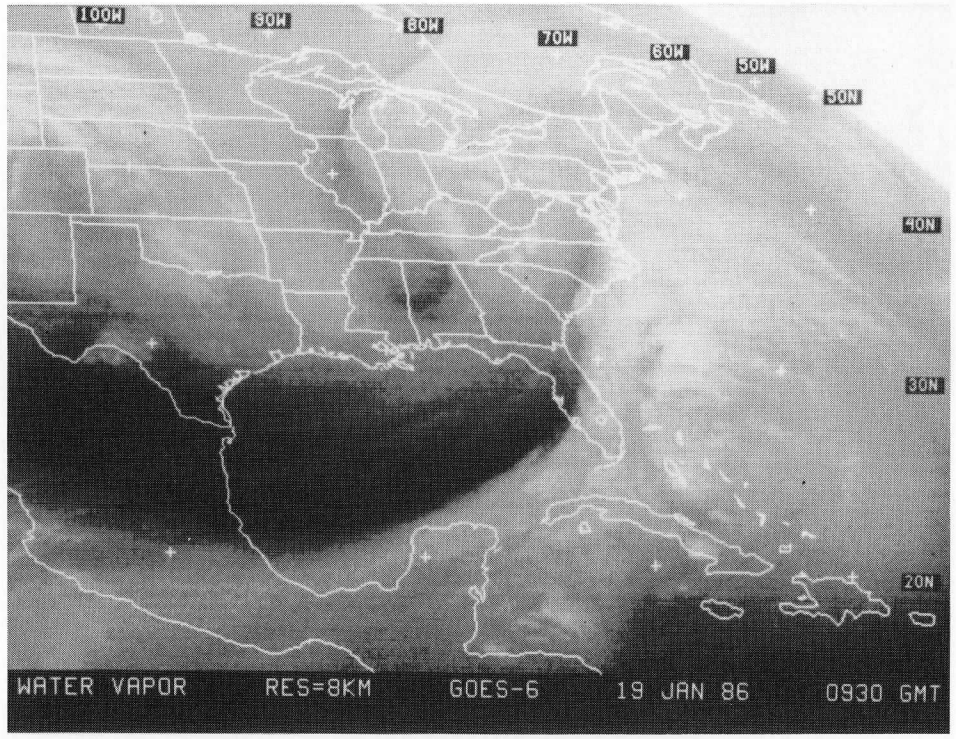
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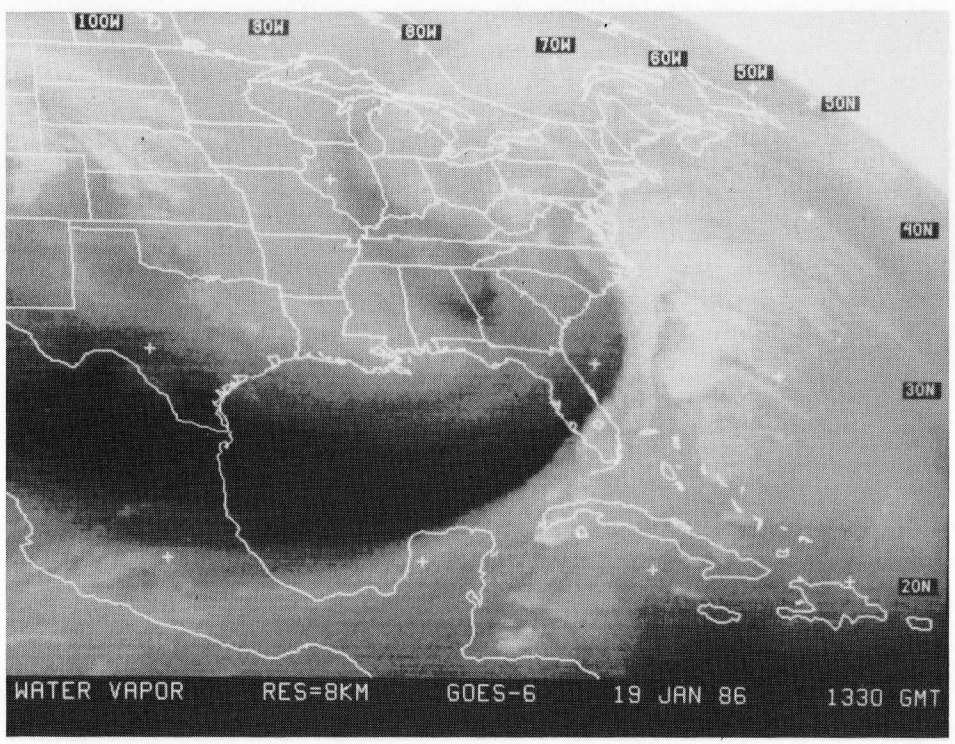
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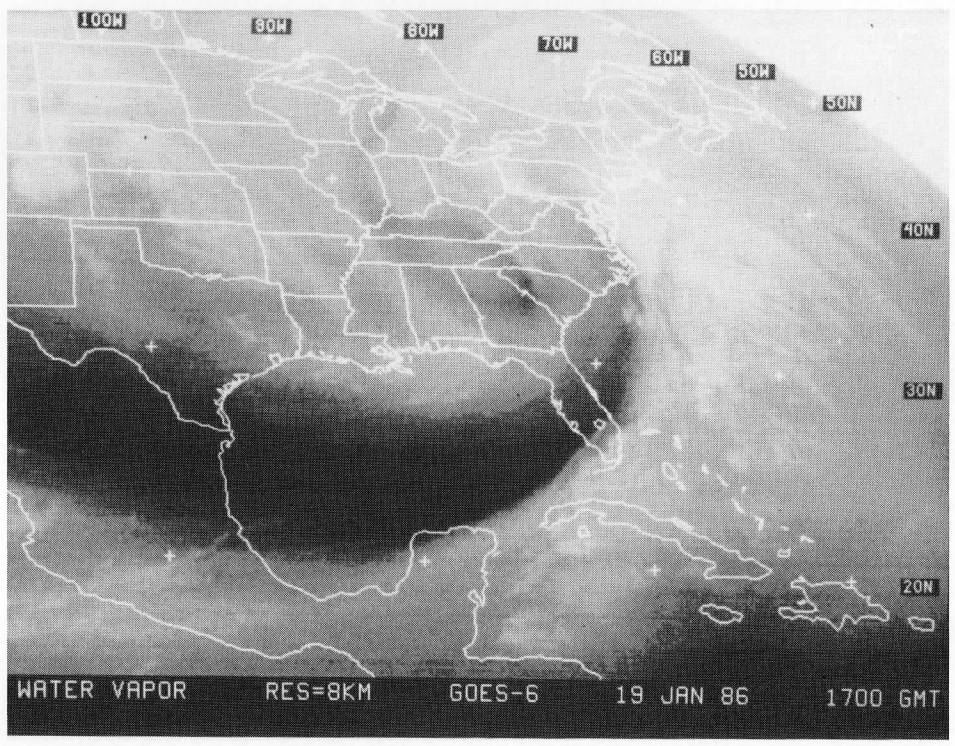
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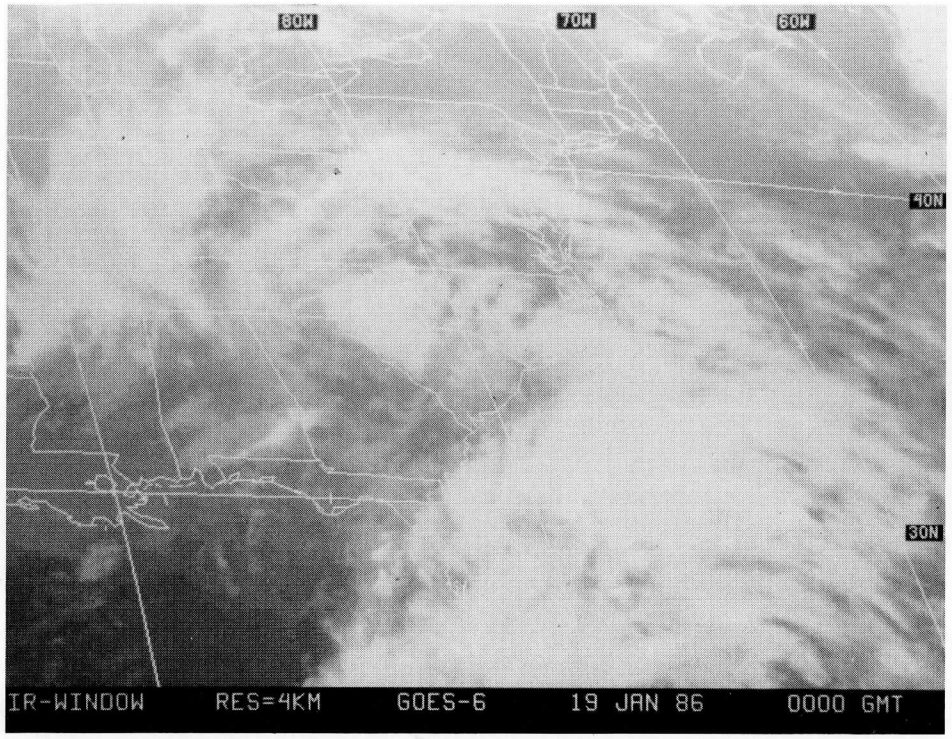
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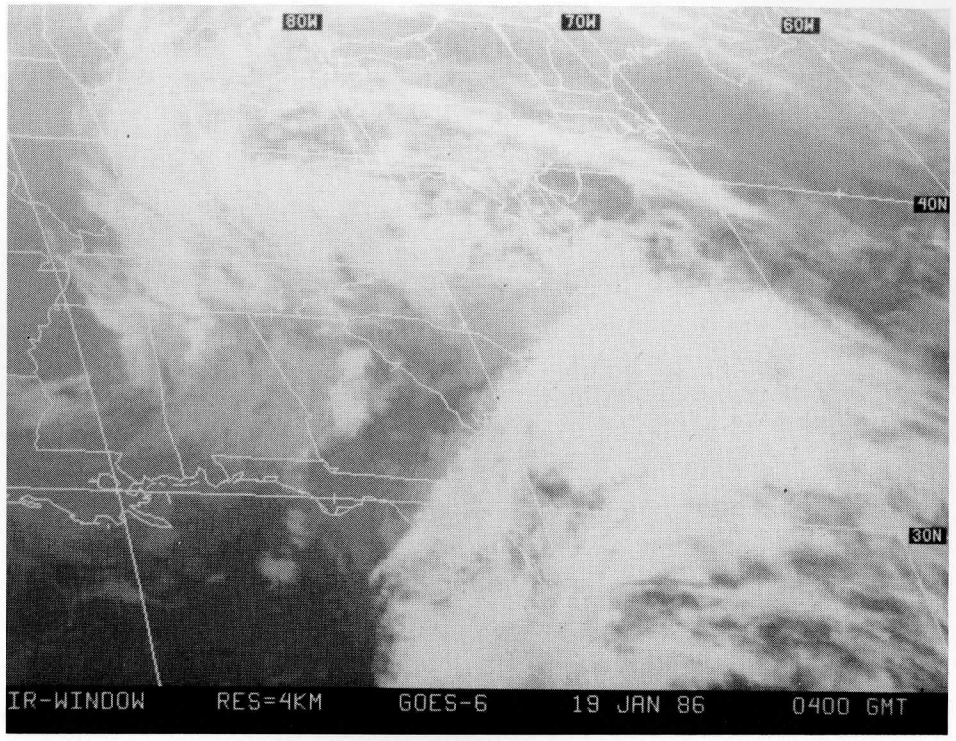
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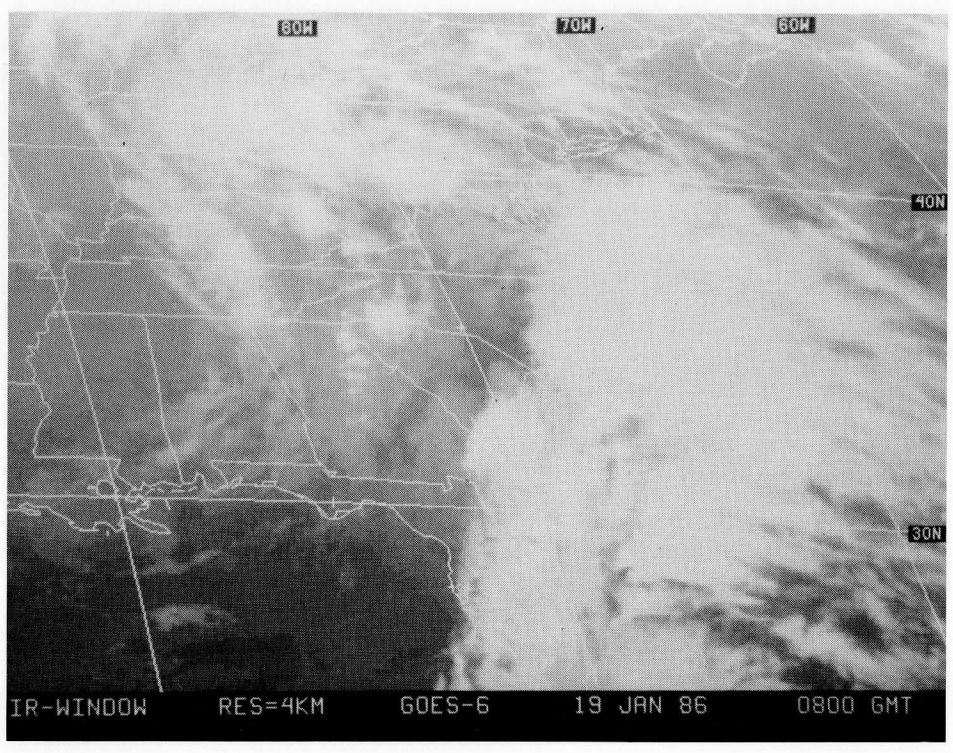
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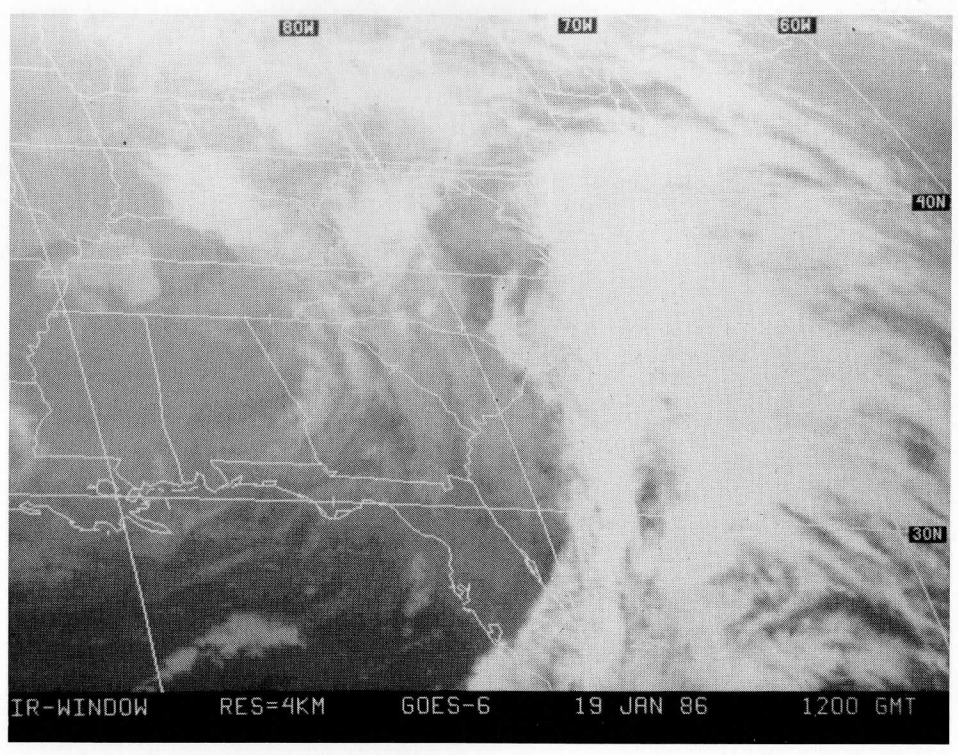
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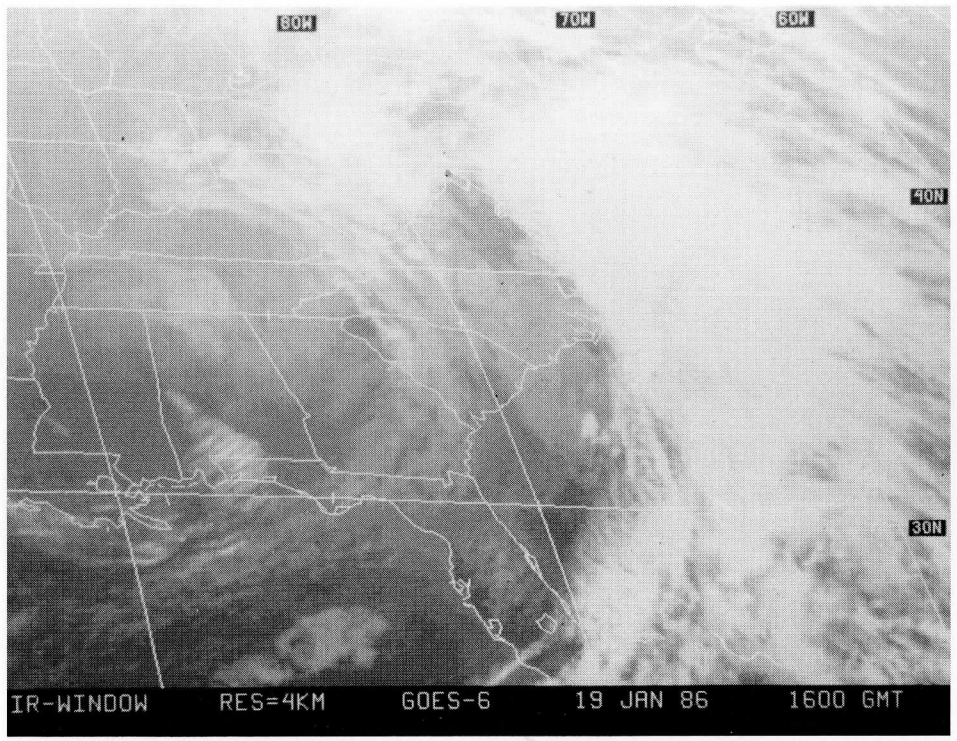
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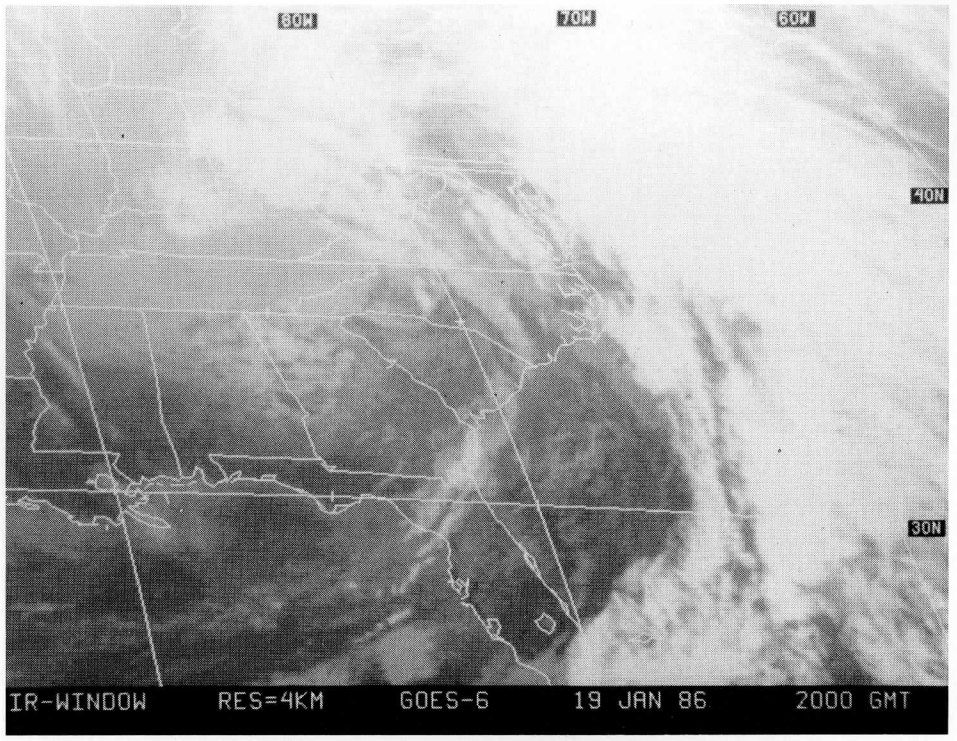
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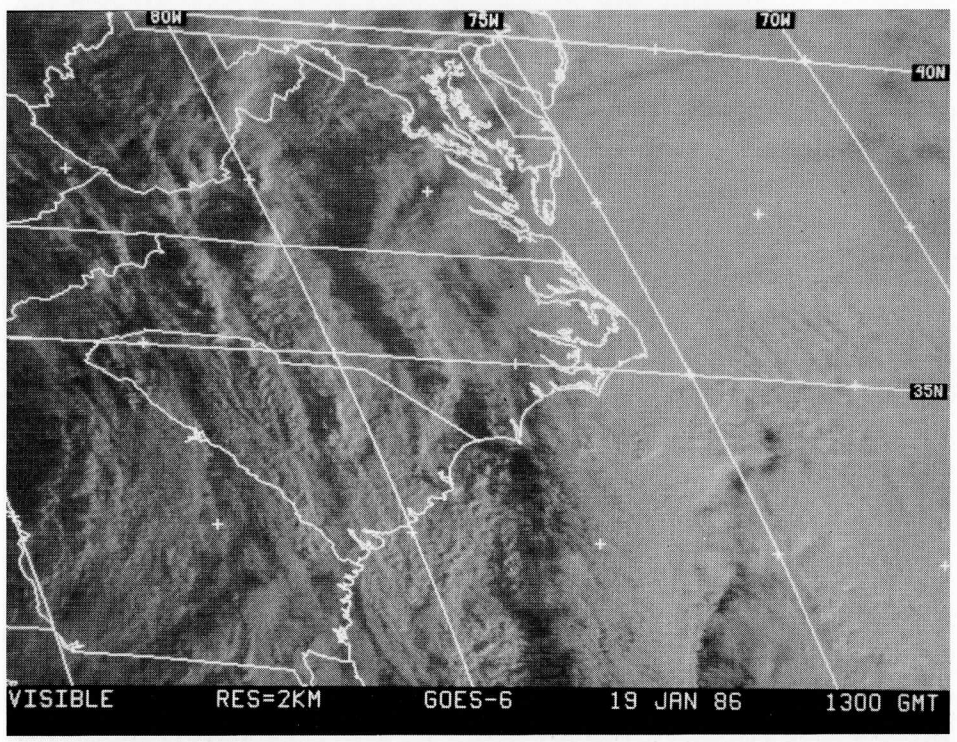
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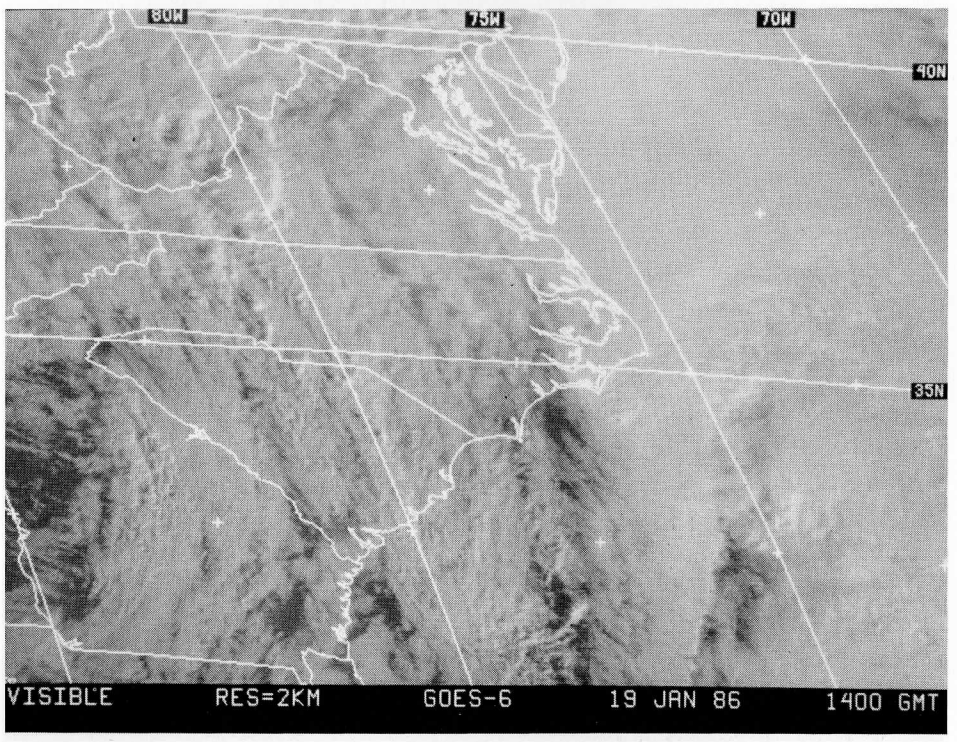
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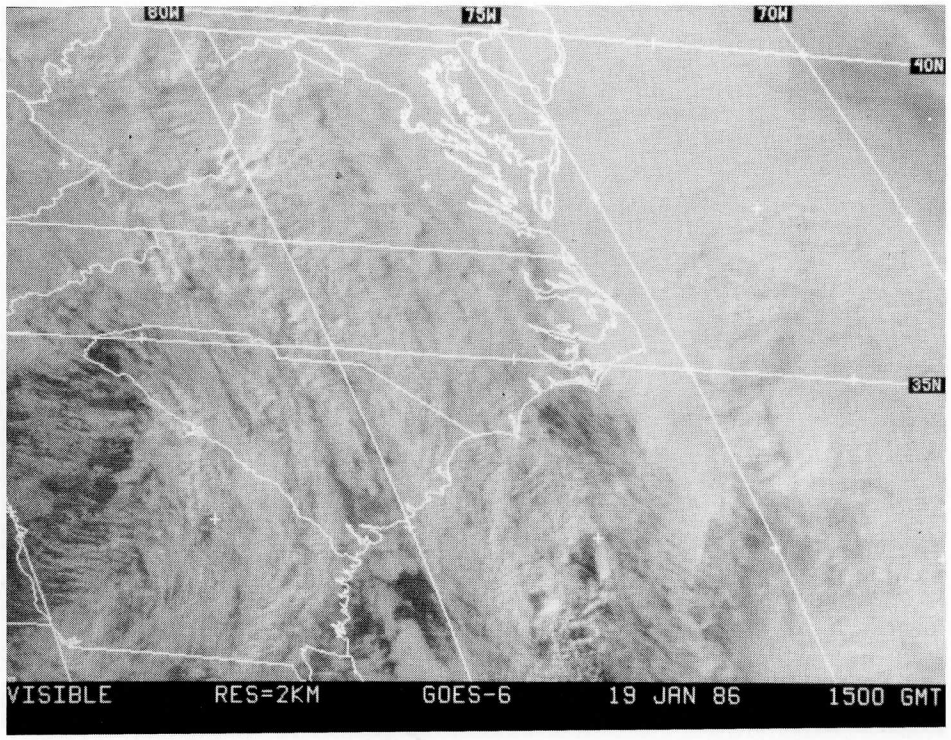
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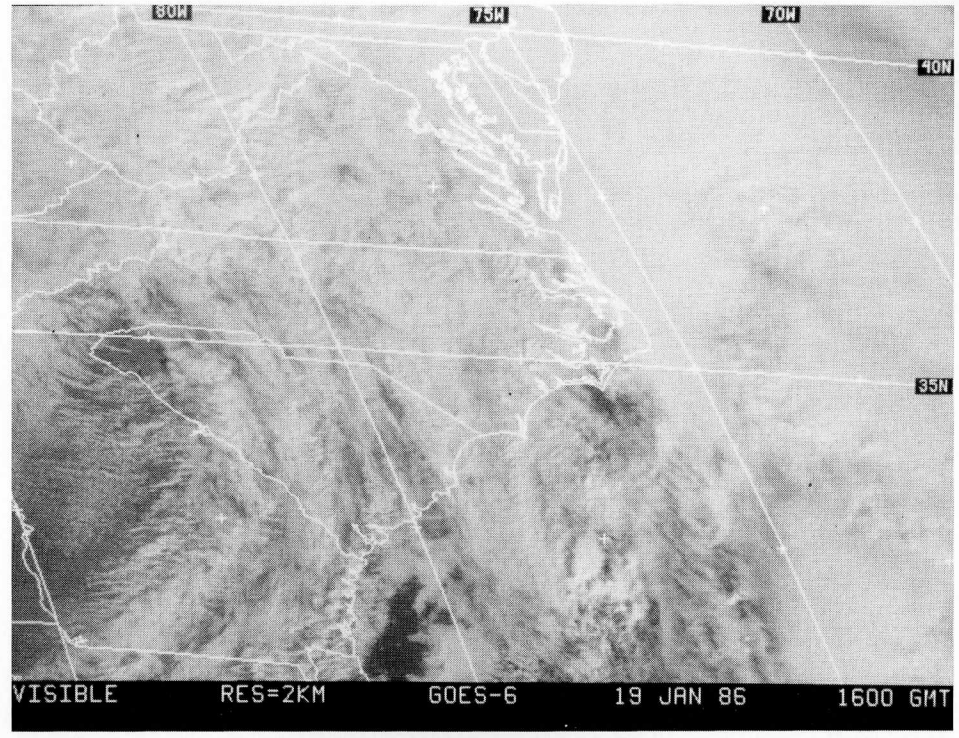
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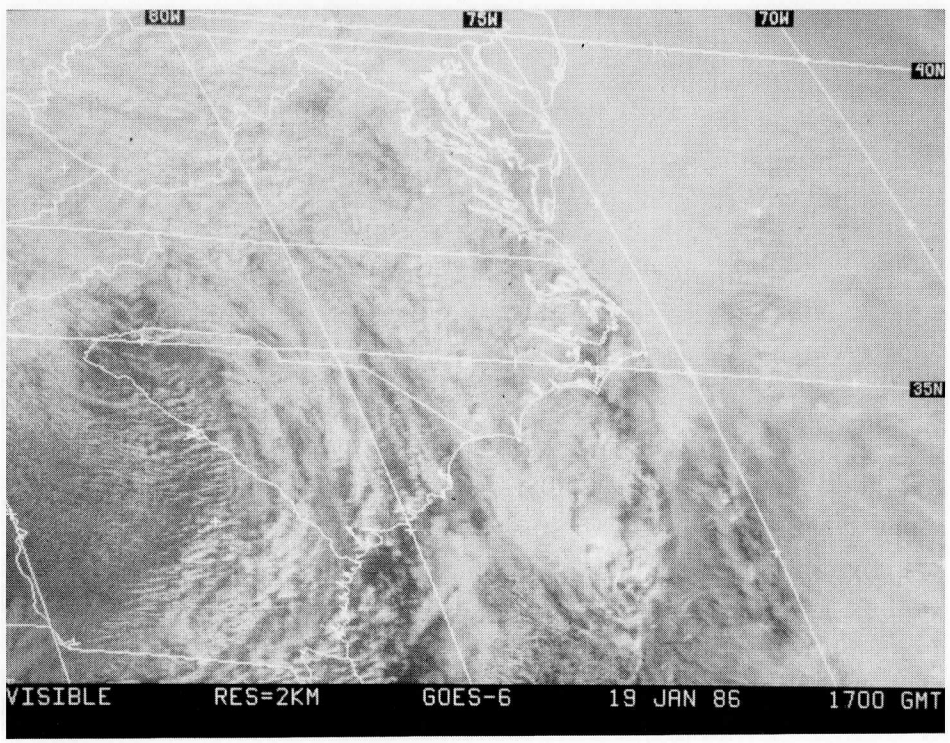
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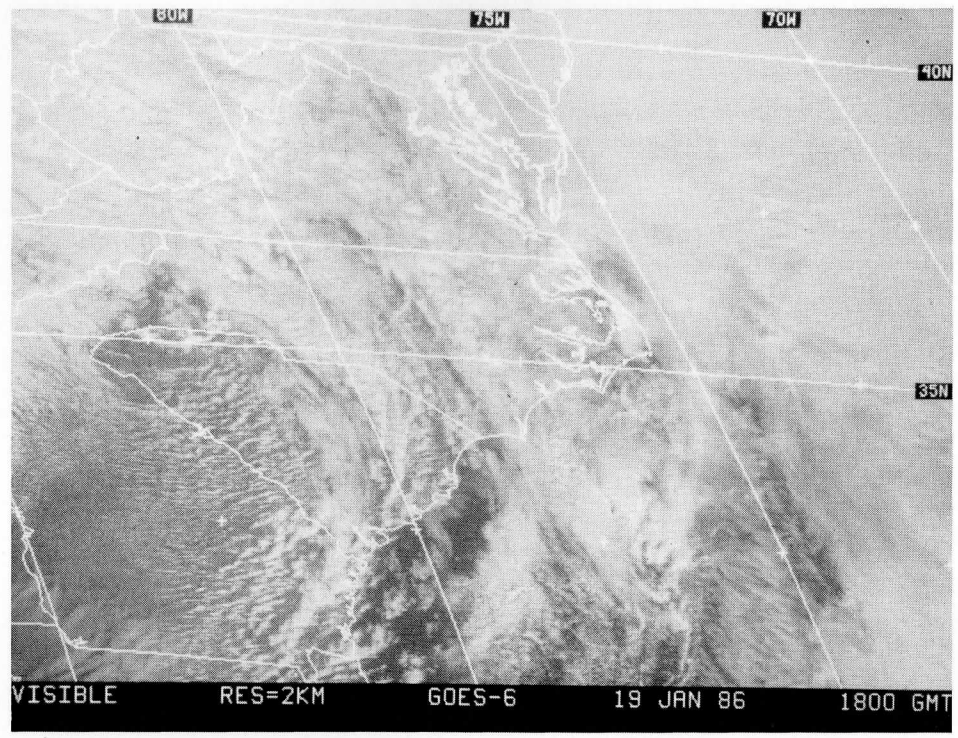
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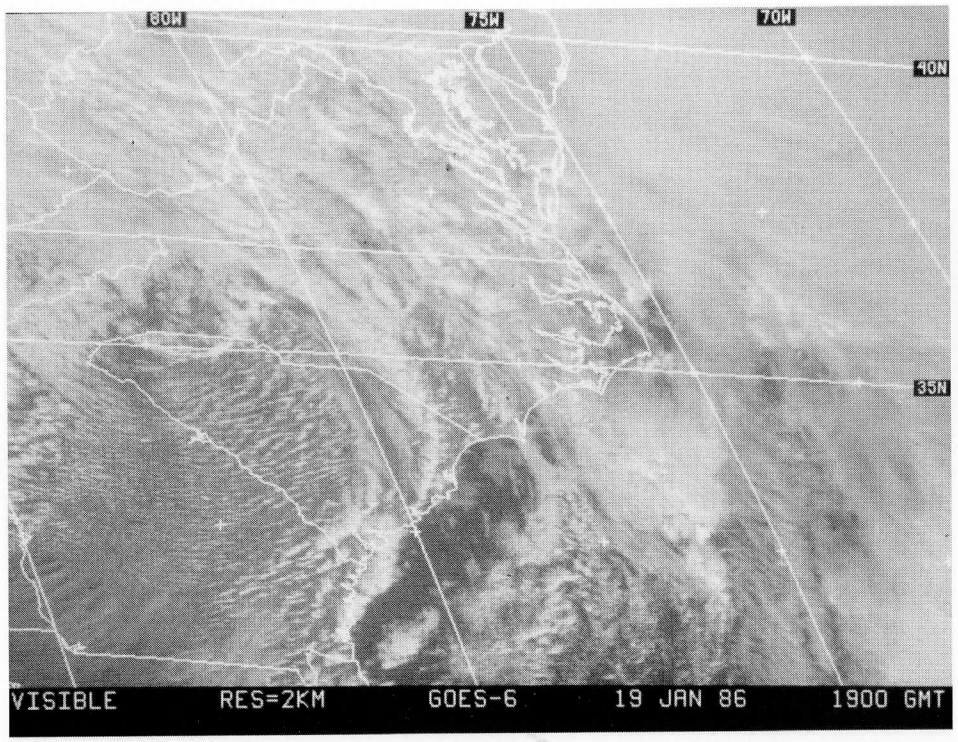
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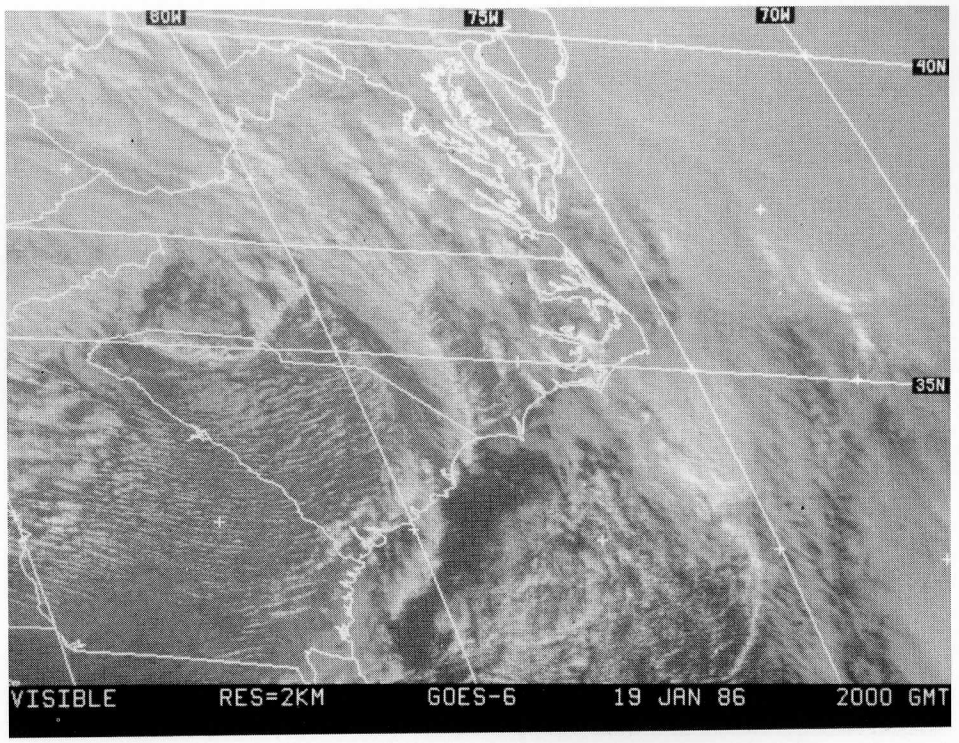
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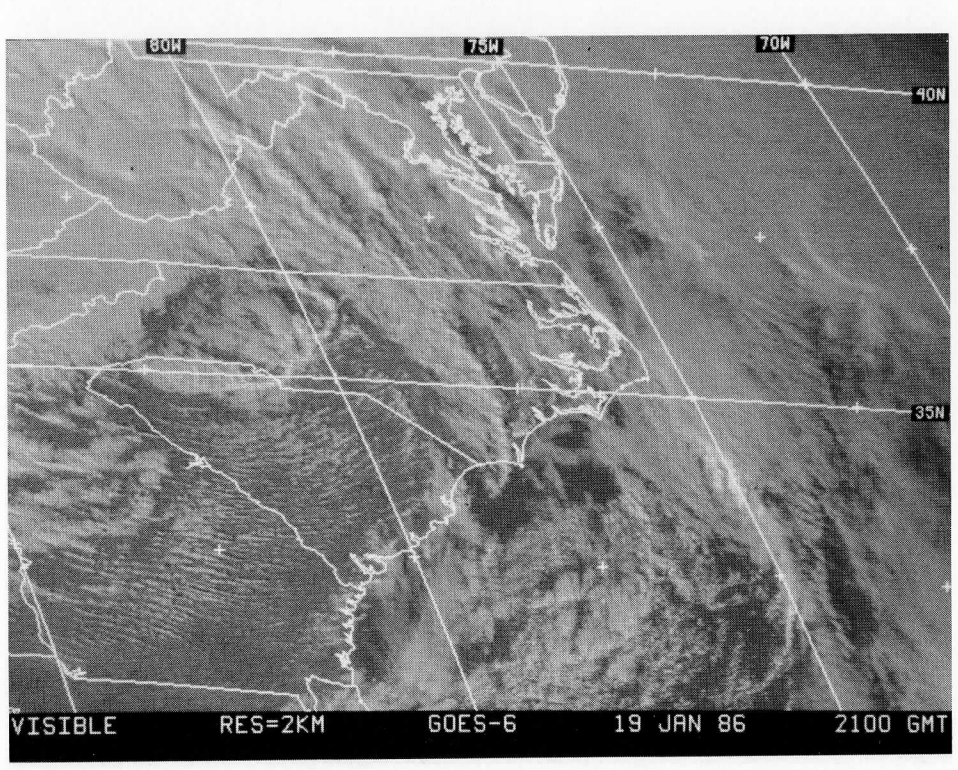
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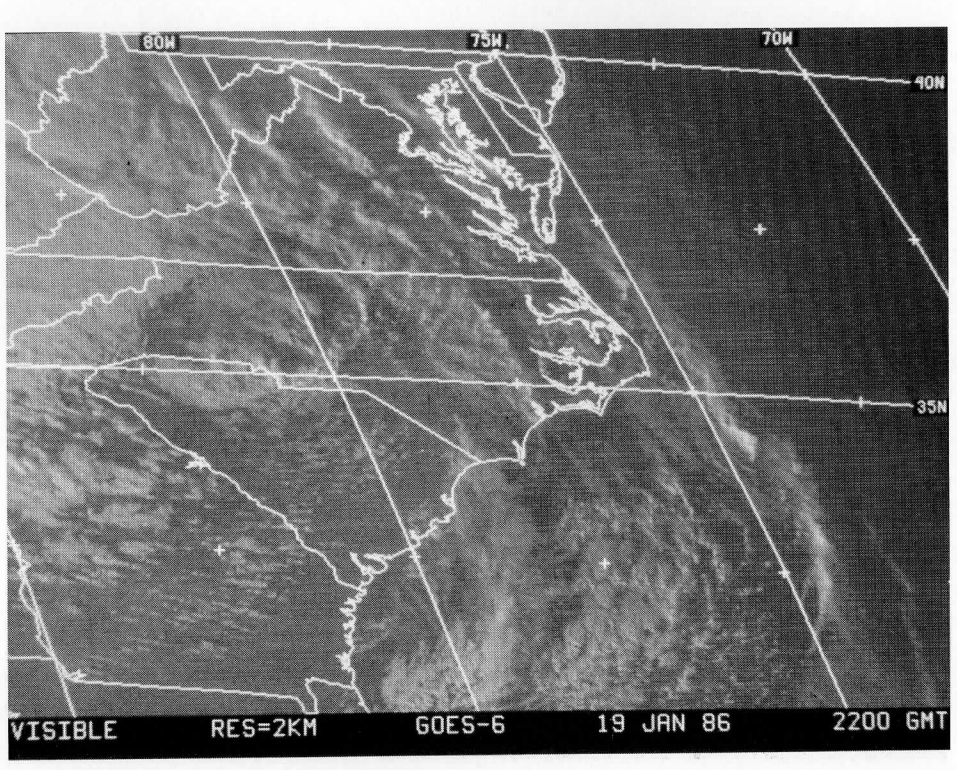
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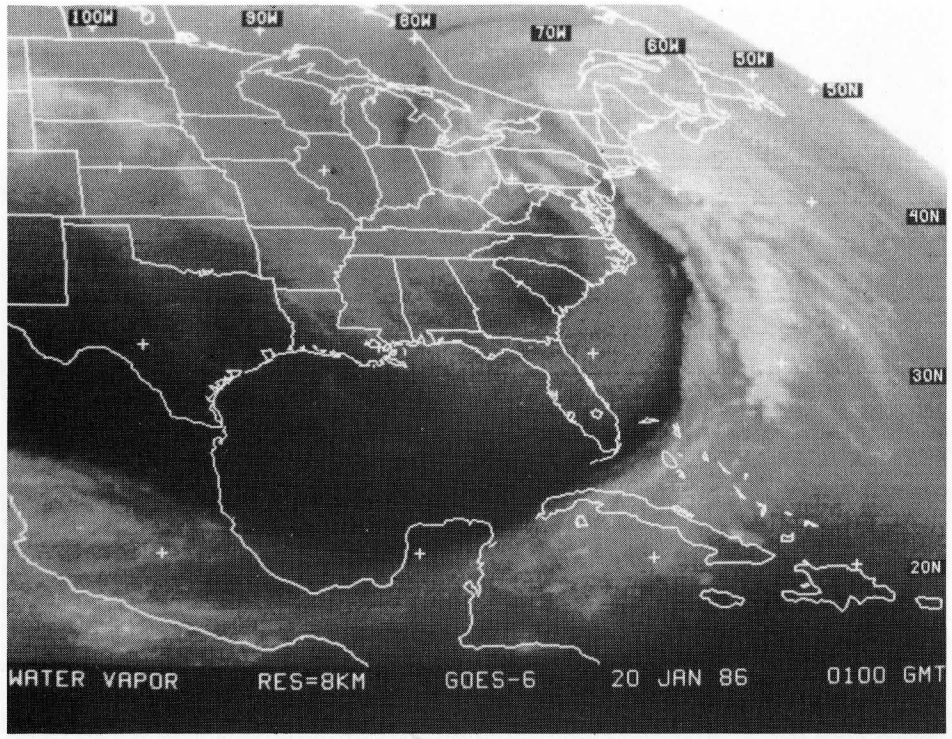
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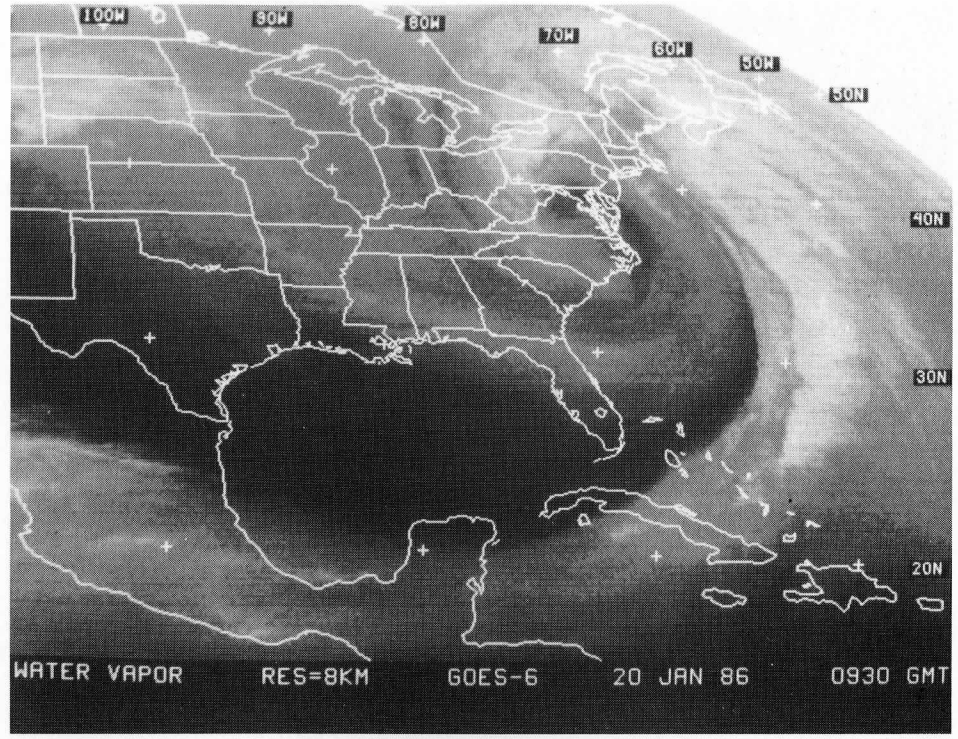
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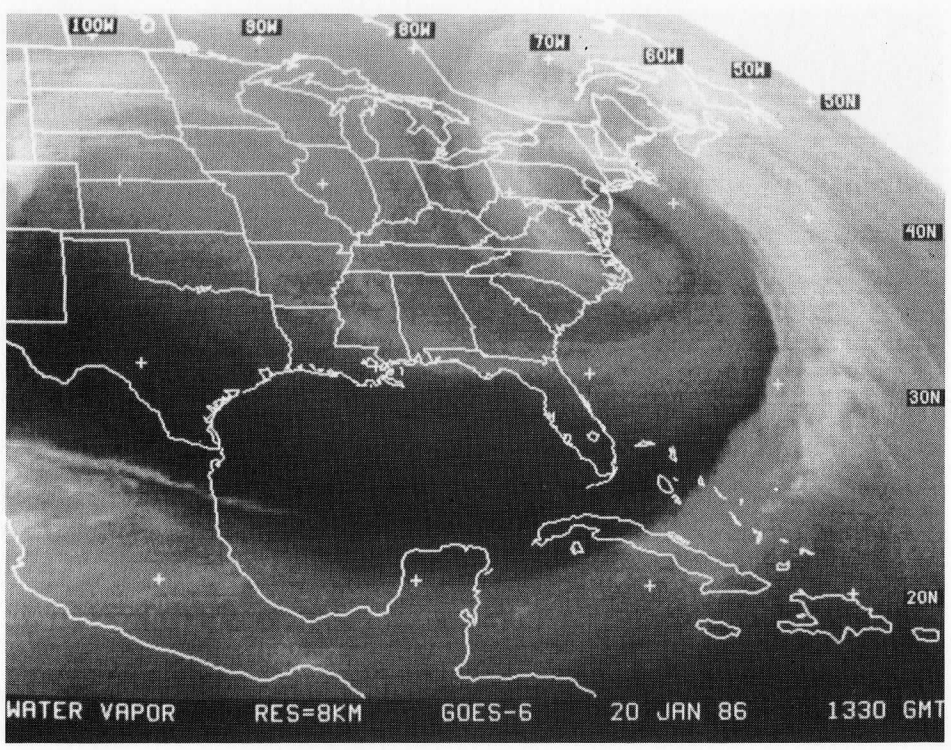
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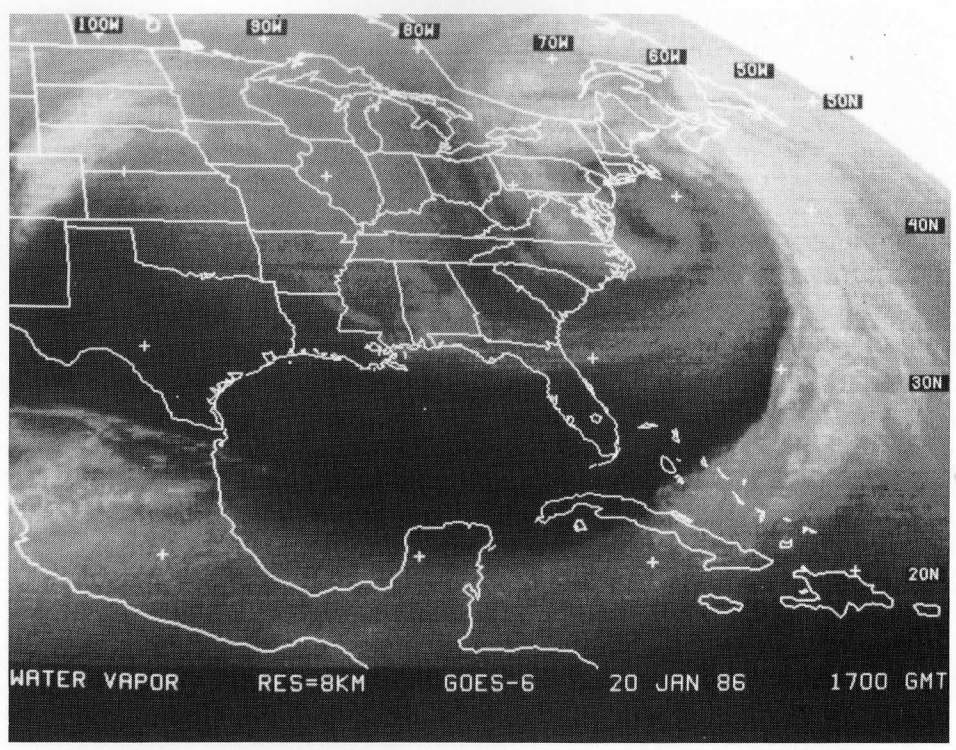
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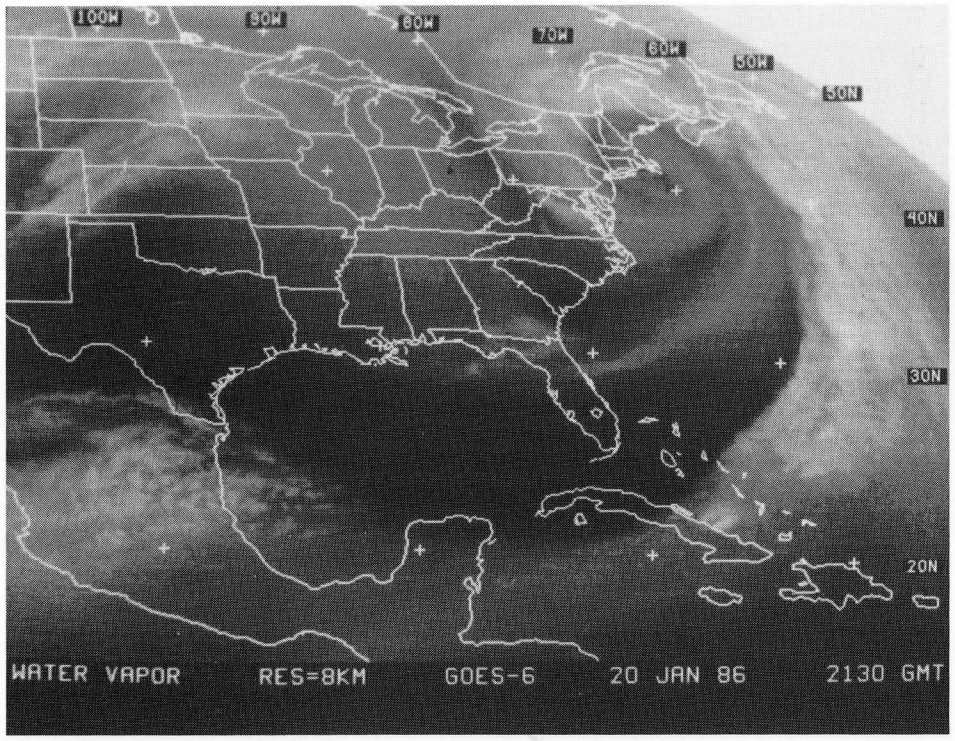
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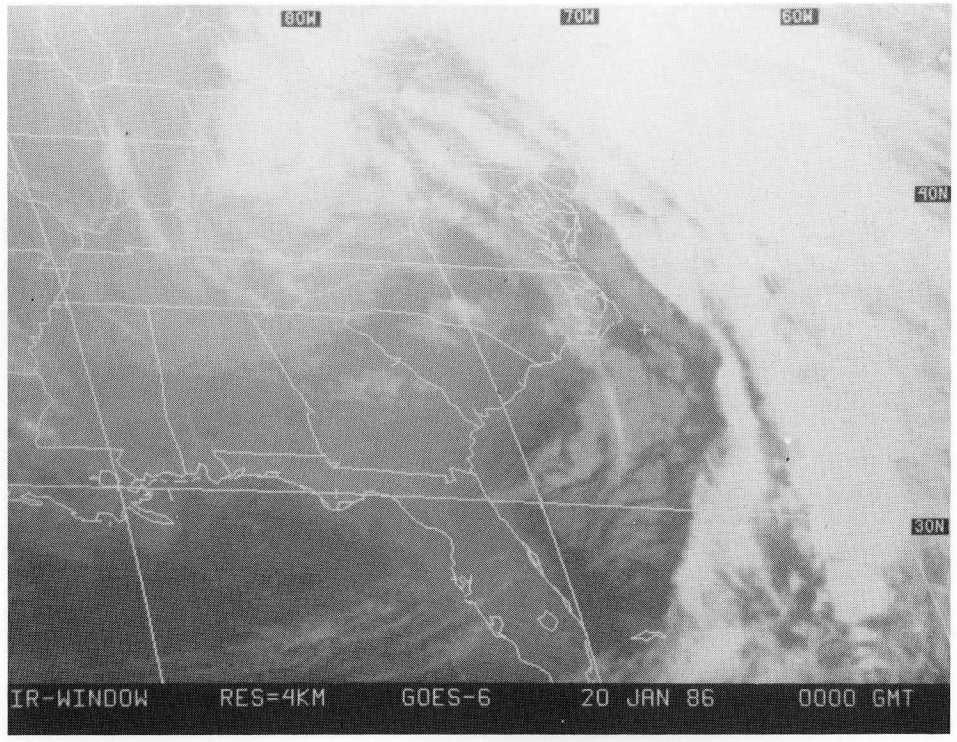
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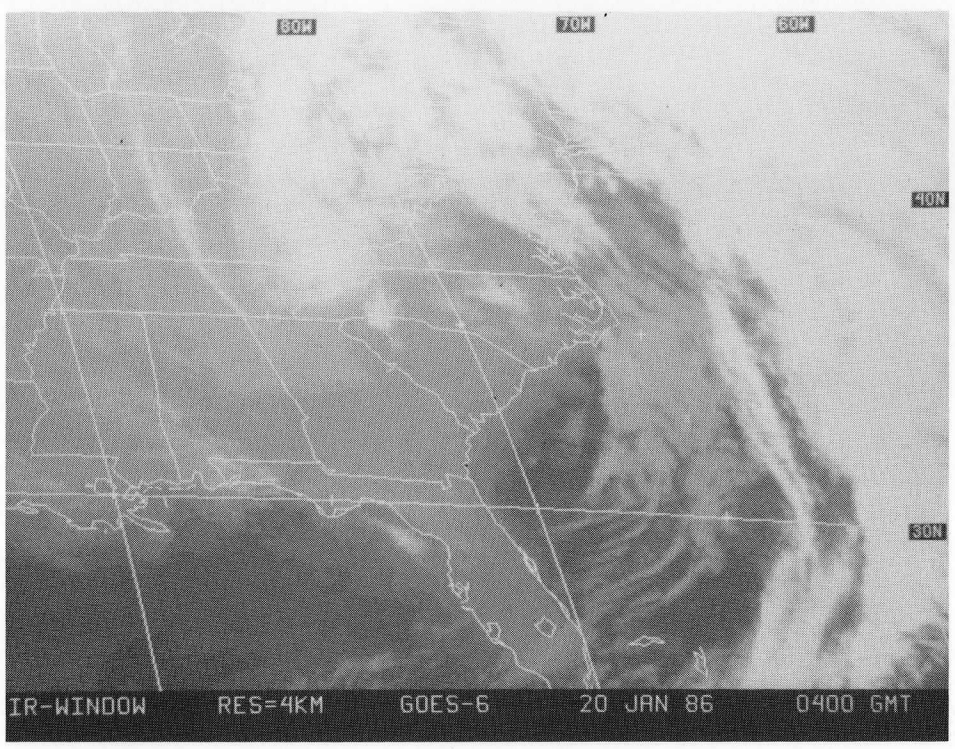
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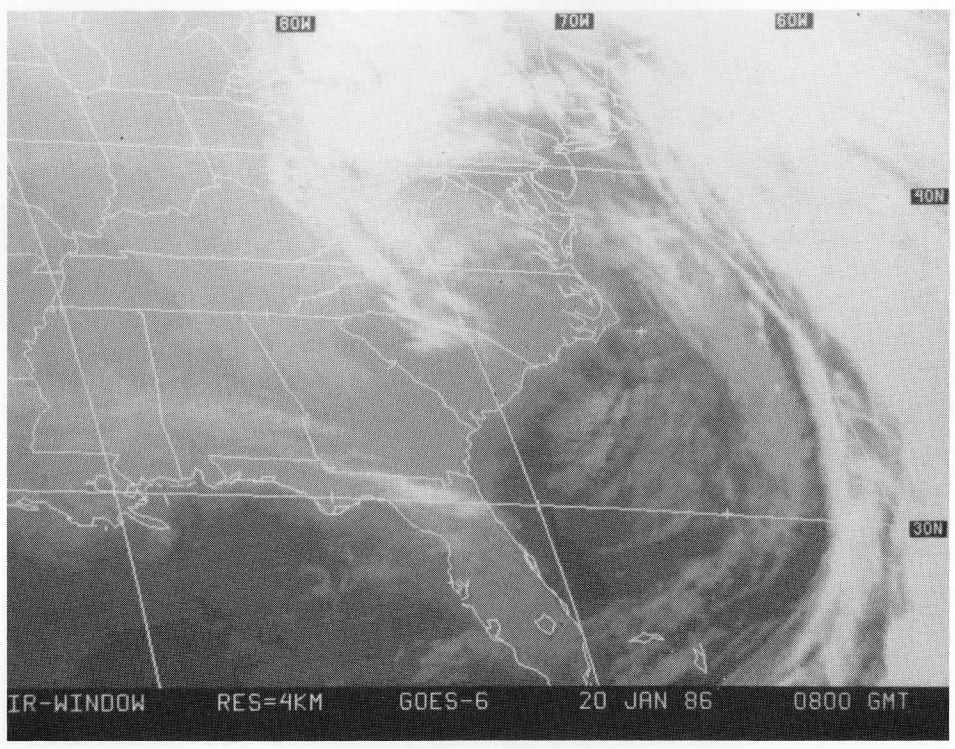
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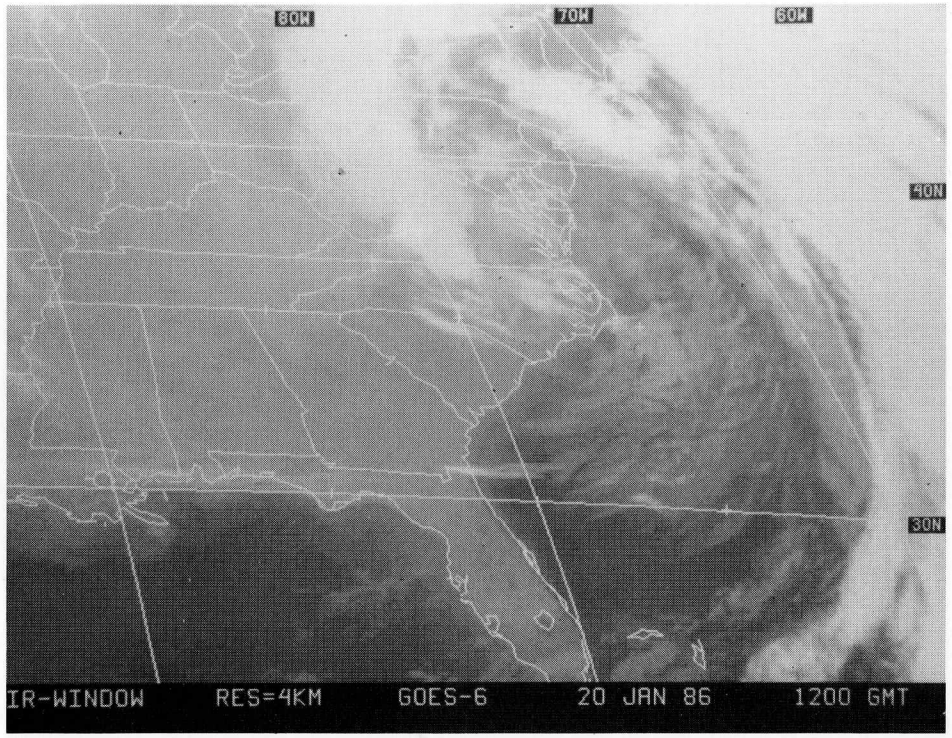
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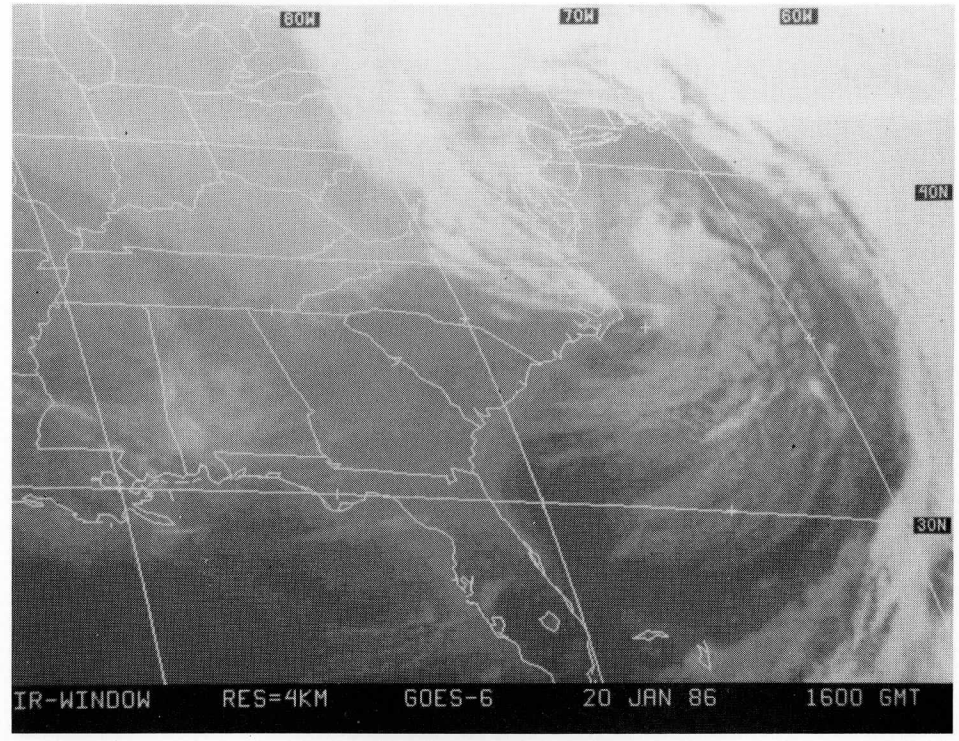
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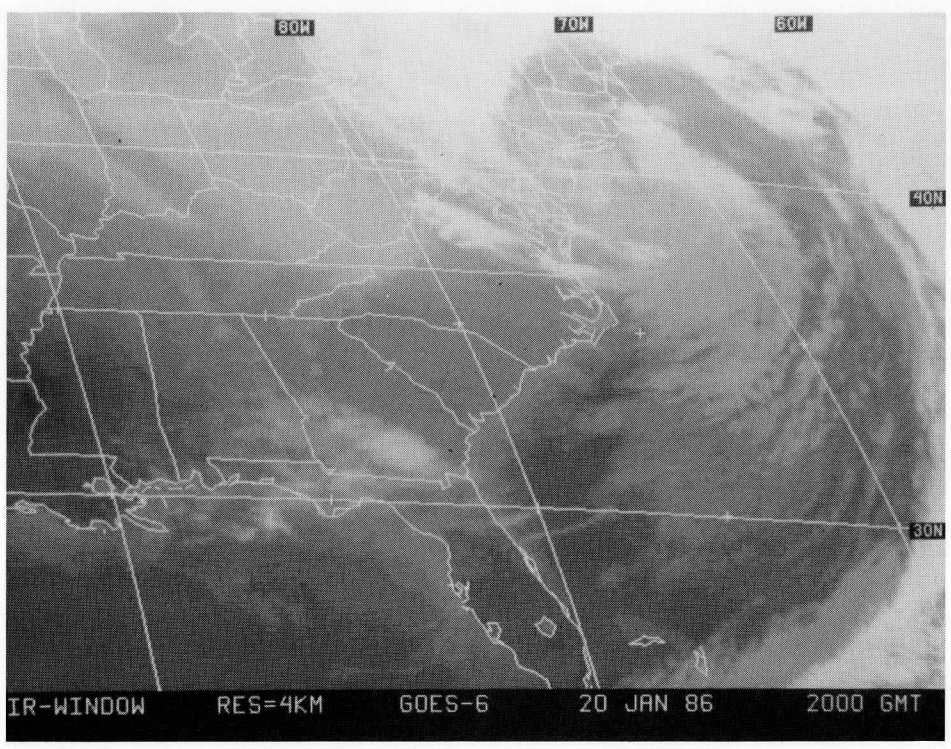
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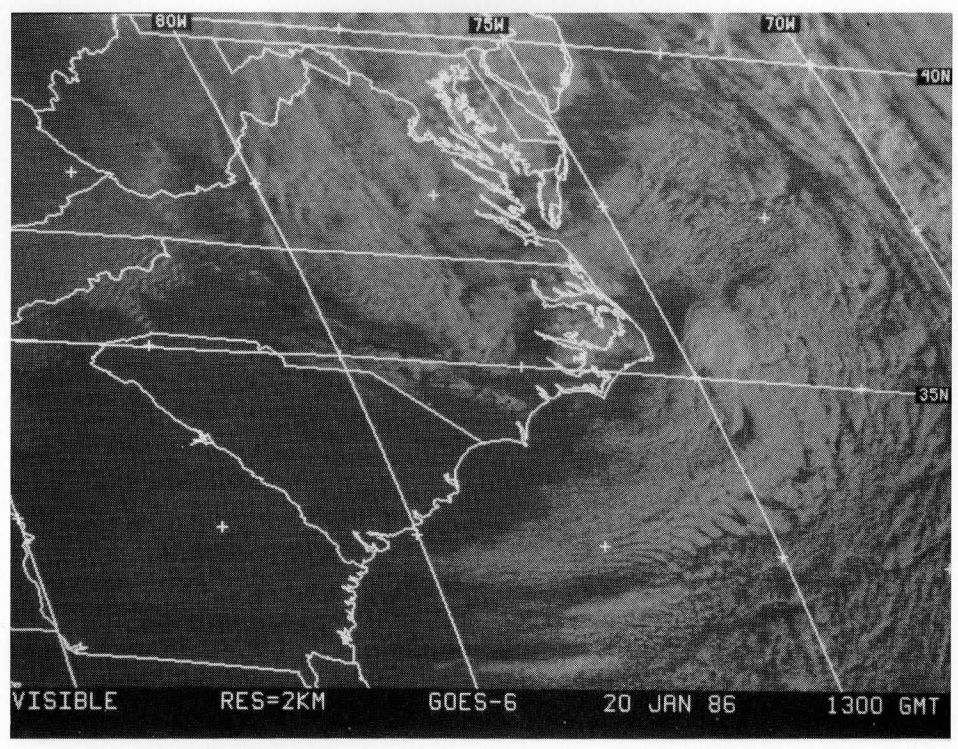
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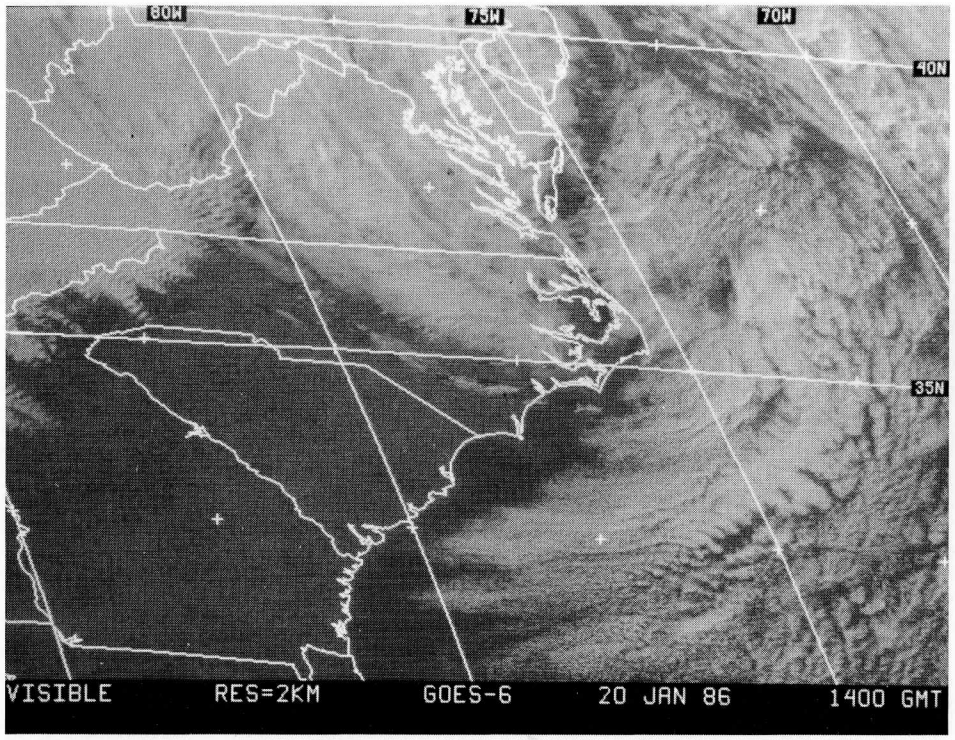
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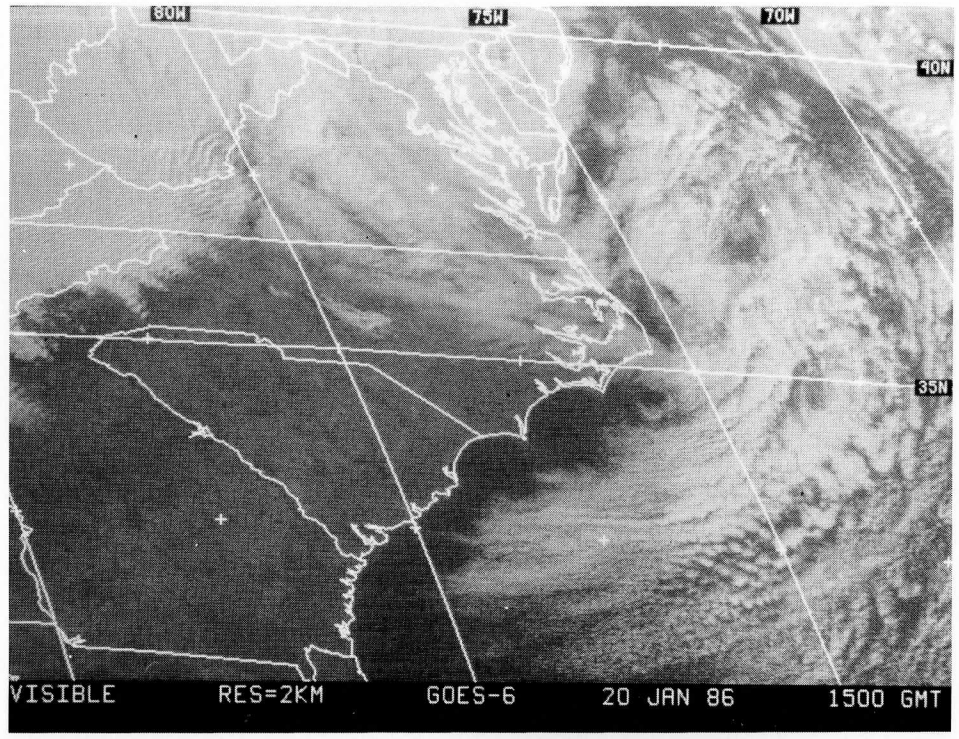
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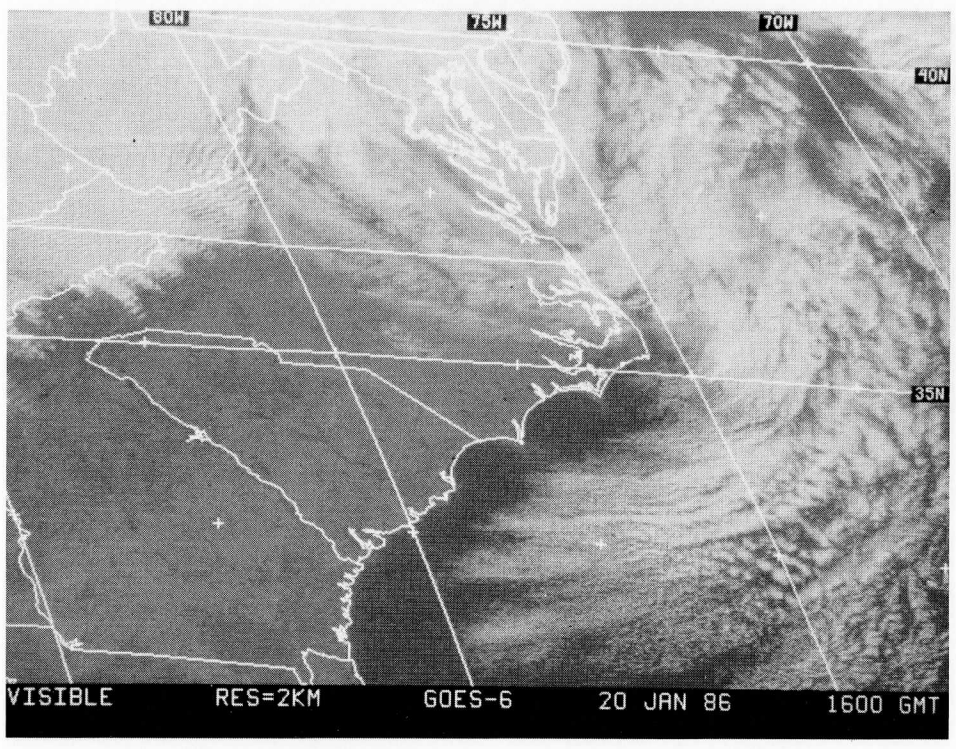
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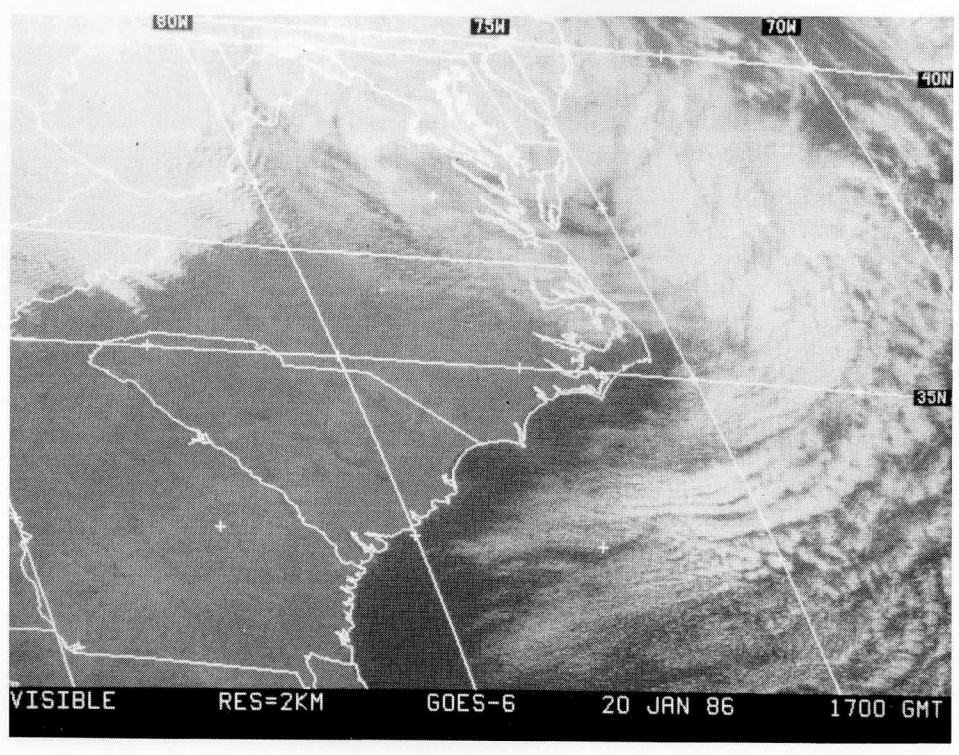
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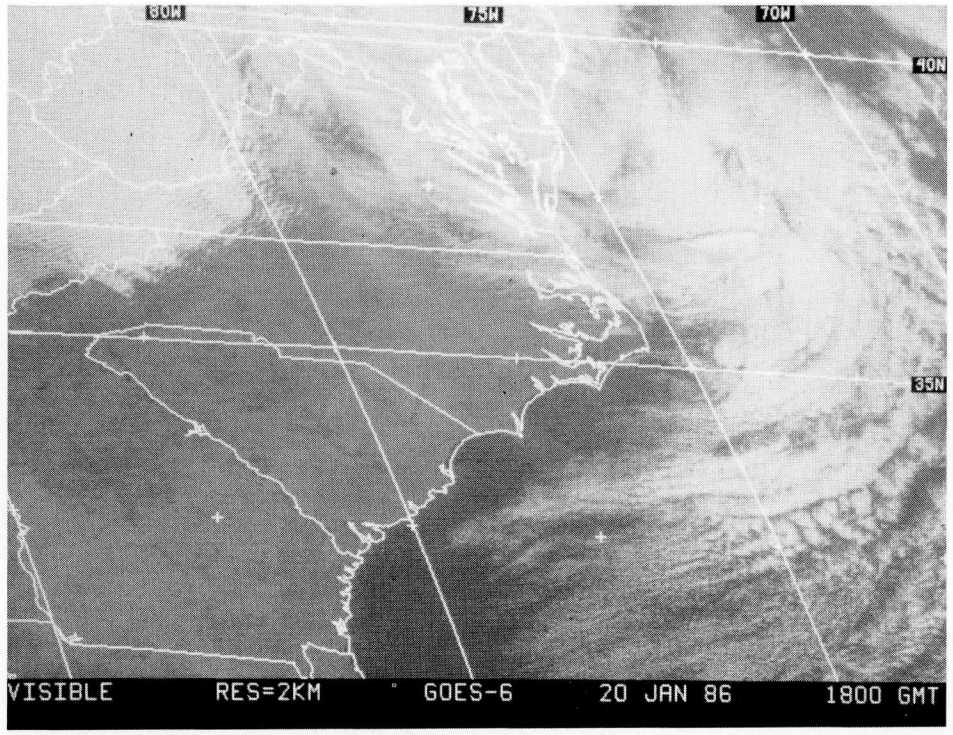
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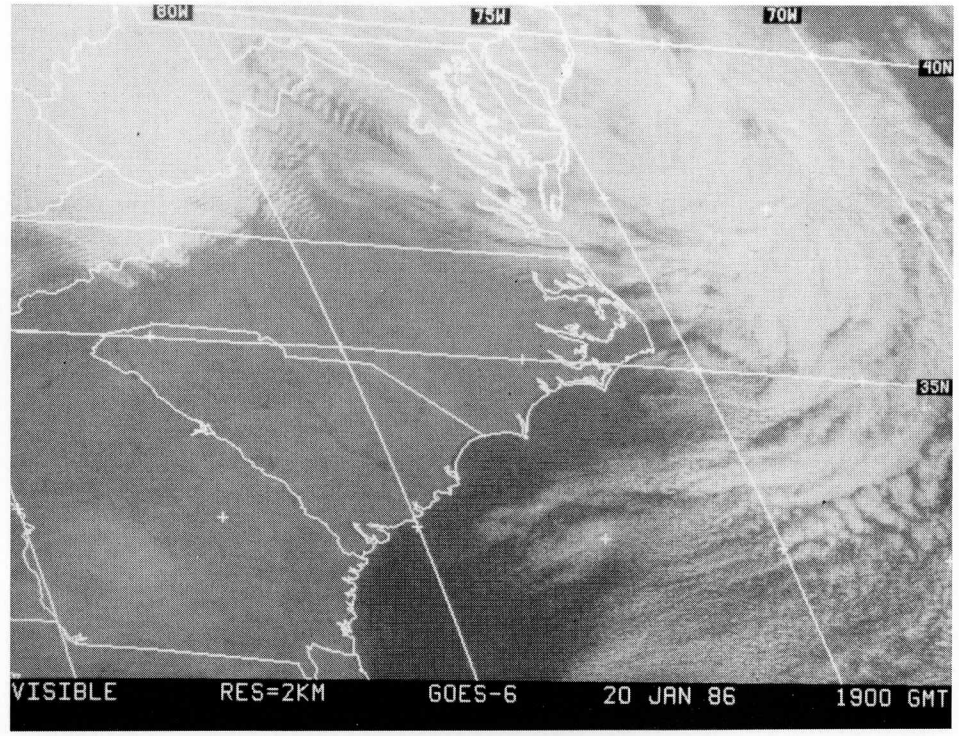
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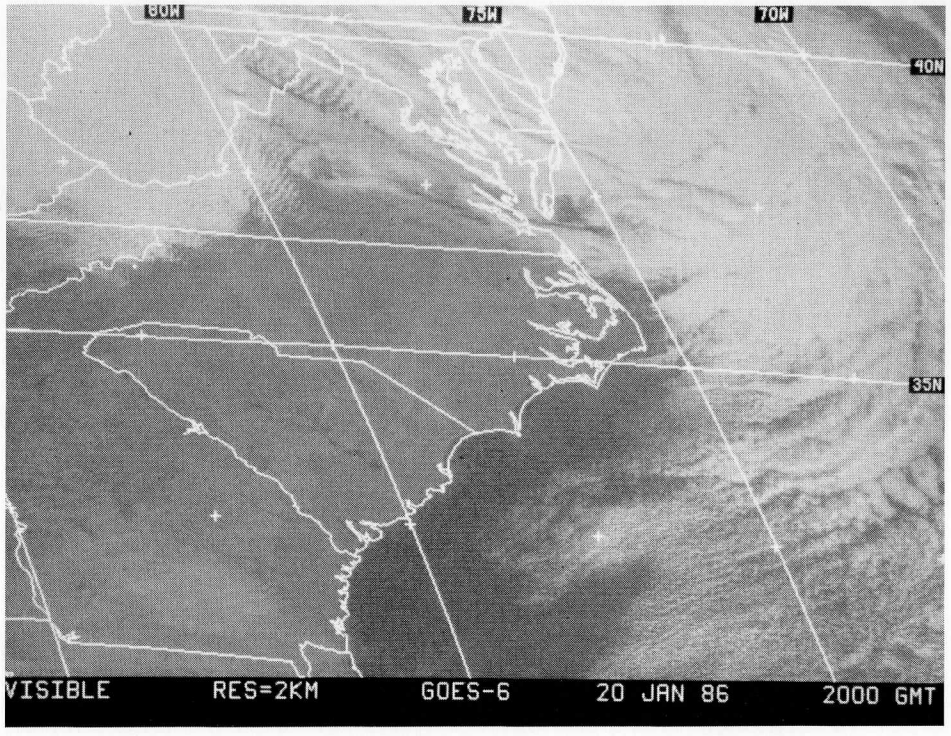
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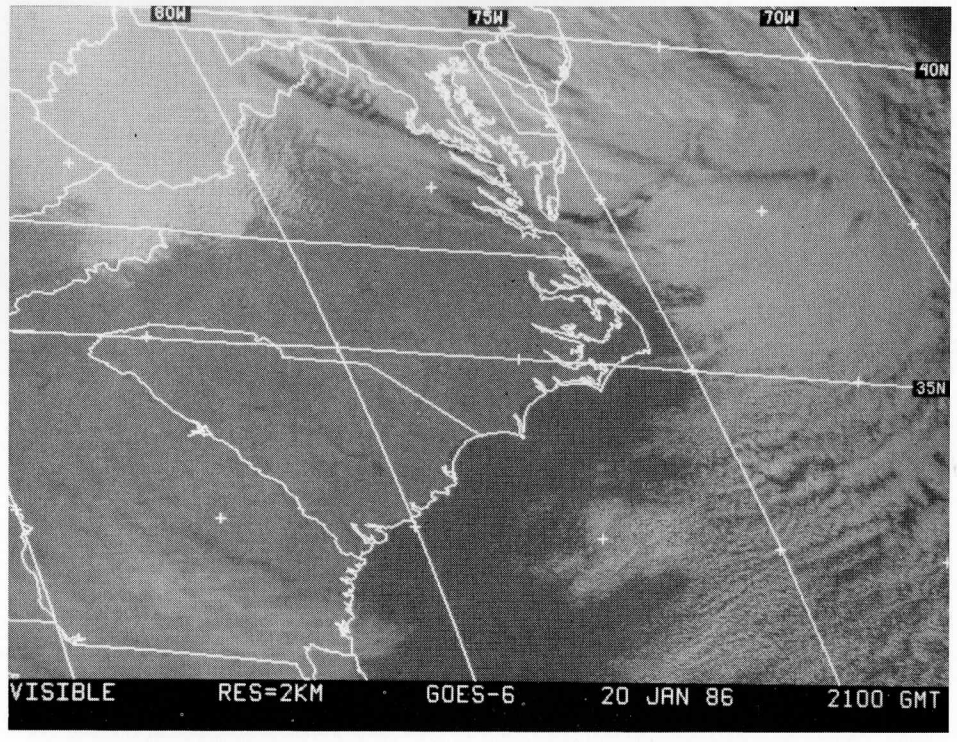
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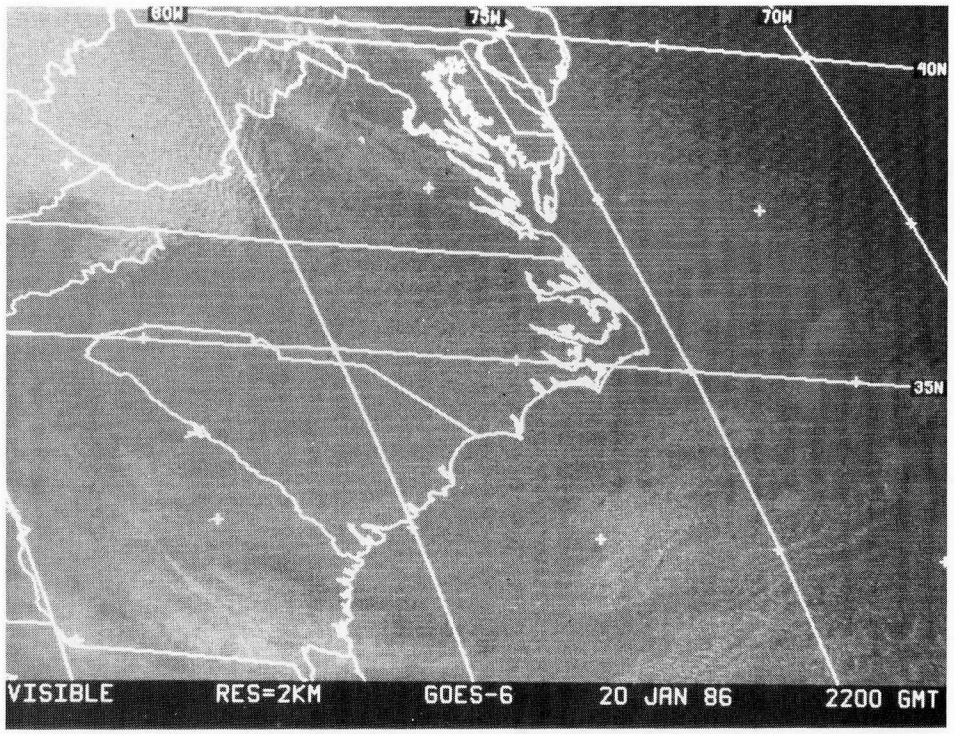

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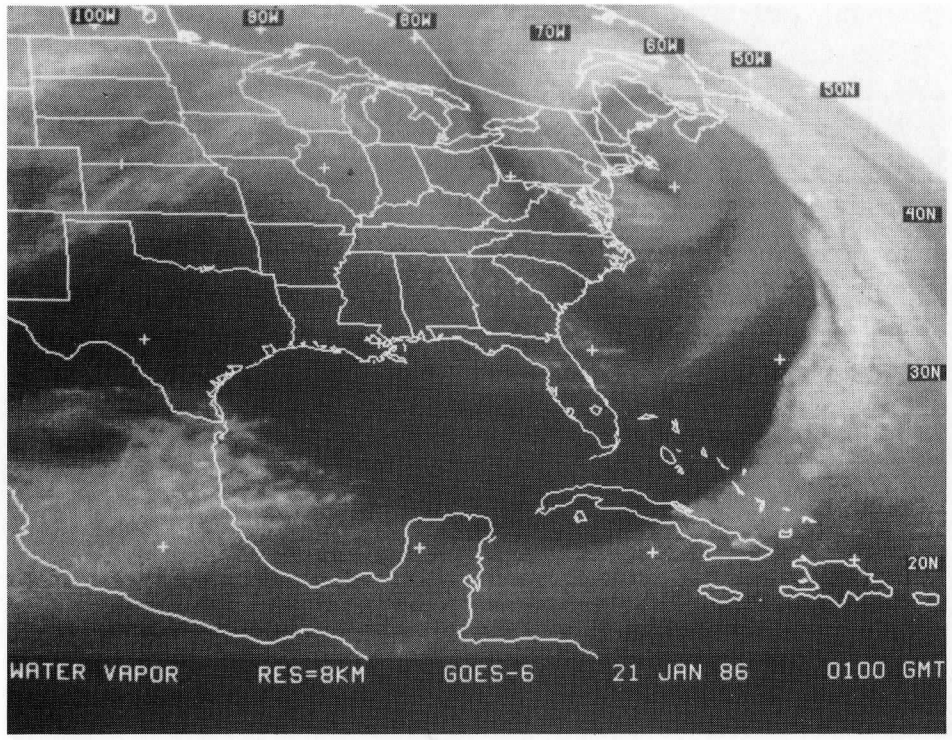
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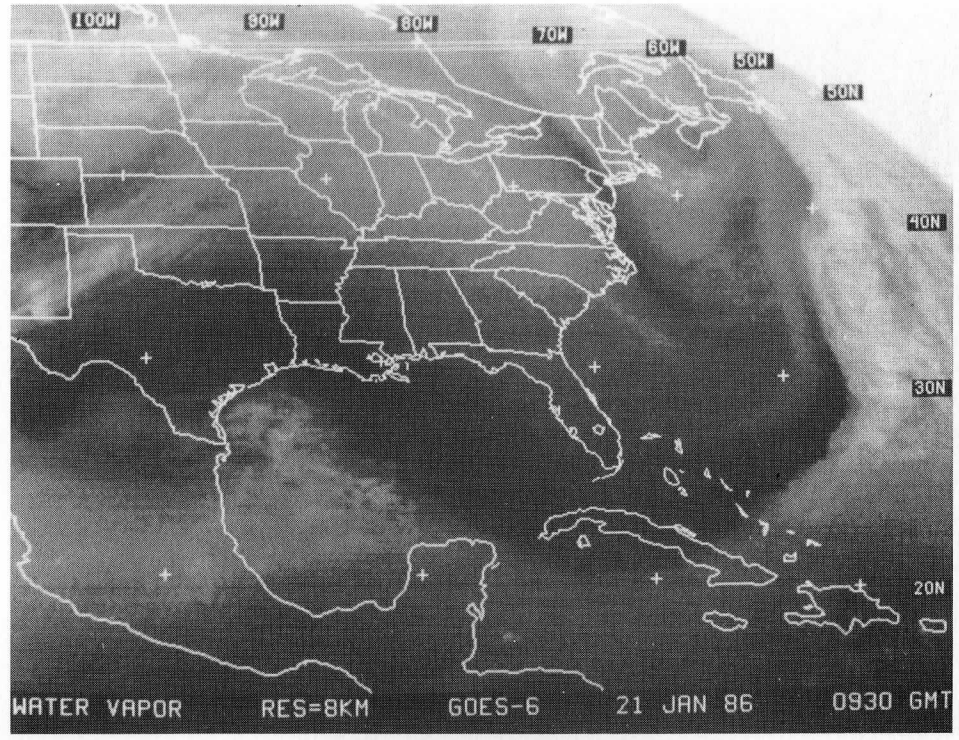
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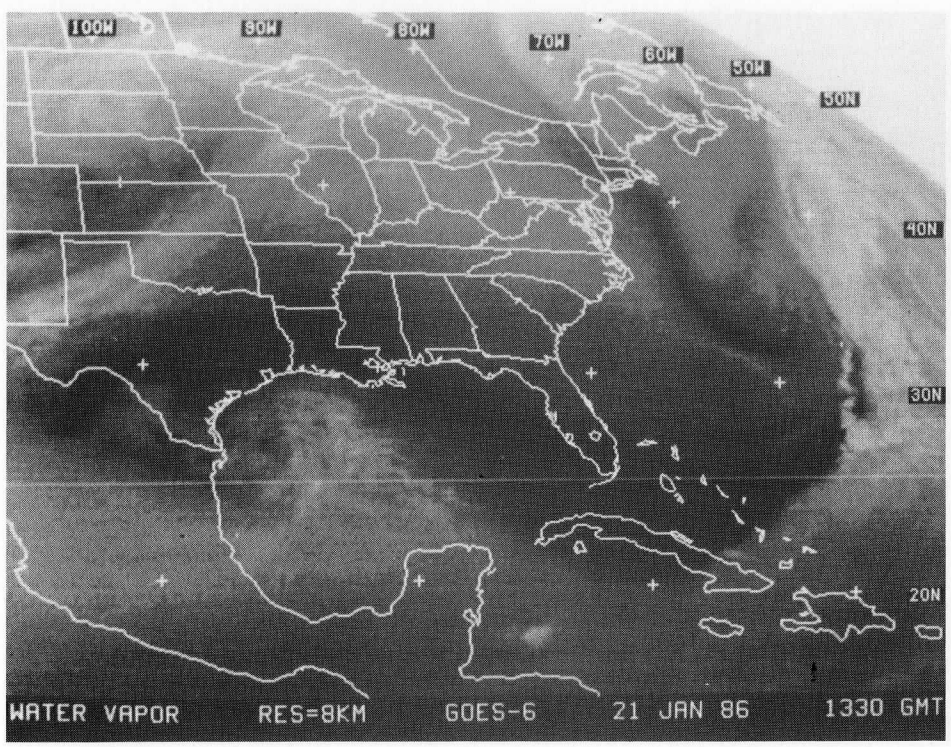
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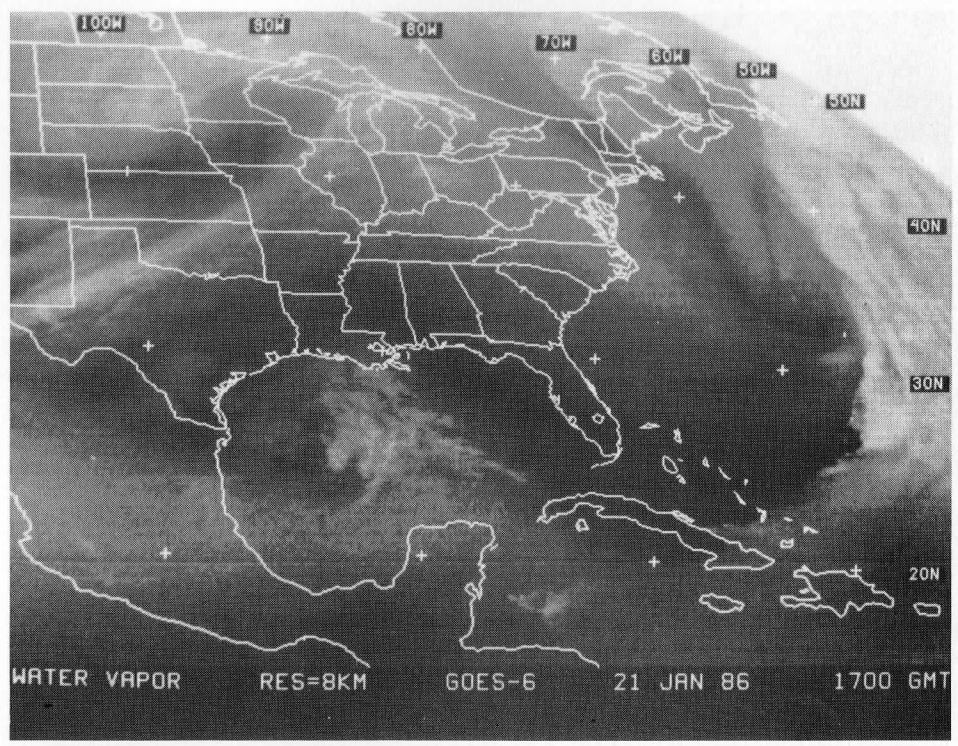
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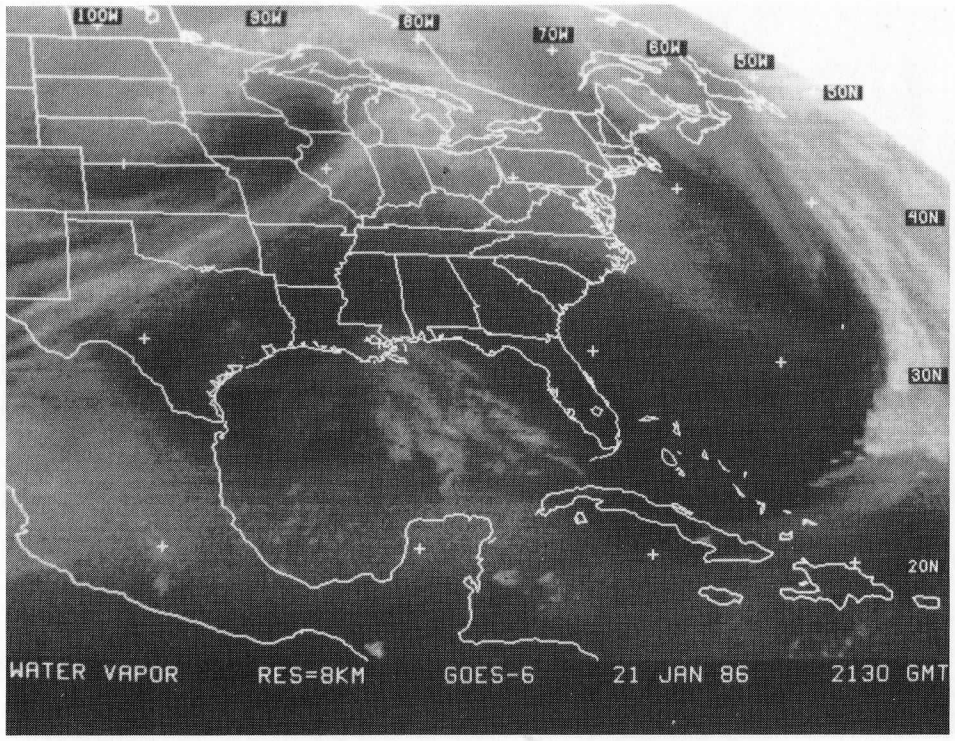
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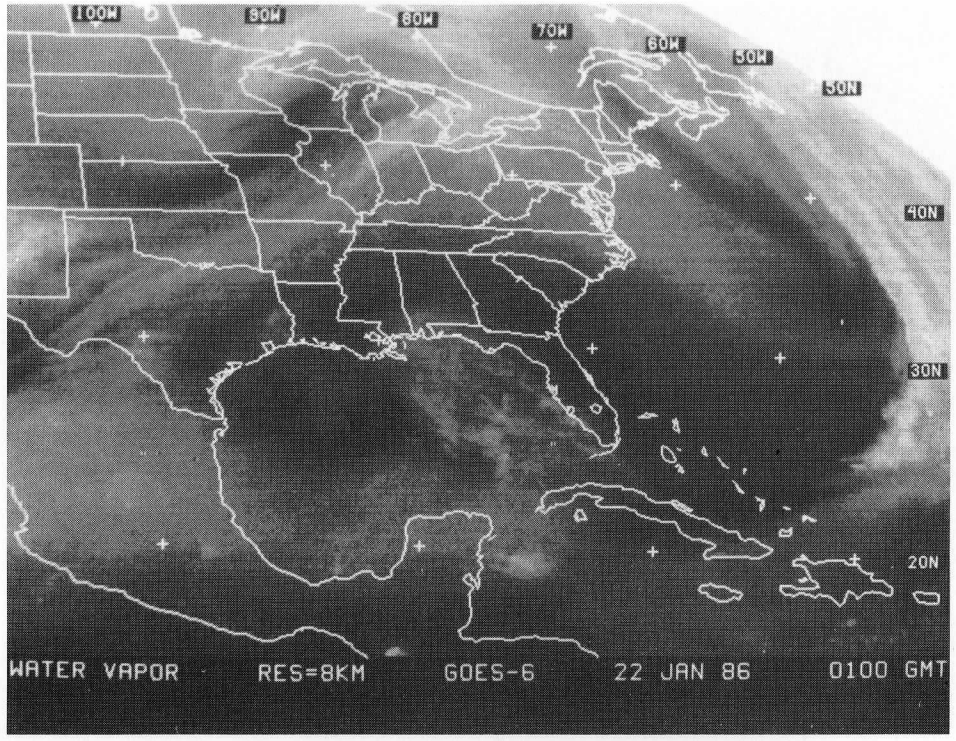
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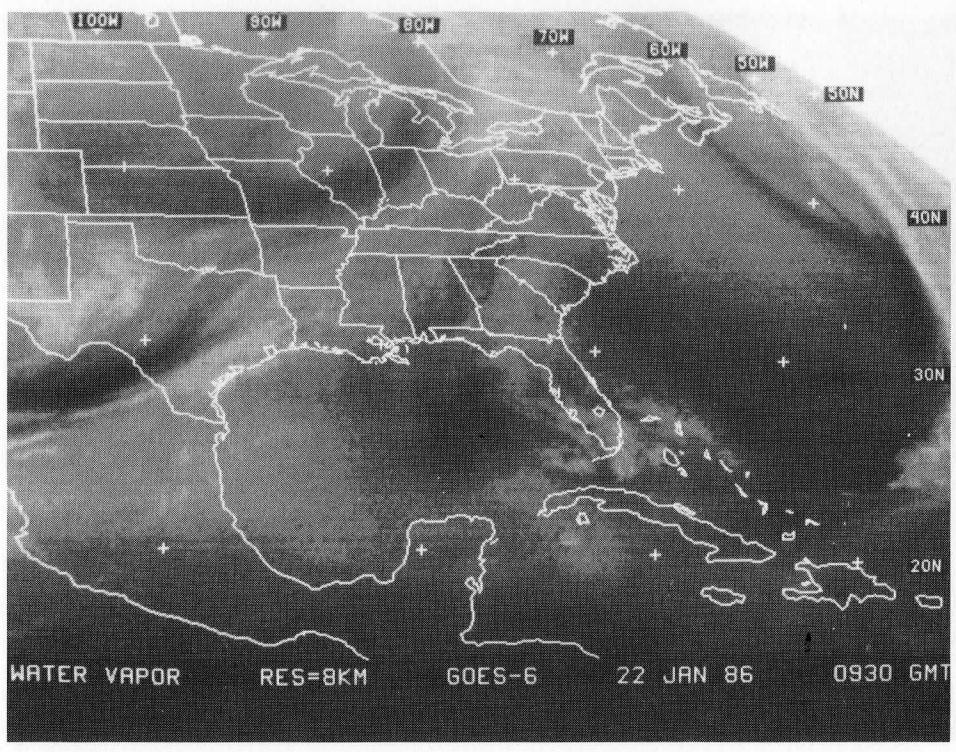
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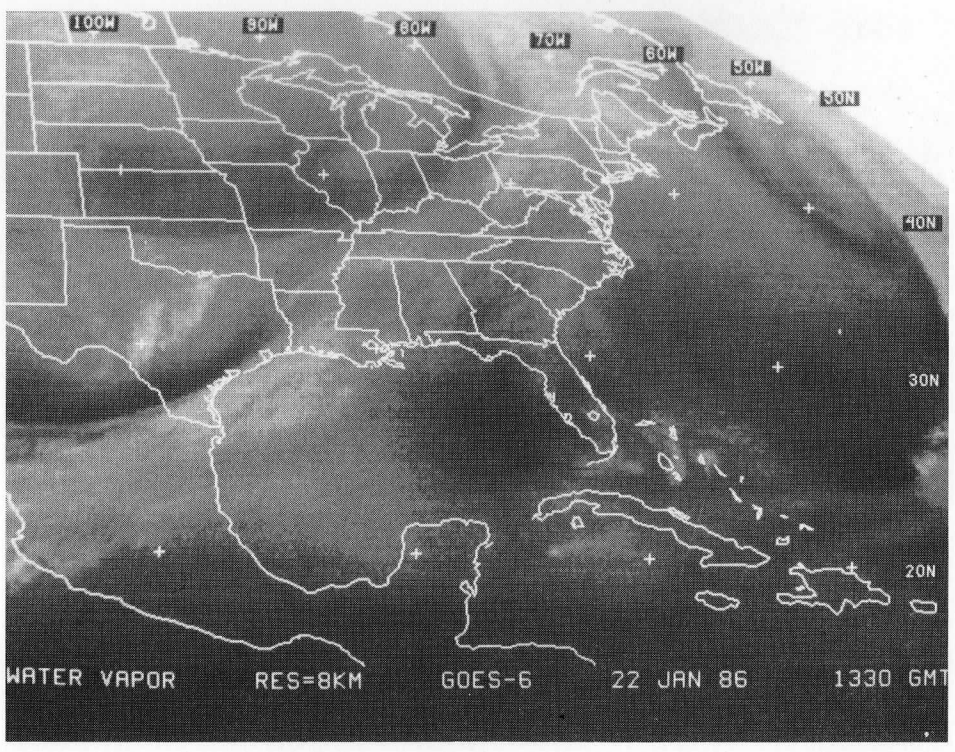
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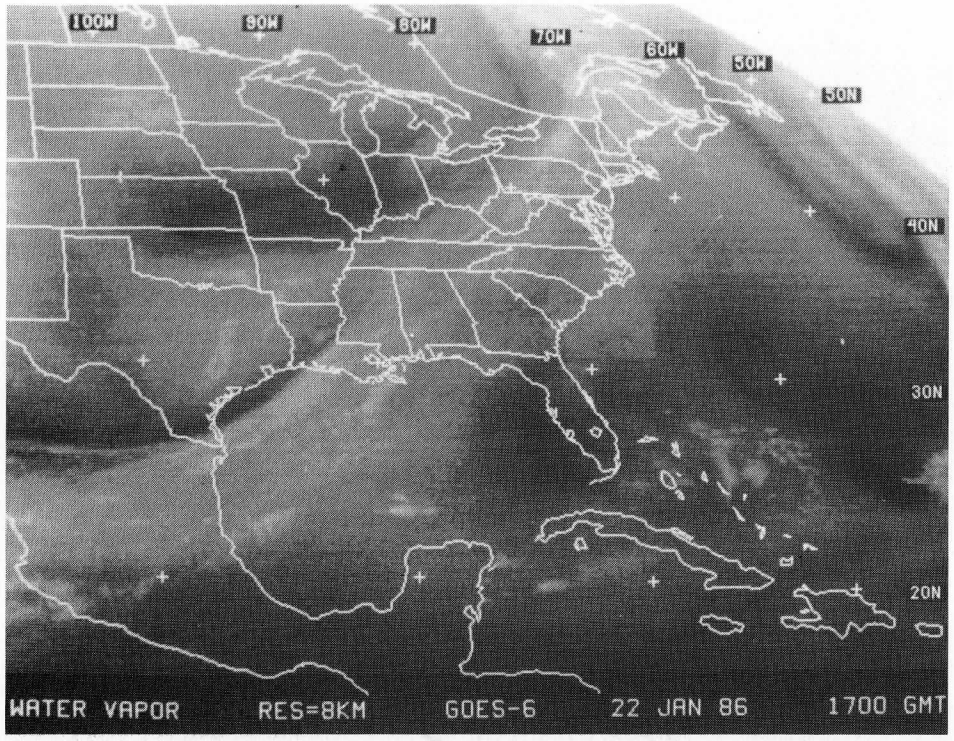
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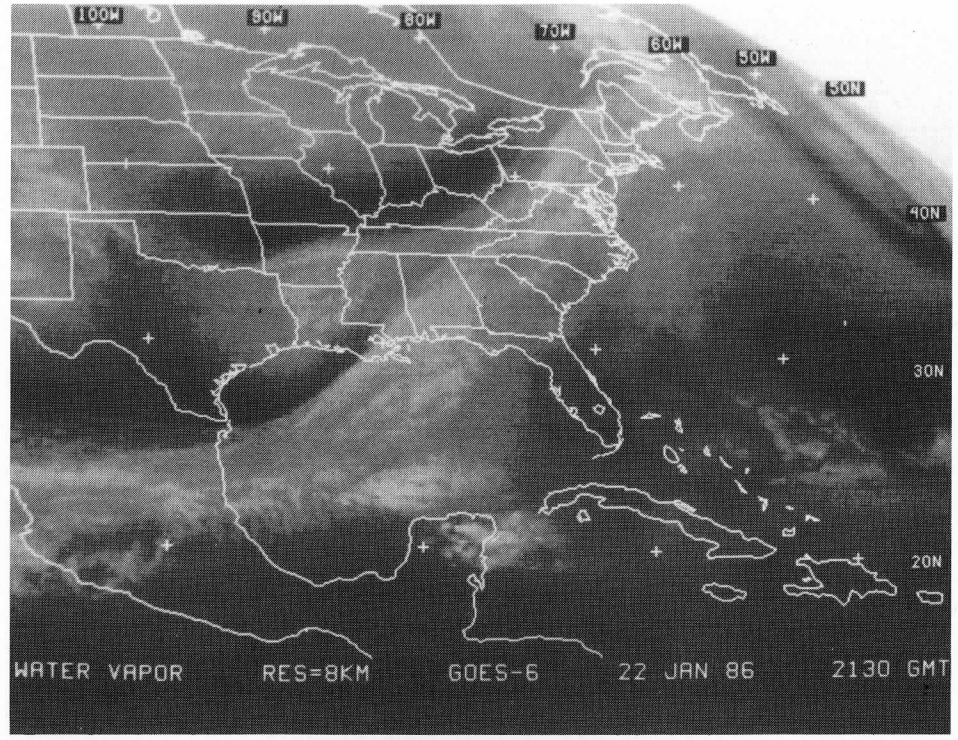
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IOP #2 - Cold Air Damming / Coastal Frontogenesis / Offshore Cyclogenesis / Cold Air Cyclogenesis
January 23 - January 29

Satellite Synopsis

Water Vapor

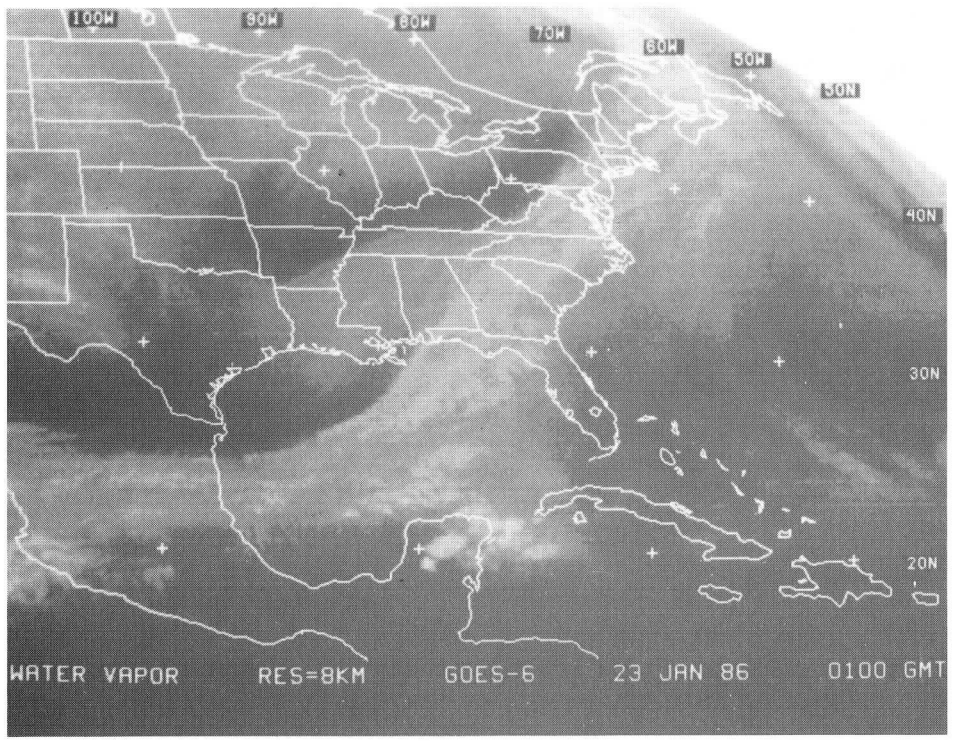
- 23rd, weak upper system near New Orleans at 00 GMT moves offshore of the Carolinas by 00 GMT on the 24th.
- 23rd, strong dry air mass exists over Florida.
- 25th, a bulge in the moisture pattern forms from Texas to Kentucky.
- 25th, strong thunderstorm line in region of dry mid-tropospheric air over the Gulf, dissipates early on the 26th.
- 26th-27th, strong dry subsidence region in Gulf associated with the jet.
- 26th-27th, strong moisture channel sets up ahead of trough from Yucatan Peninsula to Cape Hatteras to New England with a sharp cut off evident (jet axis).
- 27th, moist pocket off Carolinas early in the day becomes convective in unstable air by 18 GMT through 00 GMT on the 28th.
- 27th-28th, strong negative tilt to trough very evident.
- 27th-28th, cold air circulation evident in moisture in the Virginia and North Carolina area.
- 28th-29th, excellent demarcation of long wave trough.

IR

- 24th, at 00 GMT there is convection over Gulf Stream.
- Jet axis is apparent from cirrus edge from the 26th through the 28th (negative tilt).
- Convection explodes in cold air PVA from 27th 00 GMT through 28th 04 GMT and moves into New England.
- Cold air cloud streets exist over the Gulf and east of Florida on the 27th and the 28th with some spiral banding east of Cape Hatteras on the 28th.
- 27th-29th, solid stratocumulus deck forms about 100 km off shore.

Visible

- Thunderstorms dissipate in Georgia early on the 23rd.
- Some Gulf Stream convection on 23rd.
- 24th, some organized low level cloud streets and patterns evident to the northeast of Cape Hatteras.
- 25th, convective cloud mass forms in southeast Georgia and moves off shore by 00 GMT on the 26th.
- 26th, some early Gulf Stream convection, and more late in day with overshooting tops evident.
- 26th, clear air fills in with organized cloud streets in Georgia late.
- 27th, circulation apparent in North Carolina.
- 27th, low level convergence lines, some cloud streets.
- 27th, rapid increase in convective mass off Cape Hatteras late.
- 28th, striking cloud streets, with some banding perpendicular to the flow evident.
- 28th, some mountain wave clouds in western North Carolina.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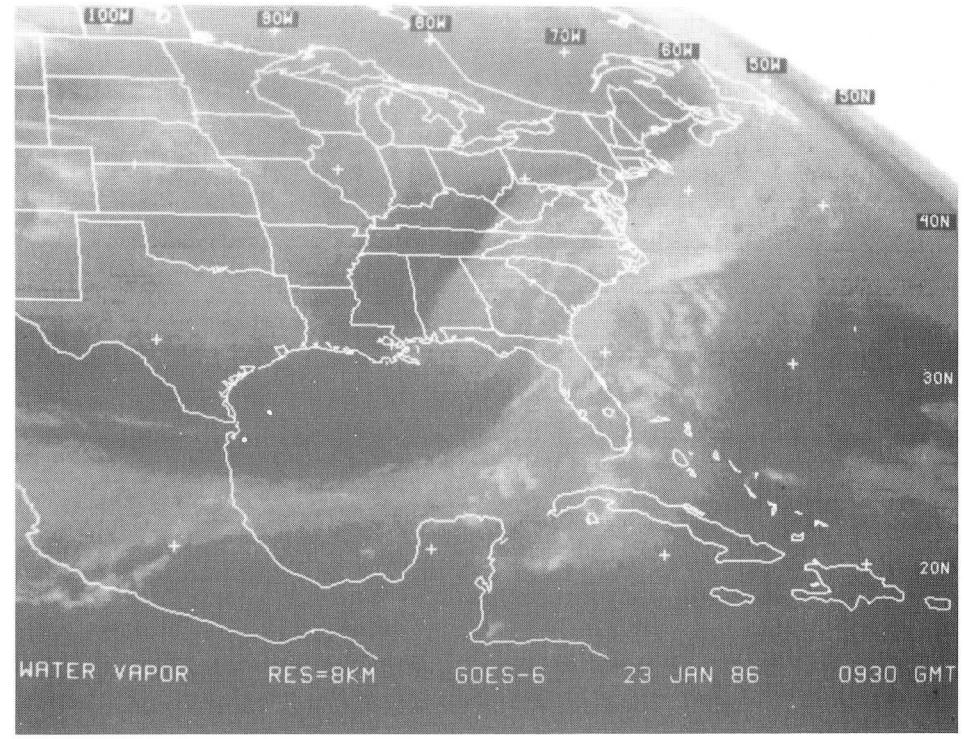
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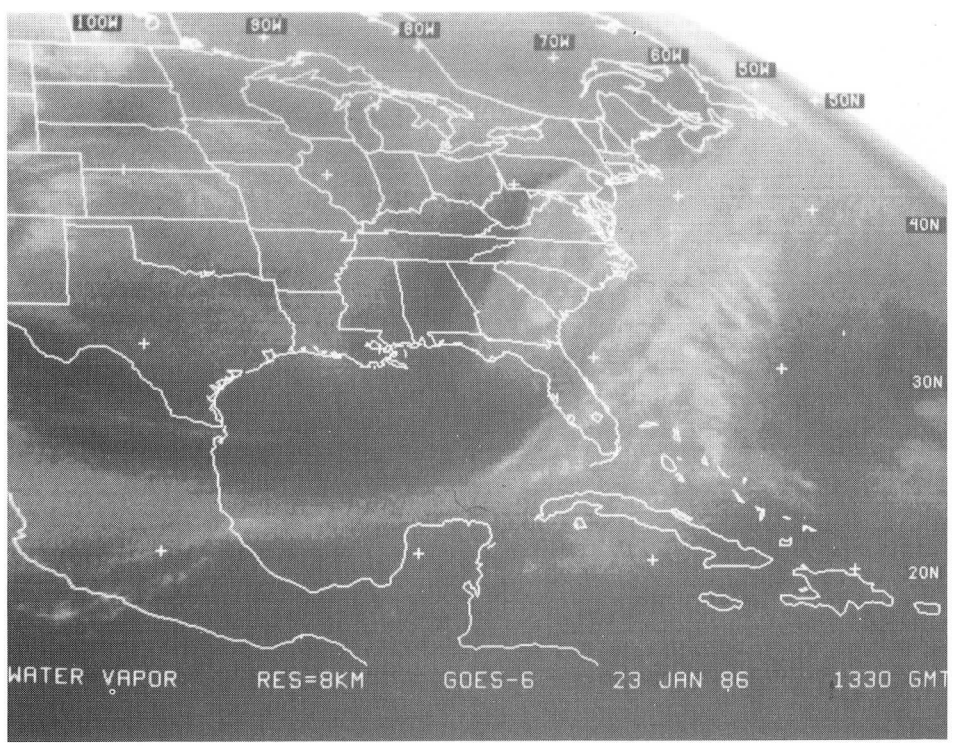
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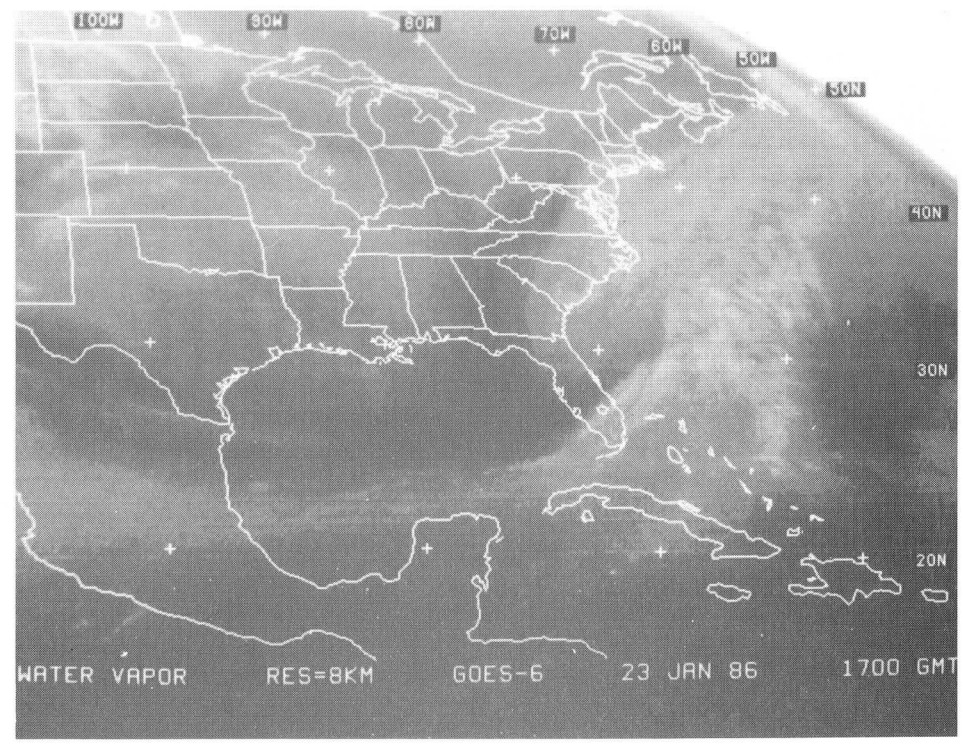
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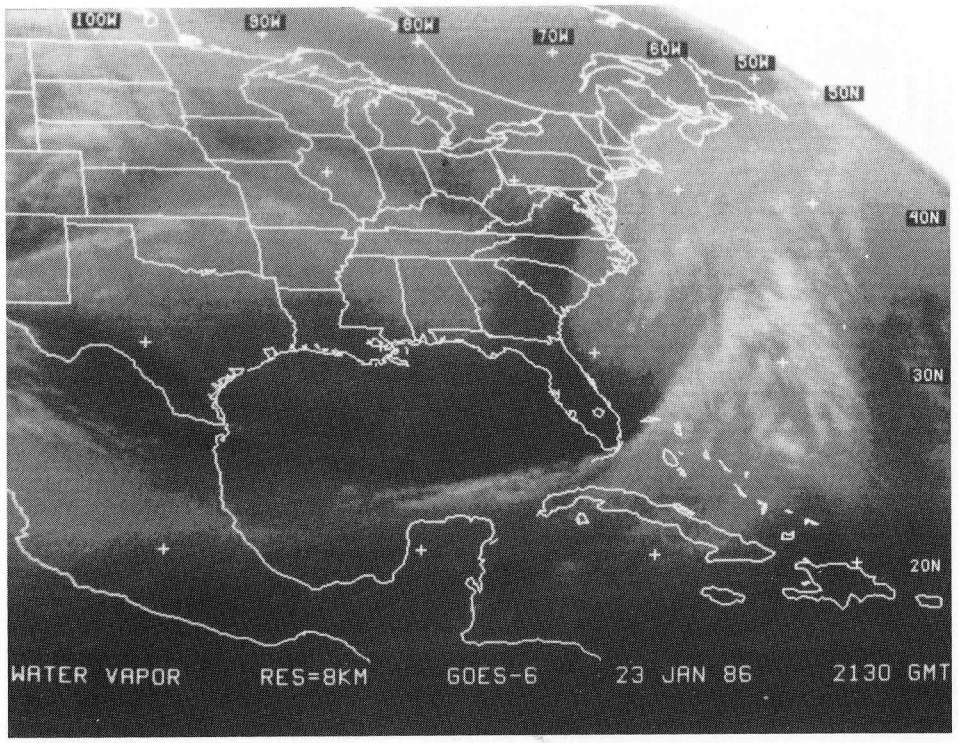
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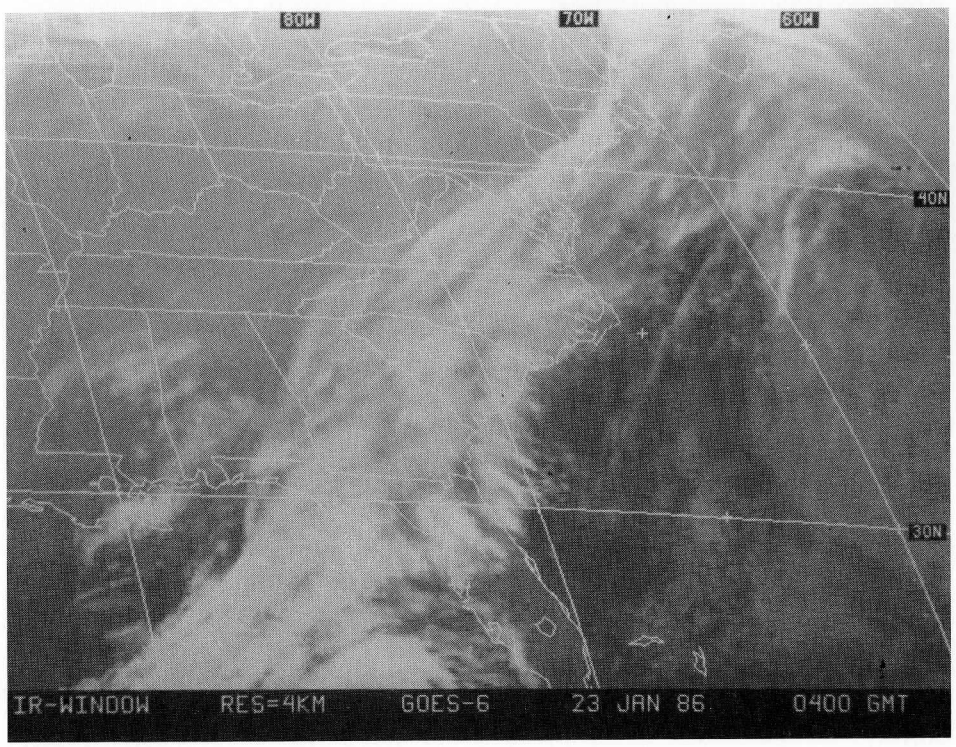
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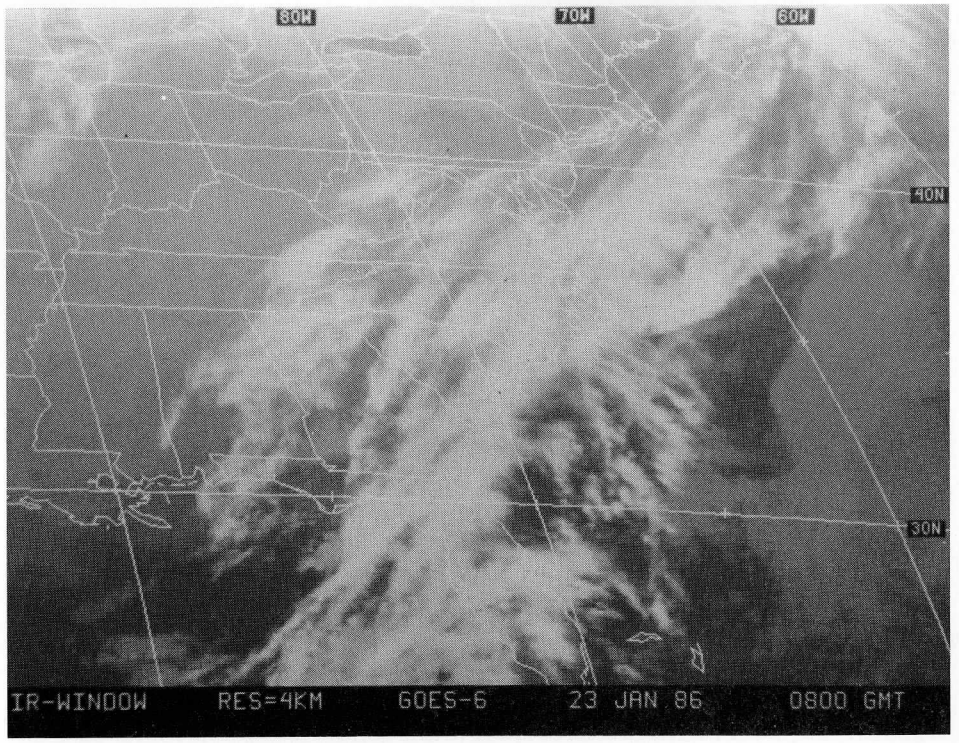
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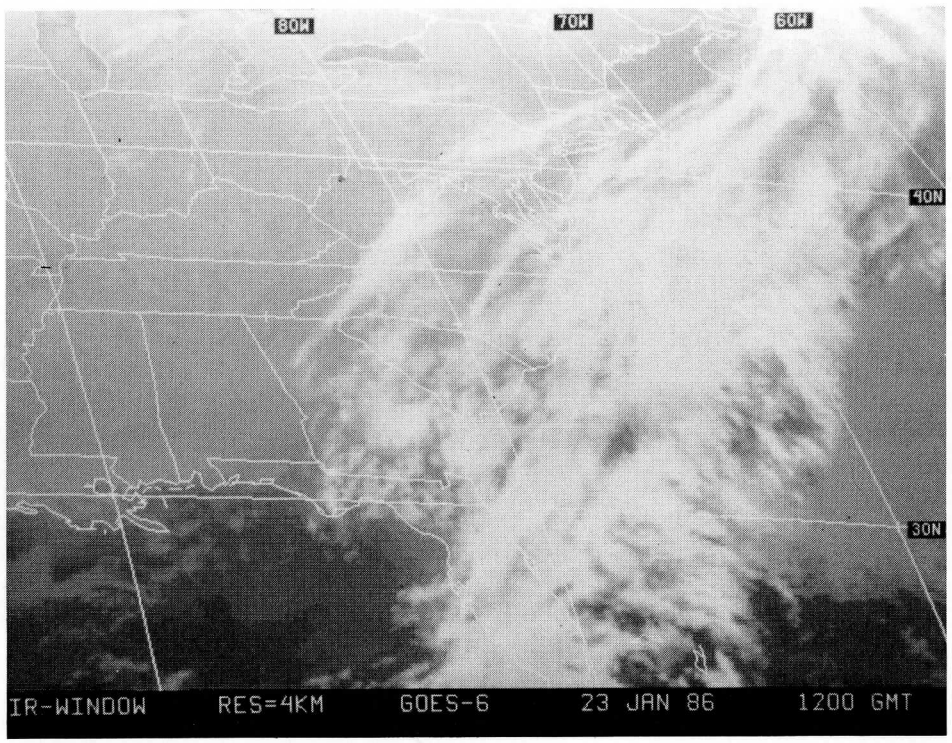
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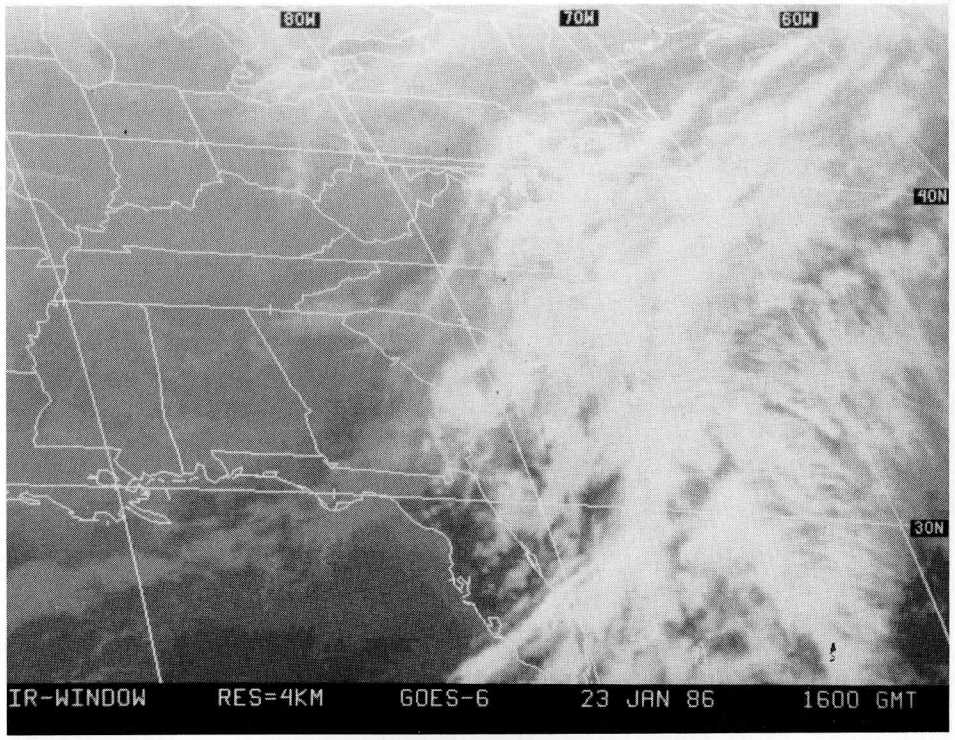
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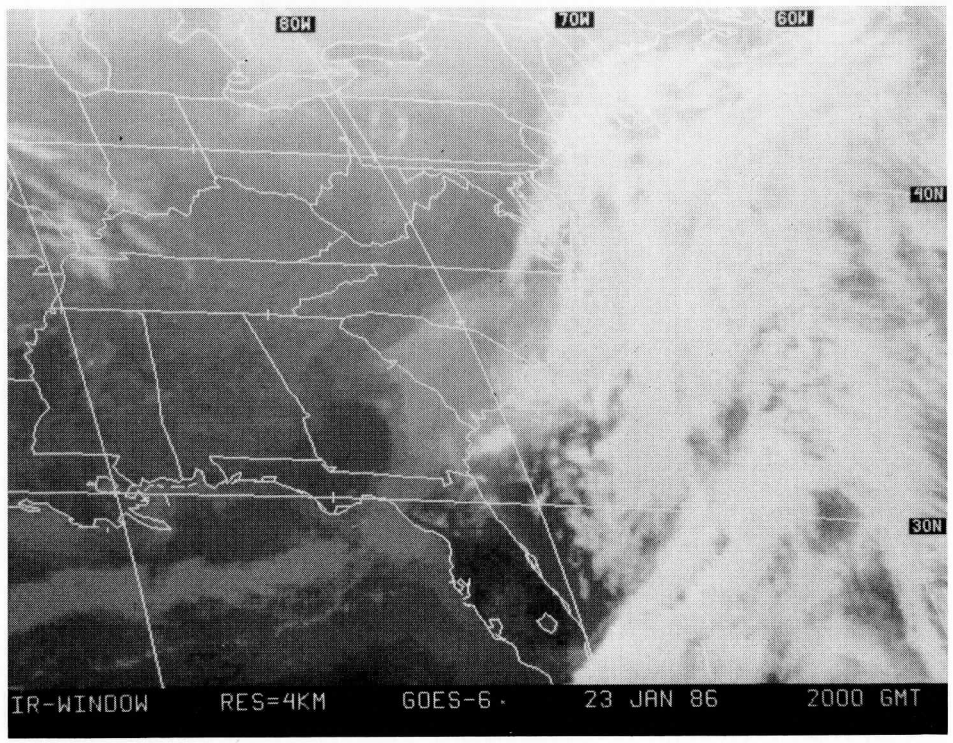
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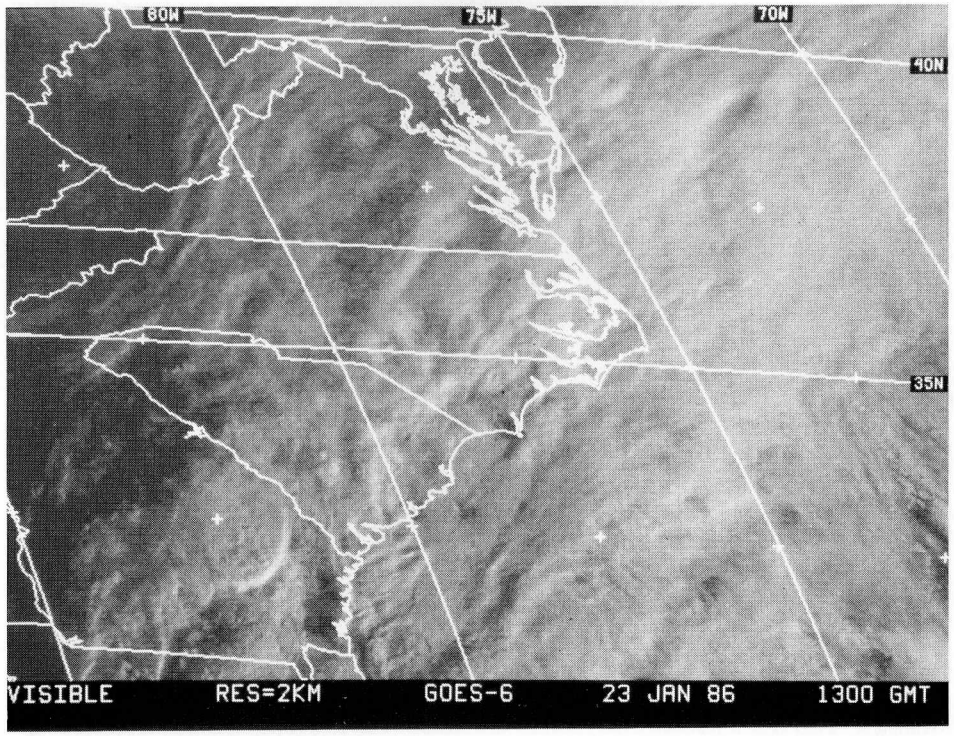
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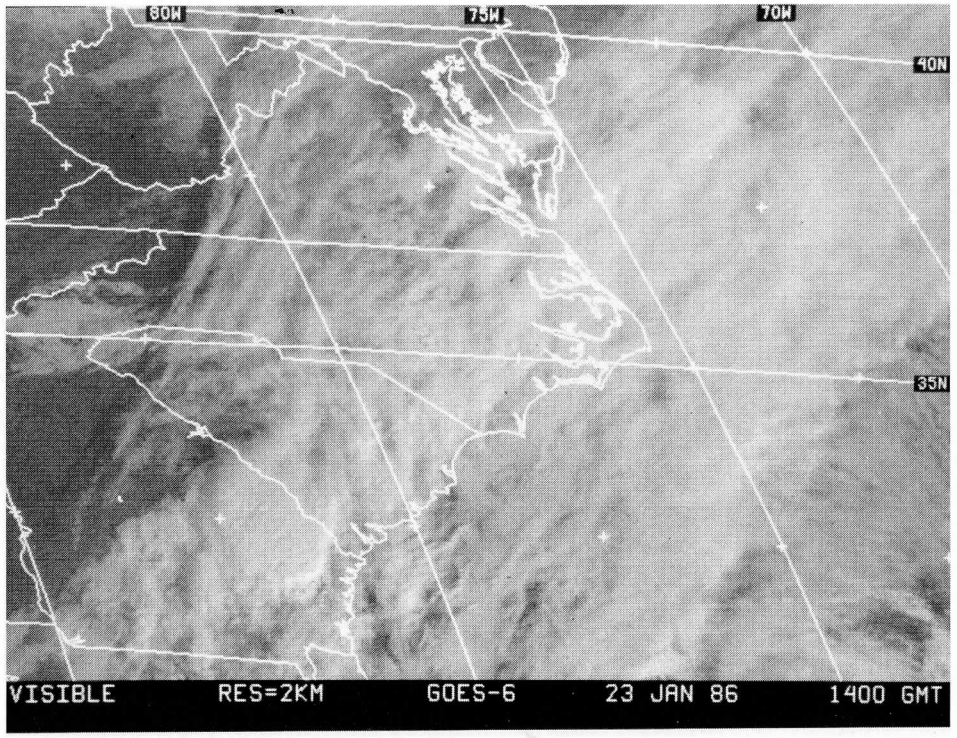
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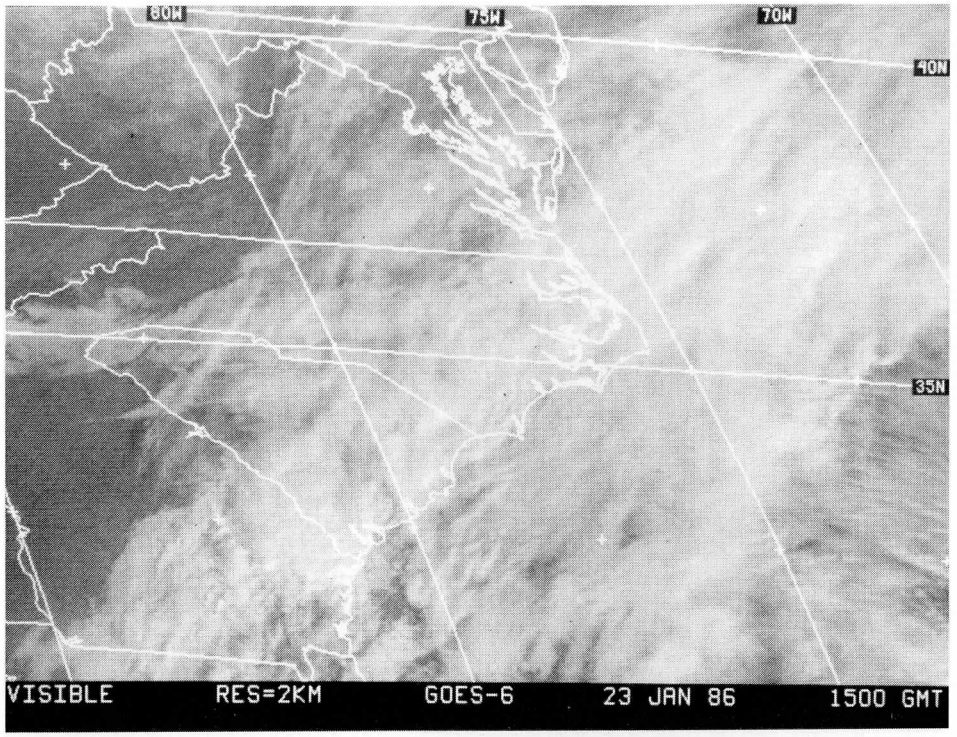
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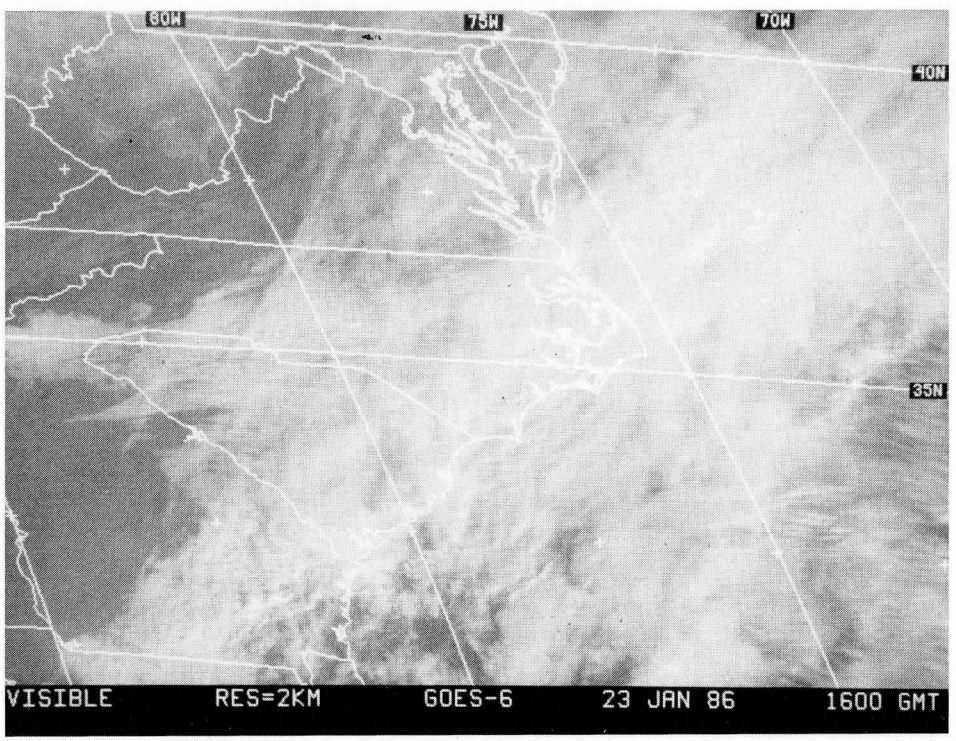
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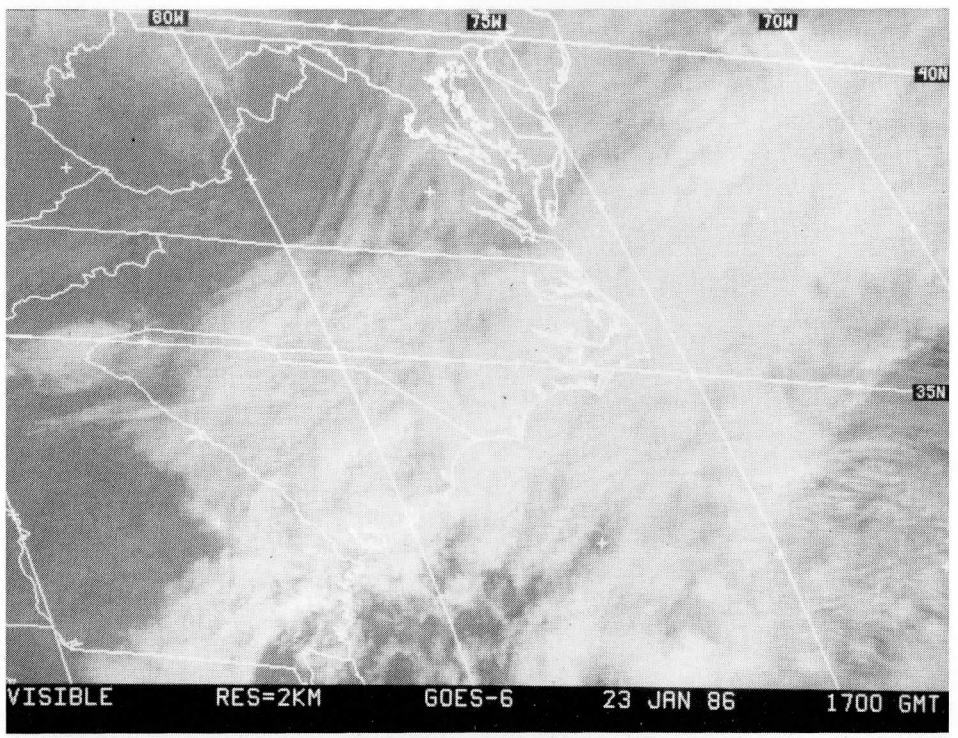
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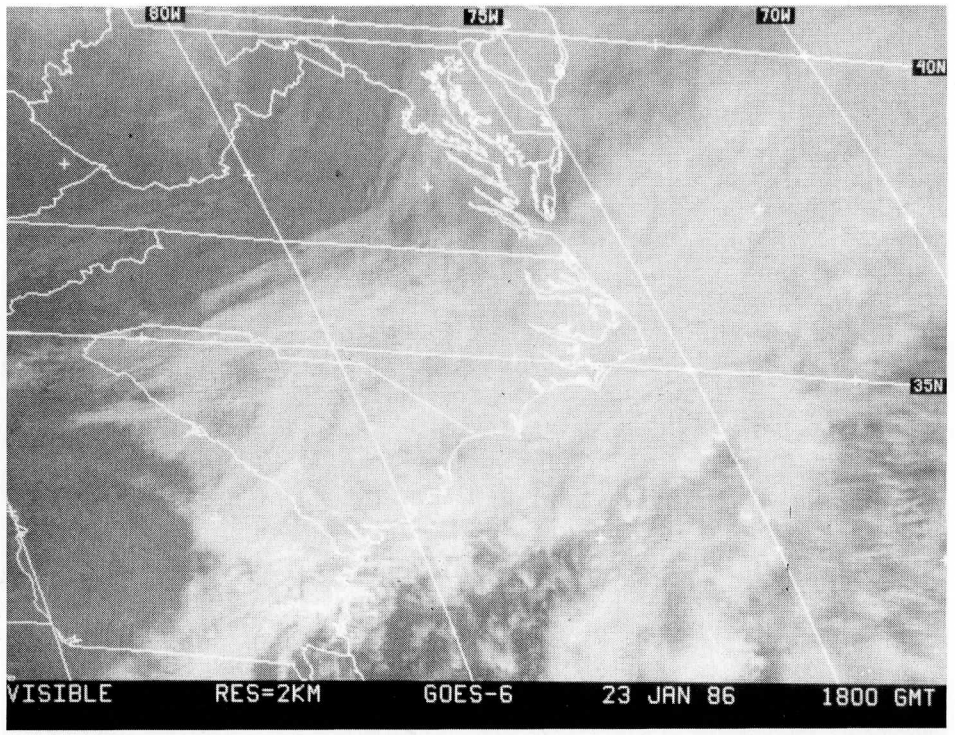
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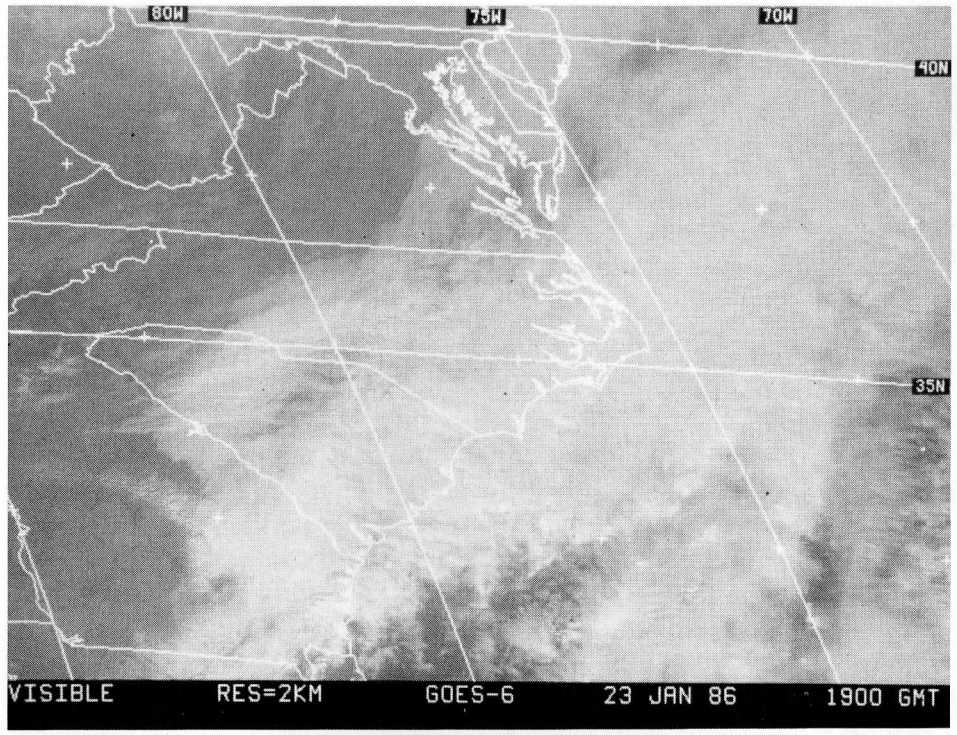
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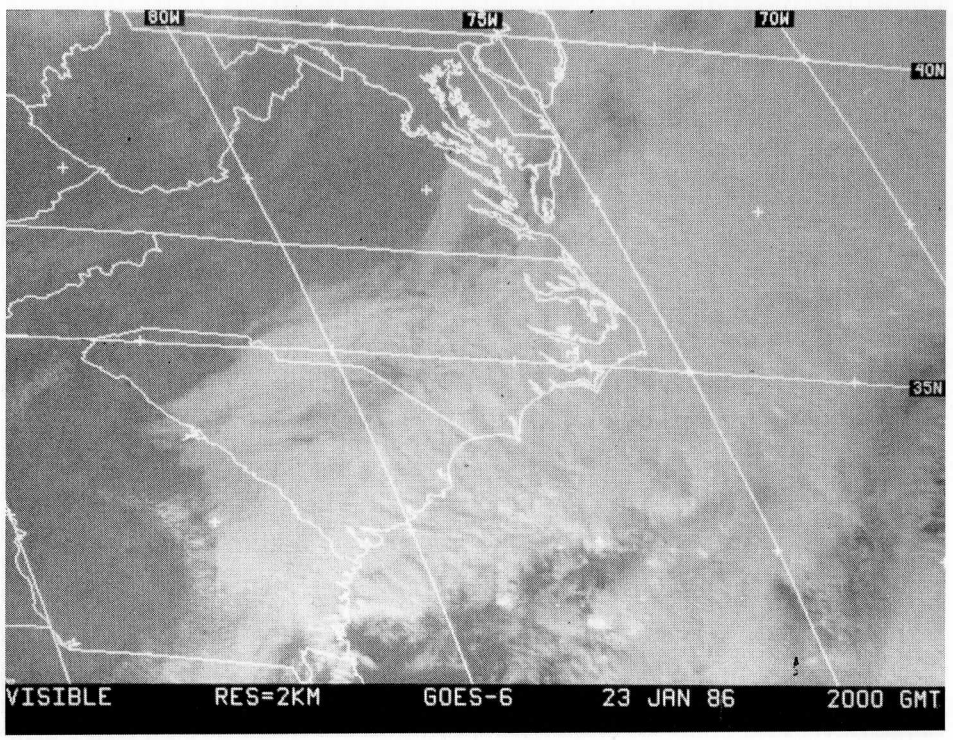
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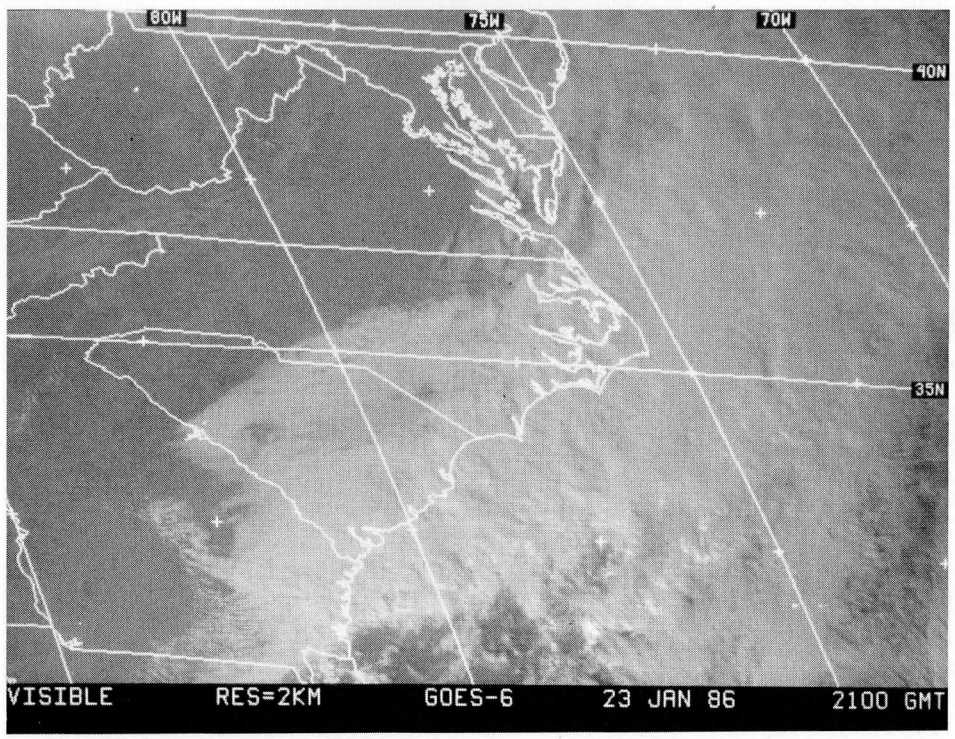
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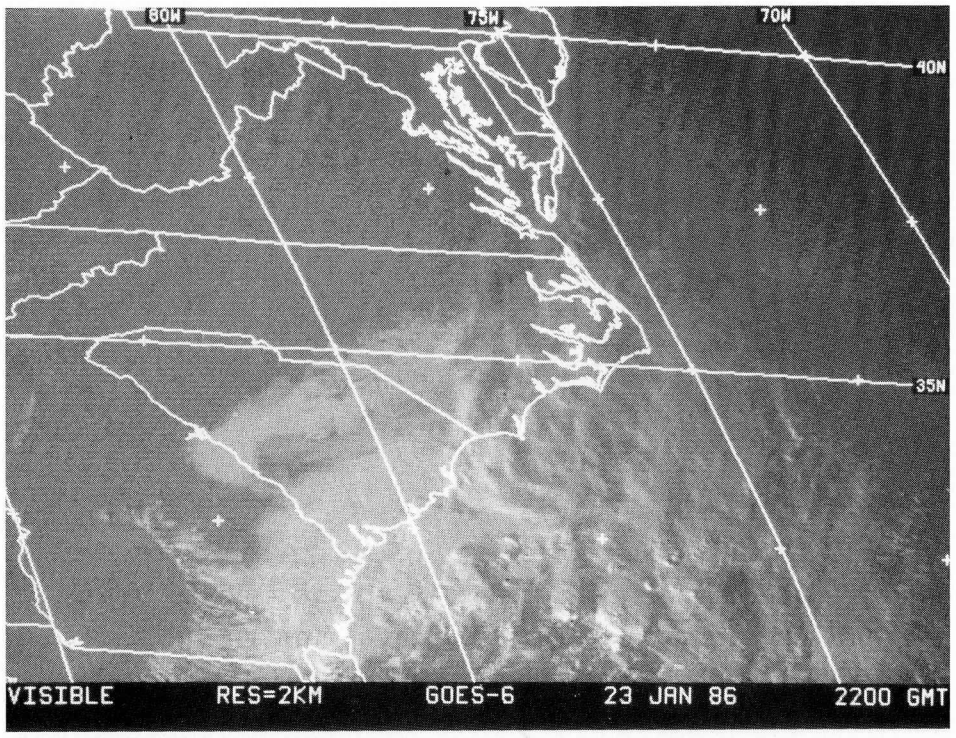
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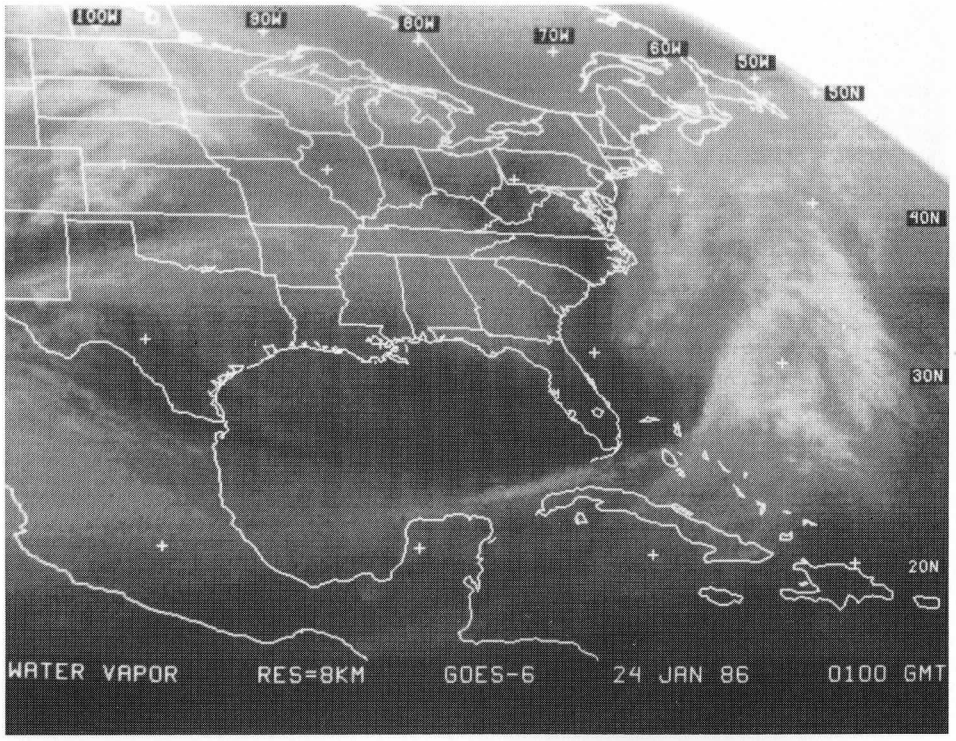
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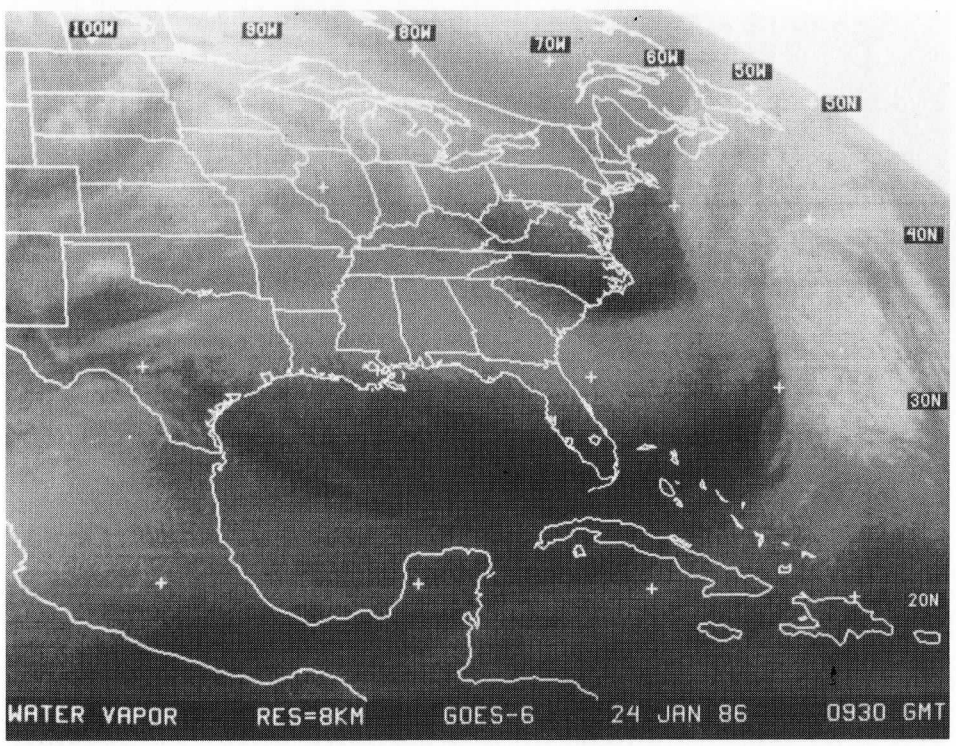
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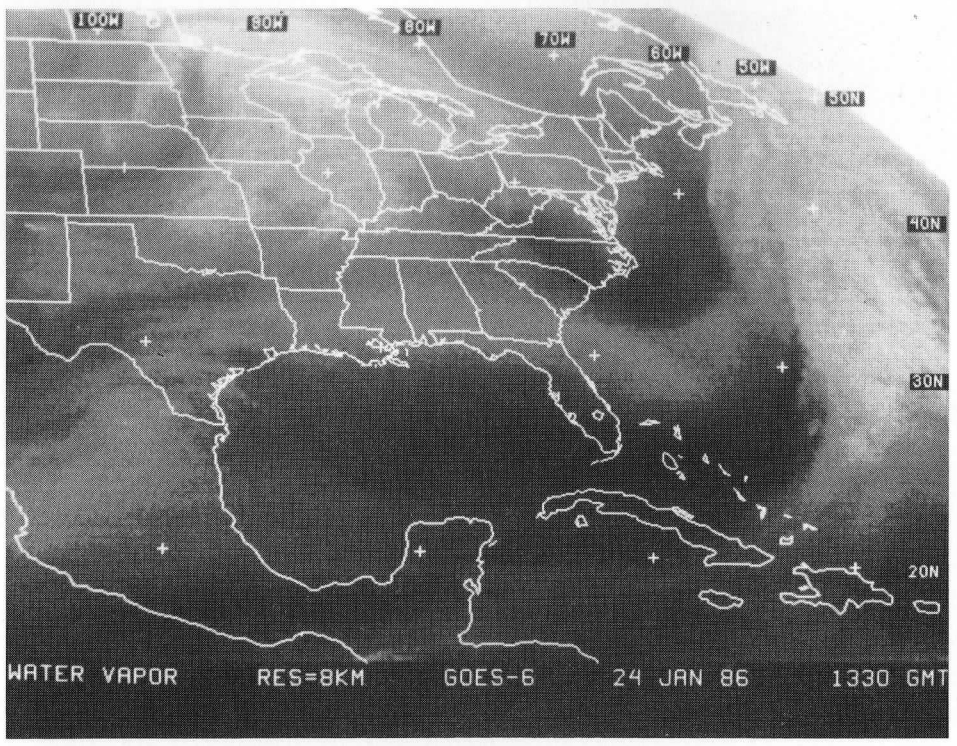
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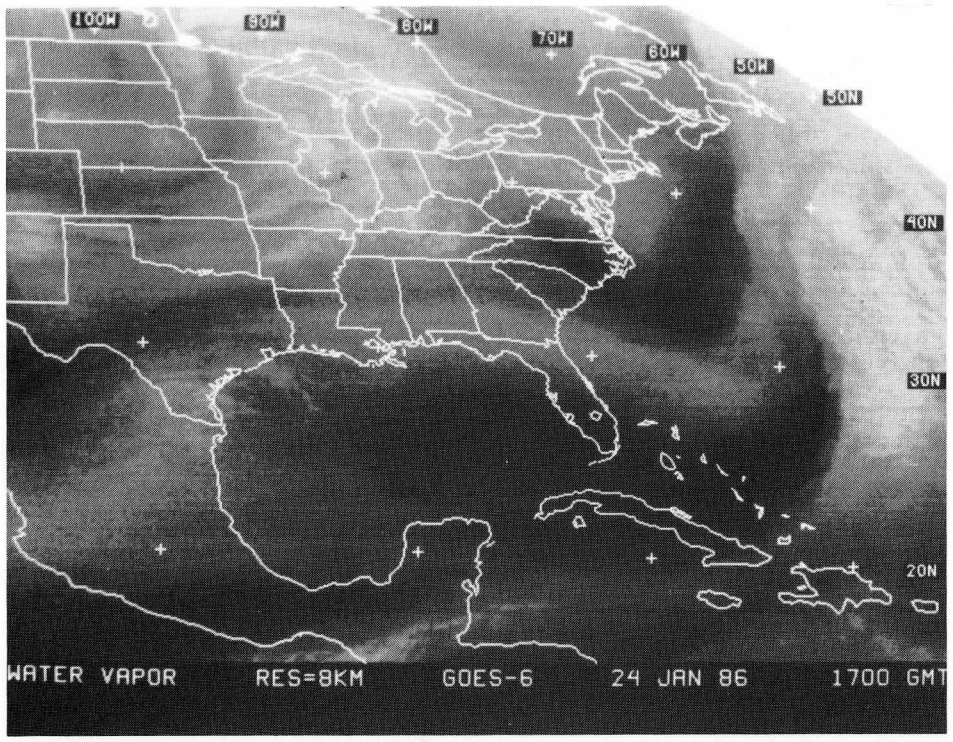
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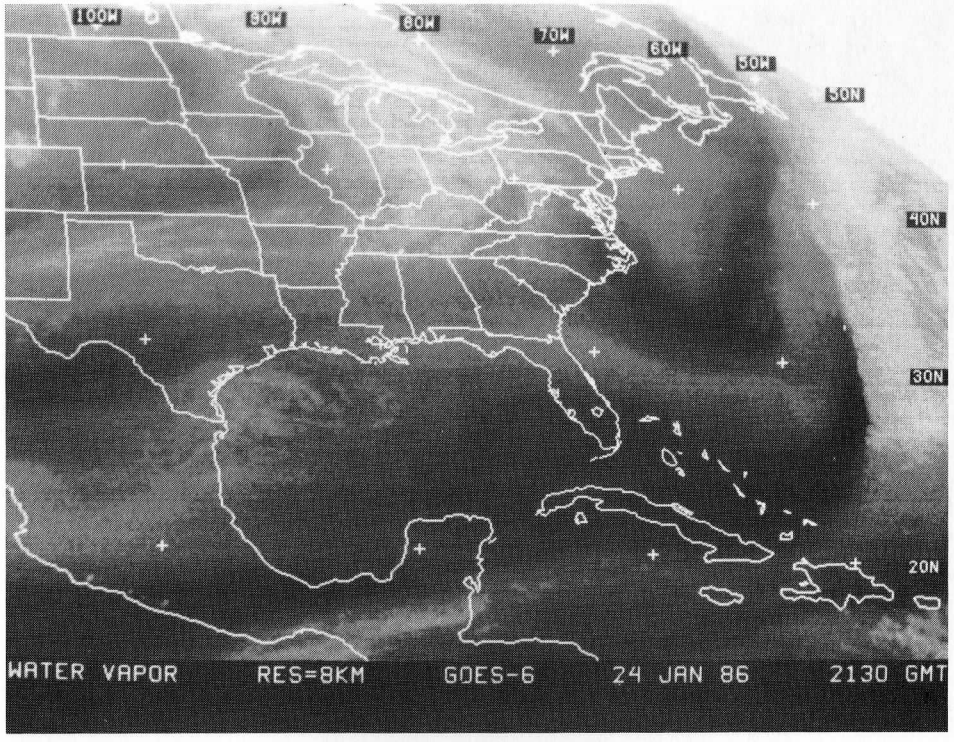
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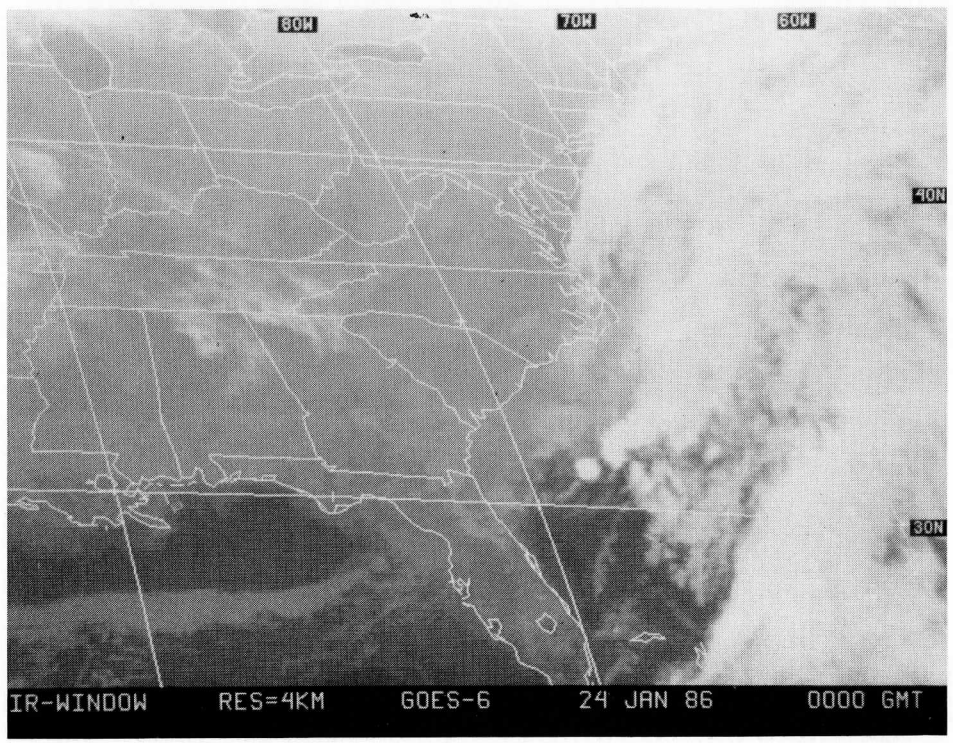
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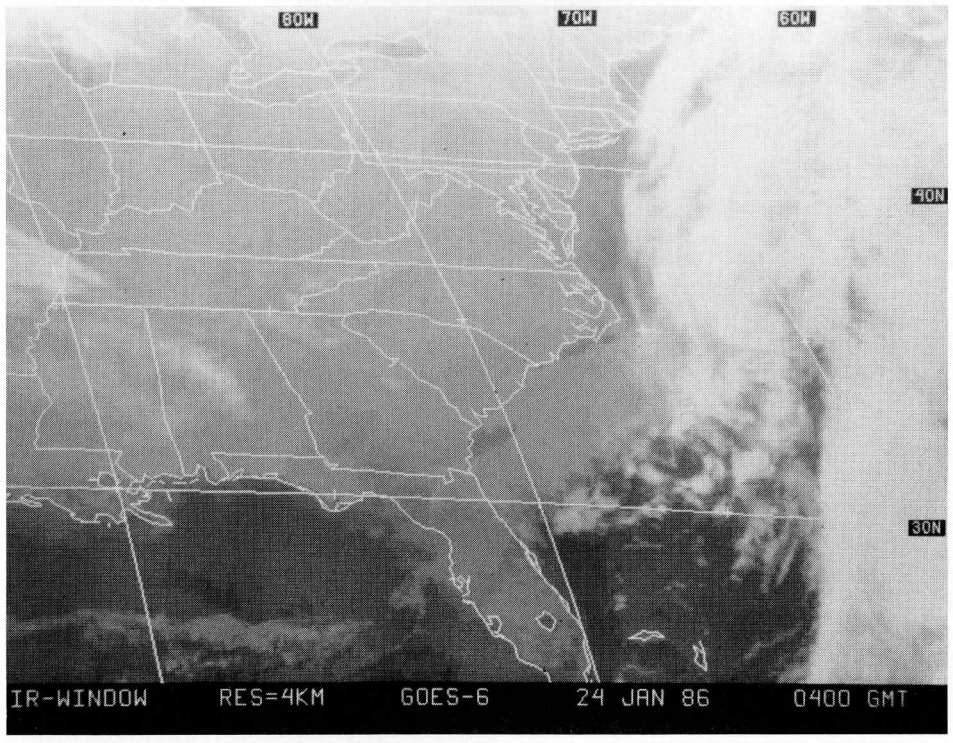
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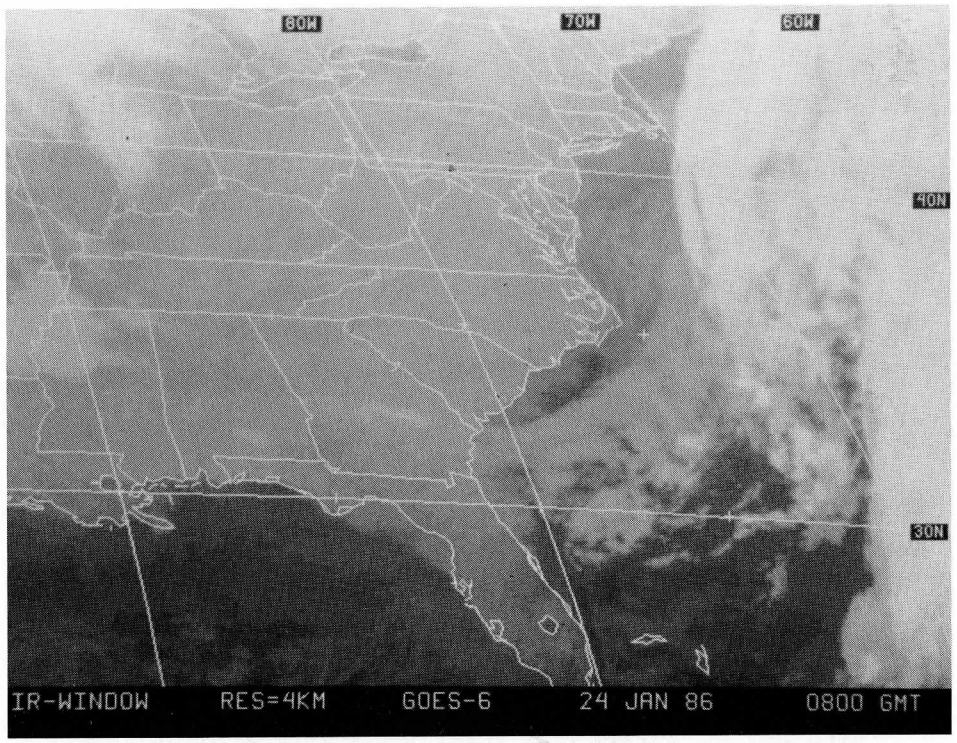
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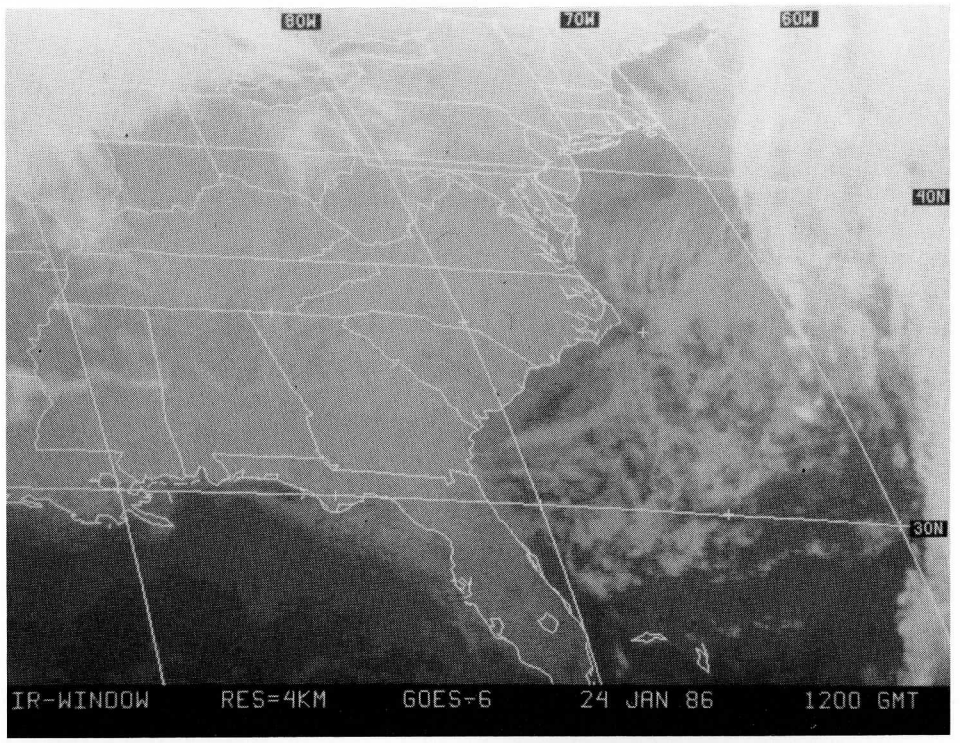
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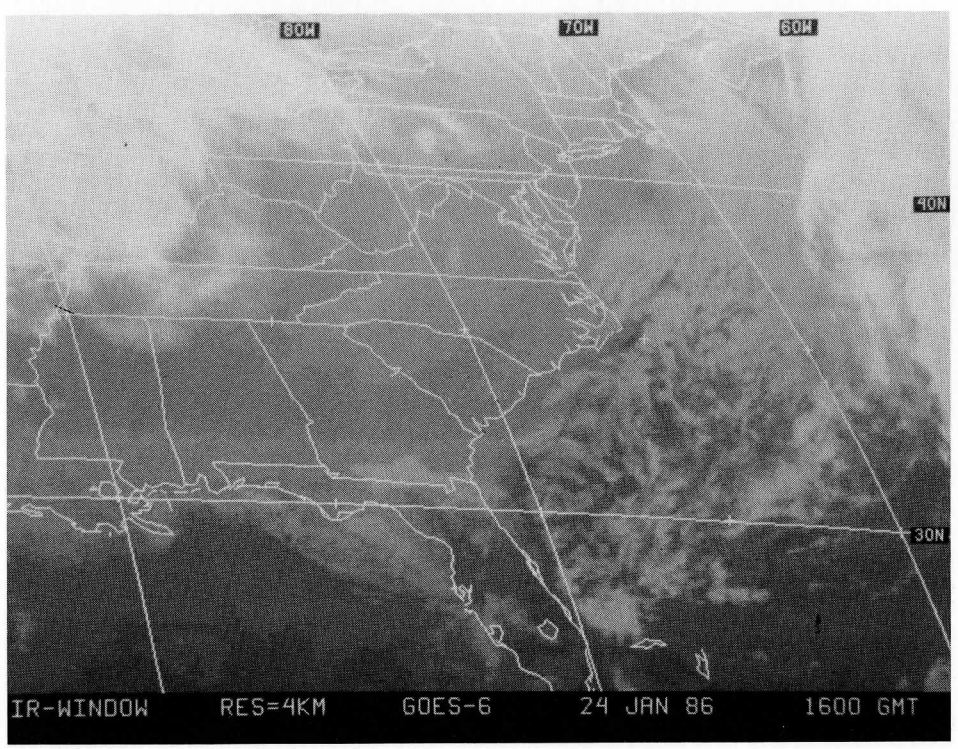
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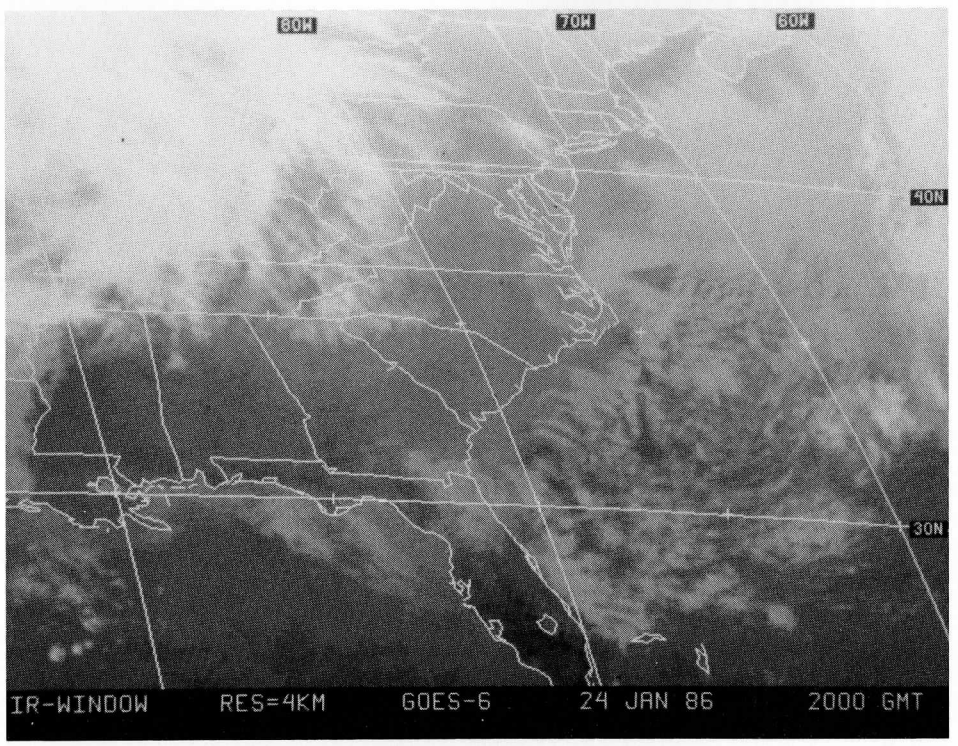
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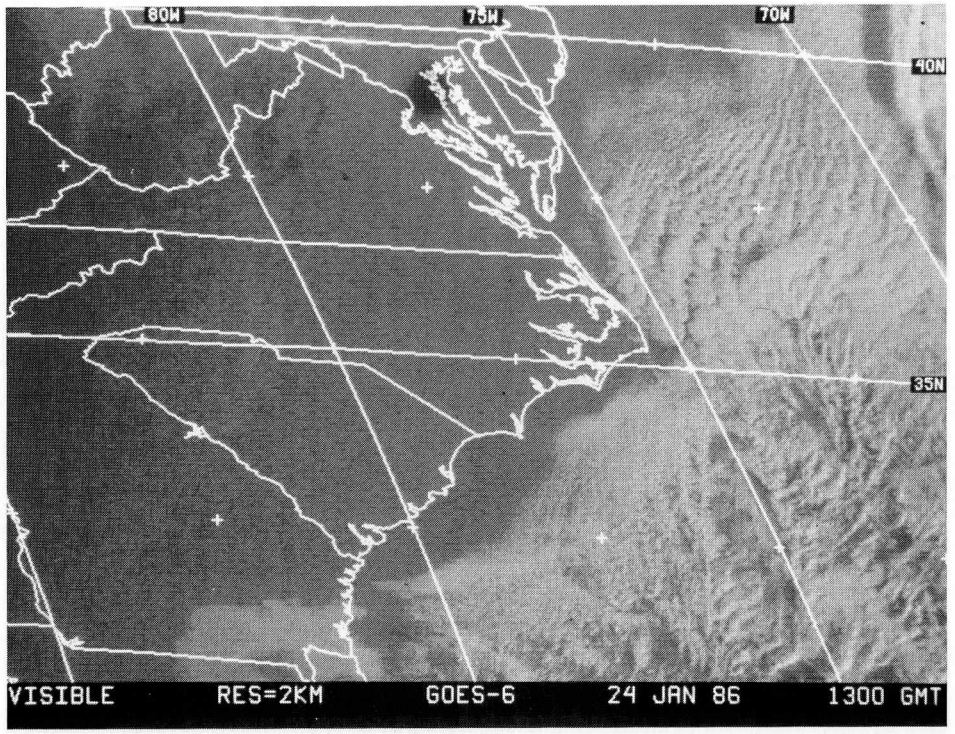
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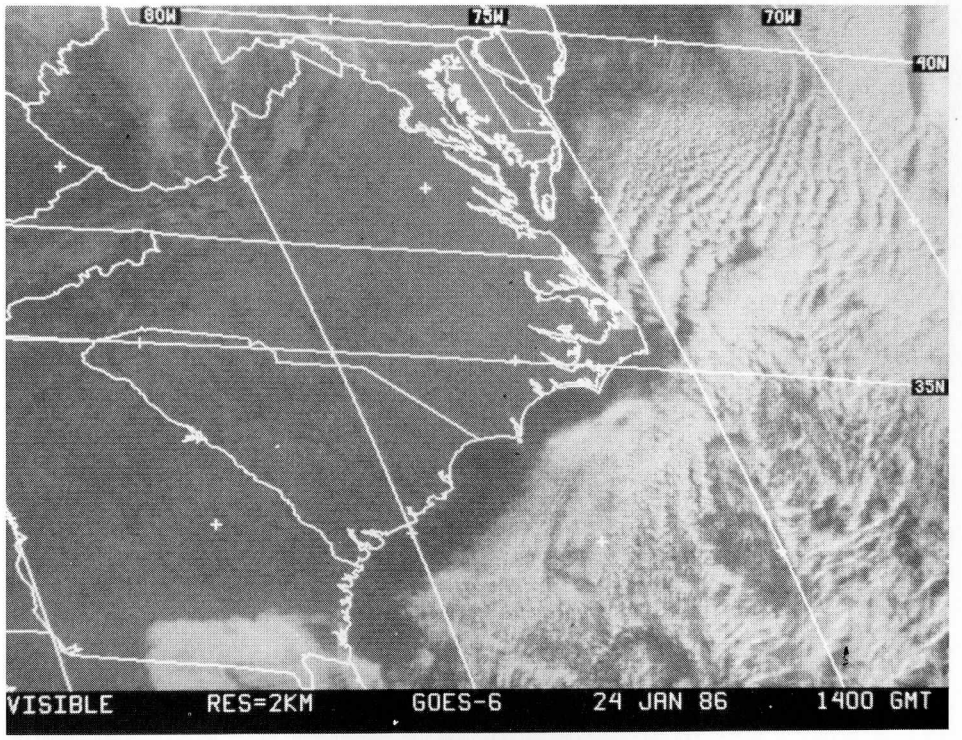
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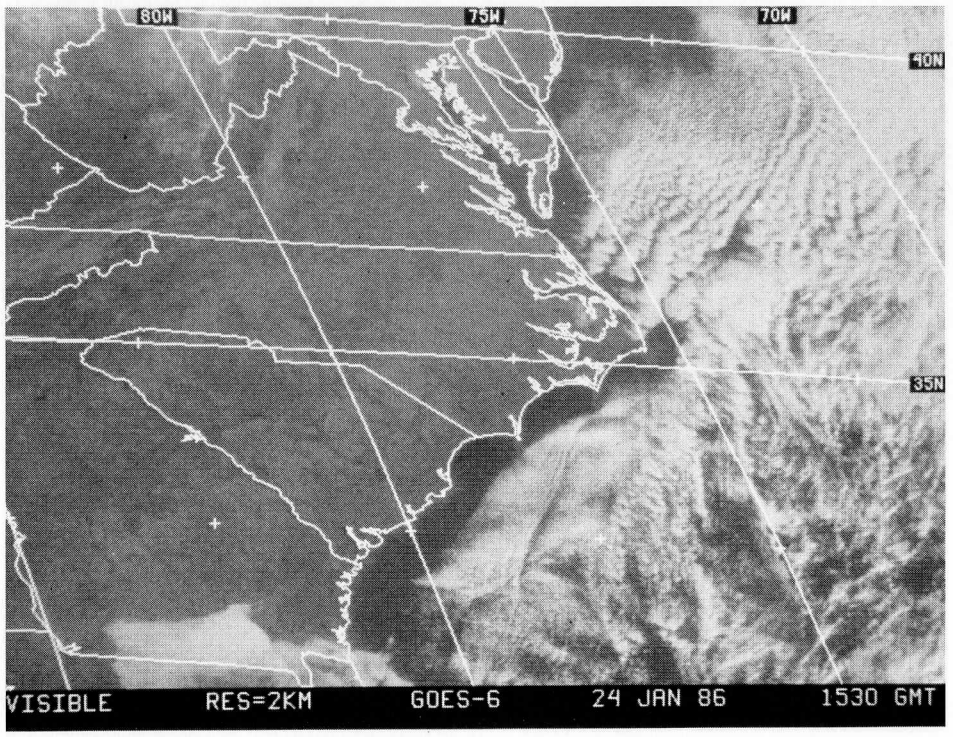
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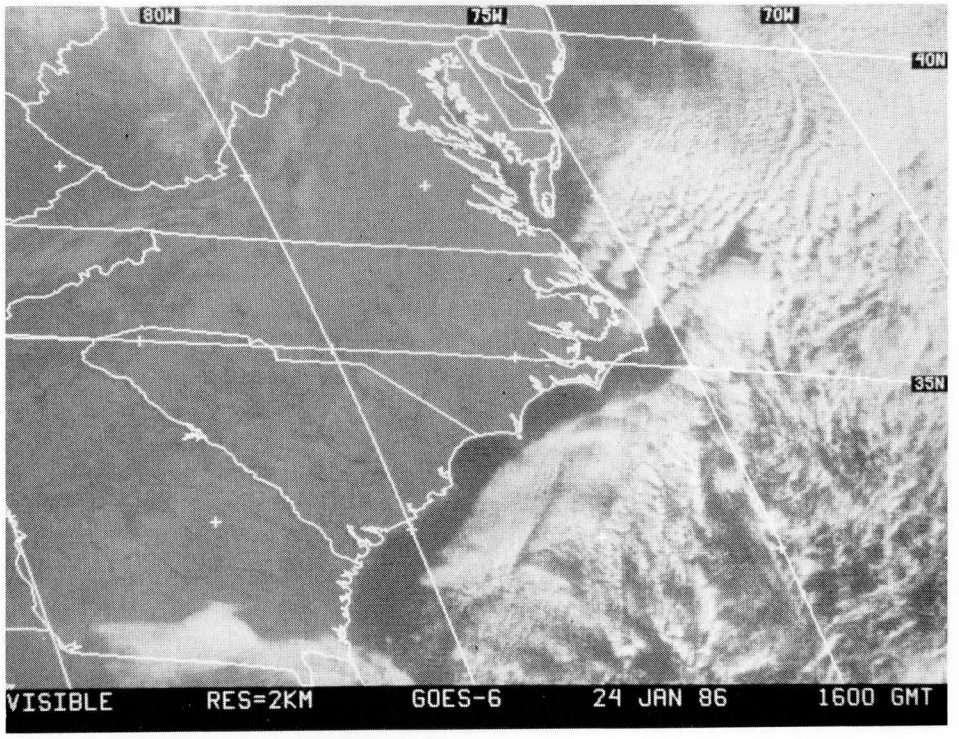
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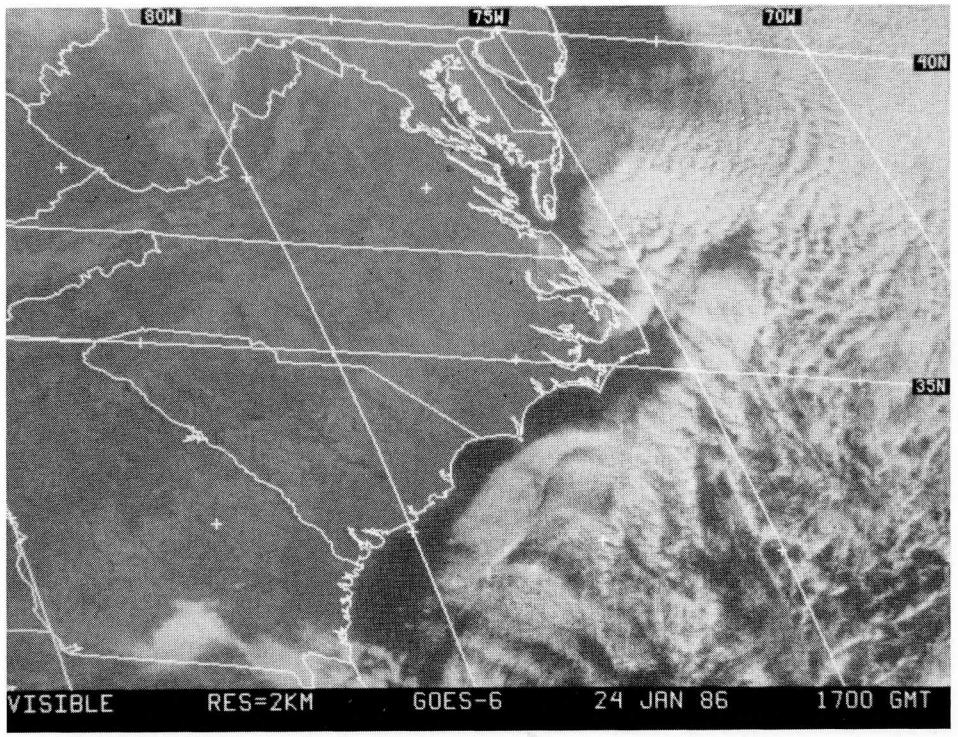
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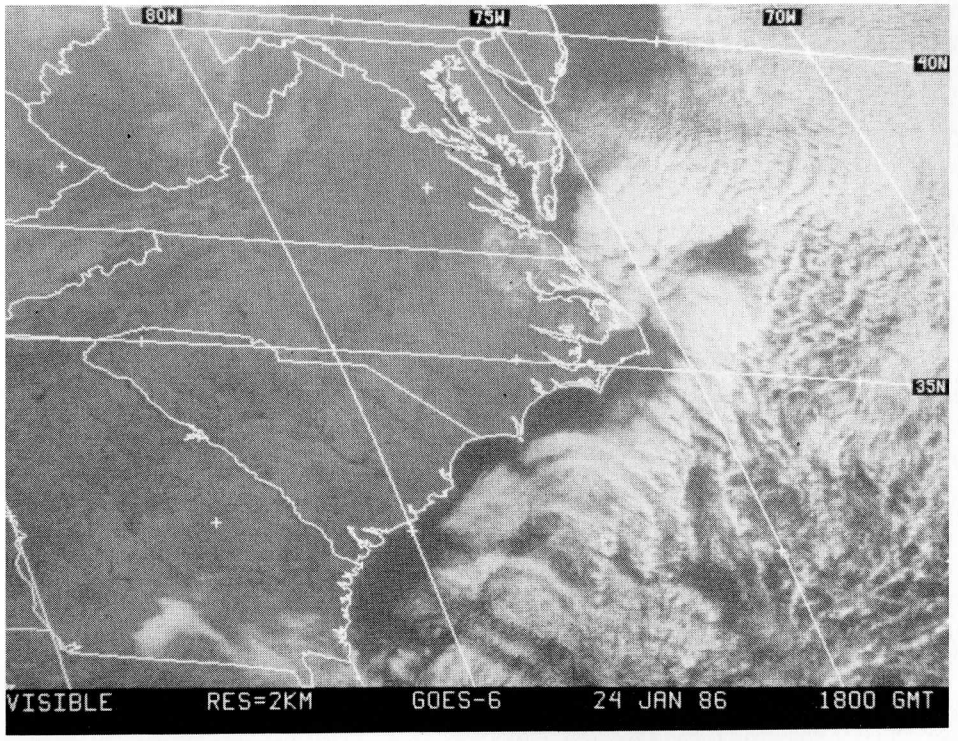
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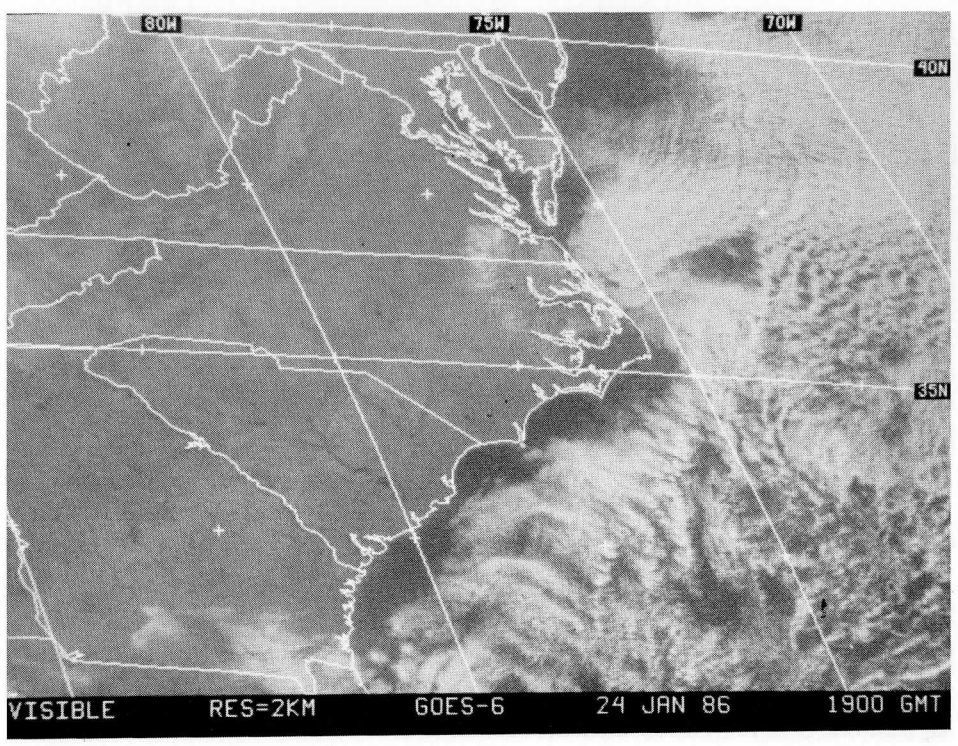
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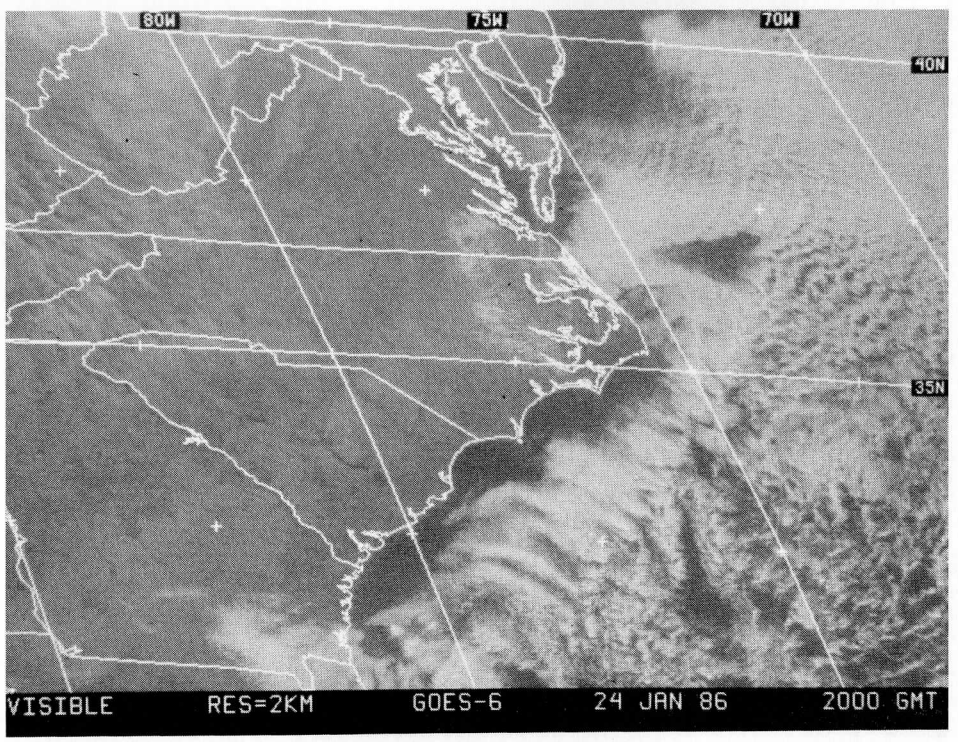
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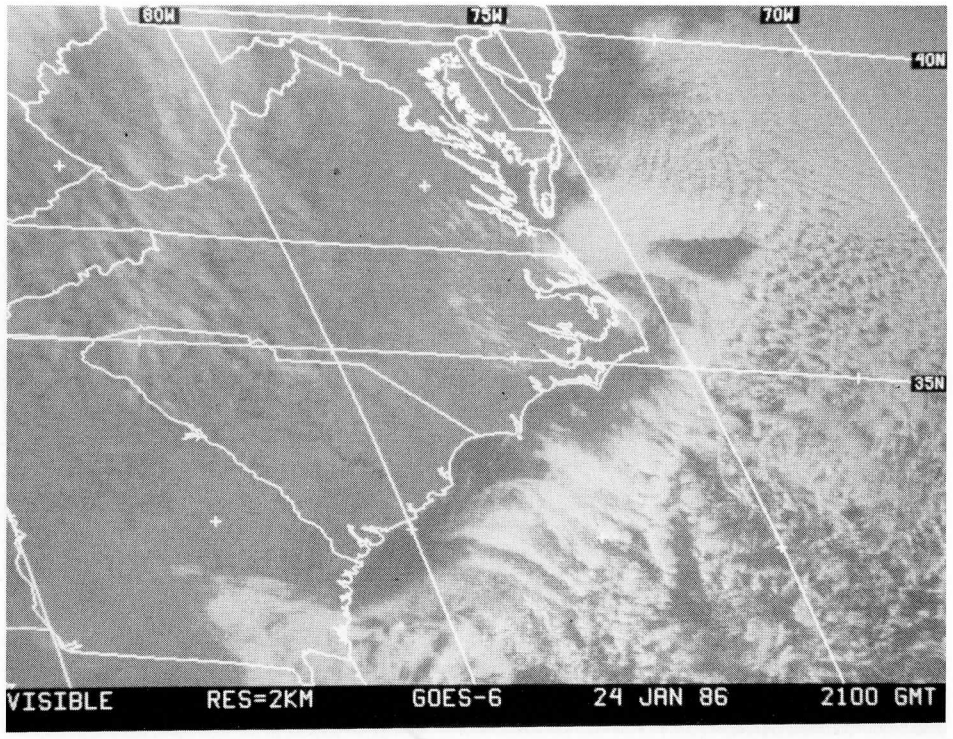
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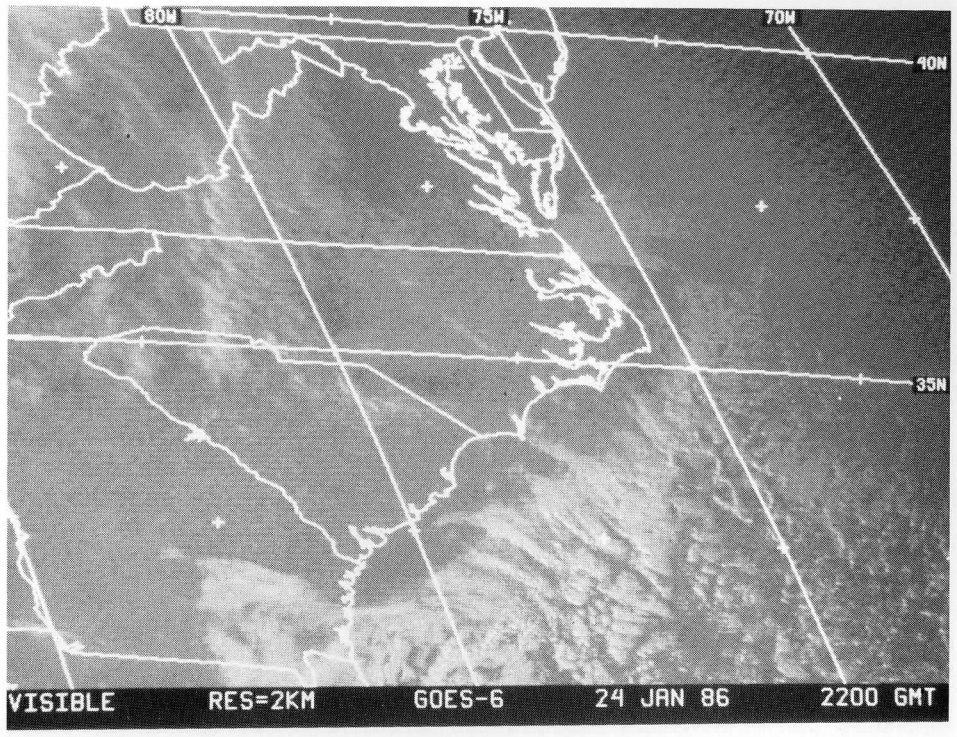
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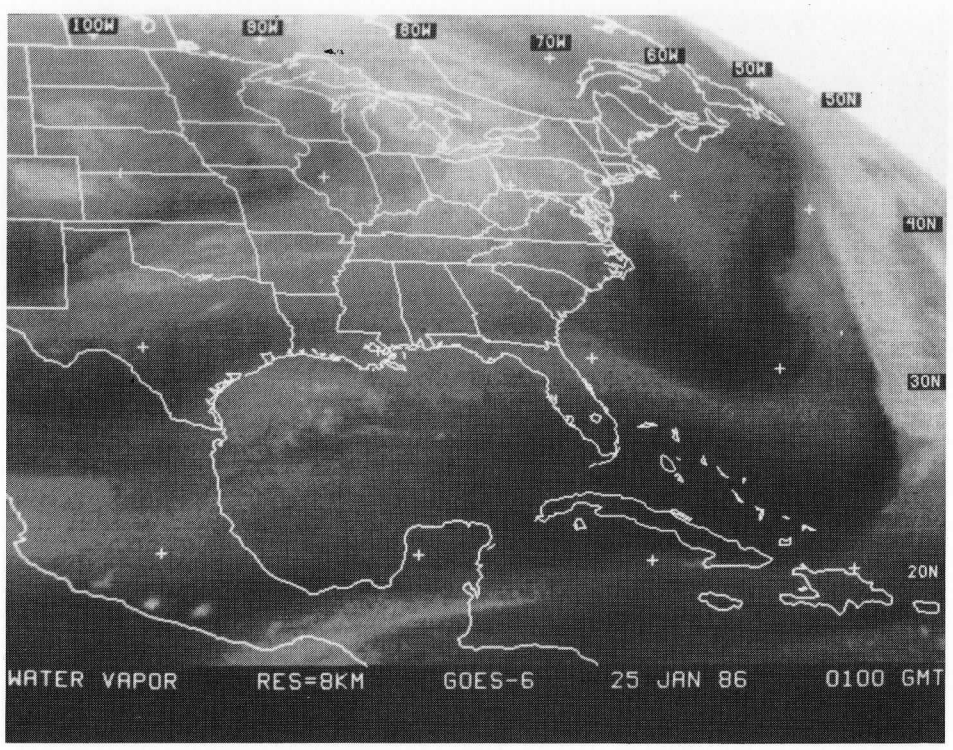
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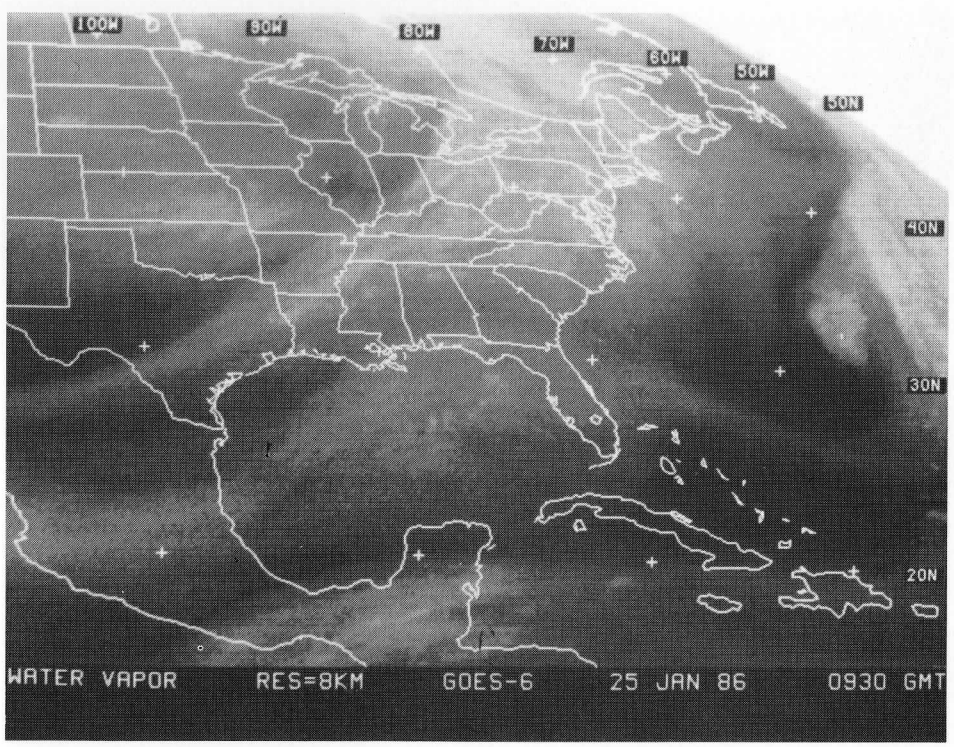
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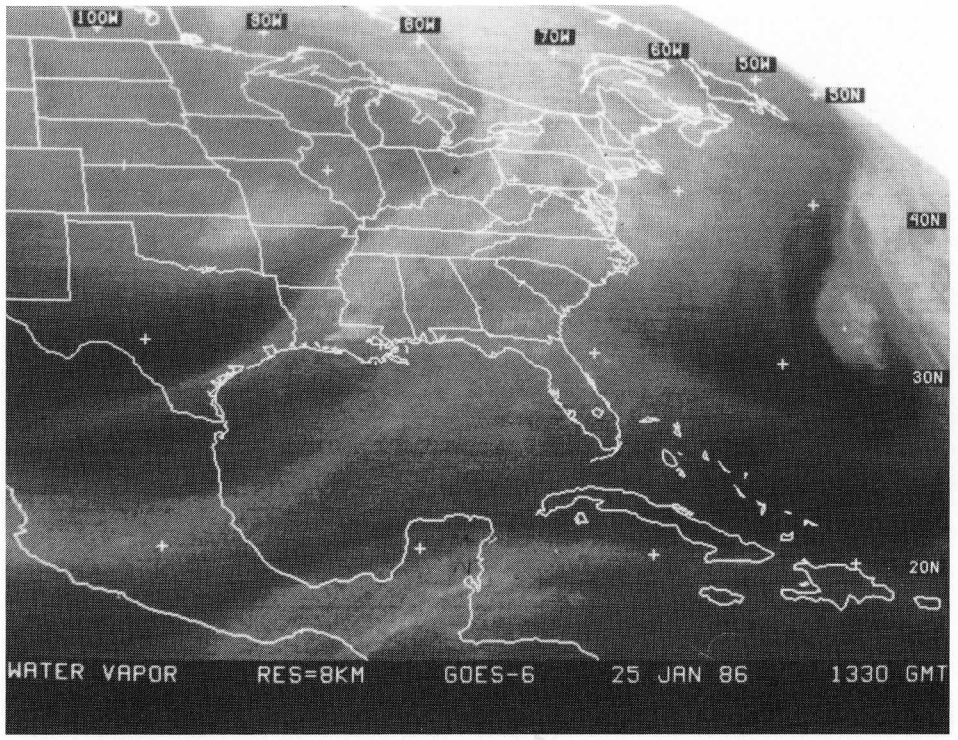
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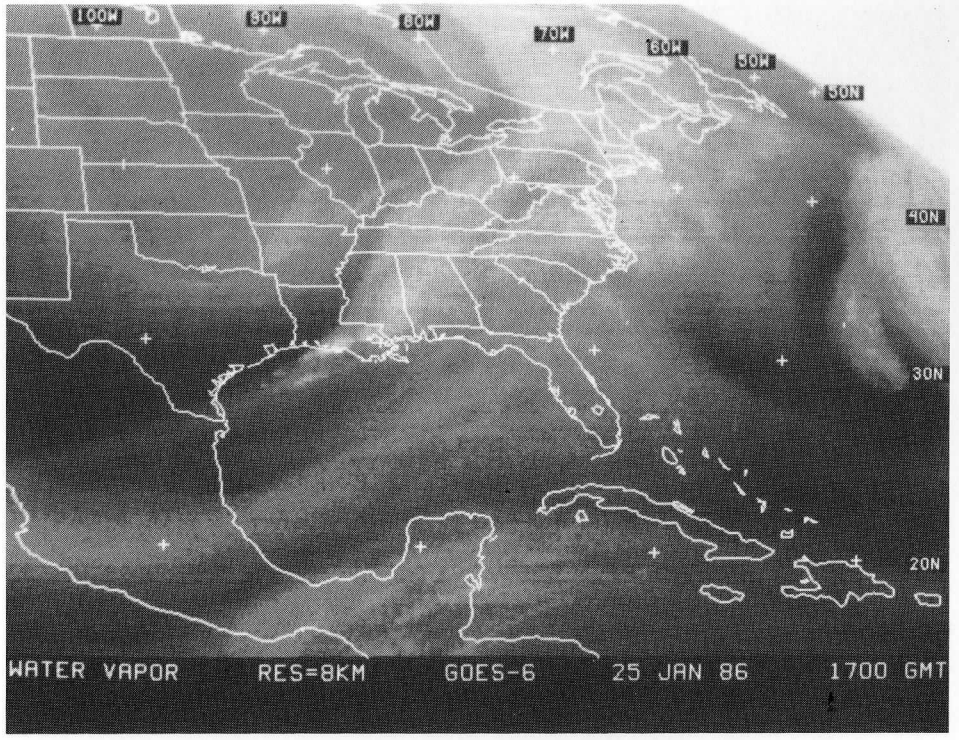
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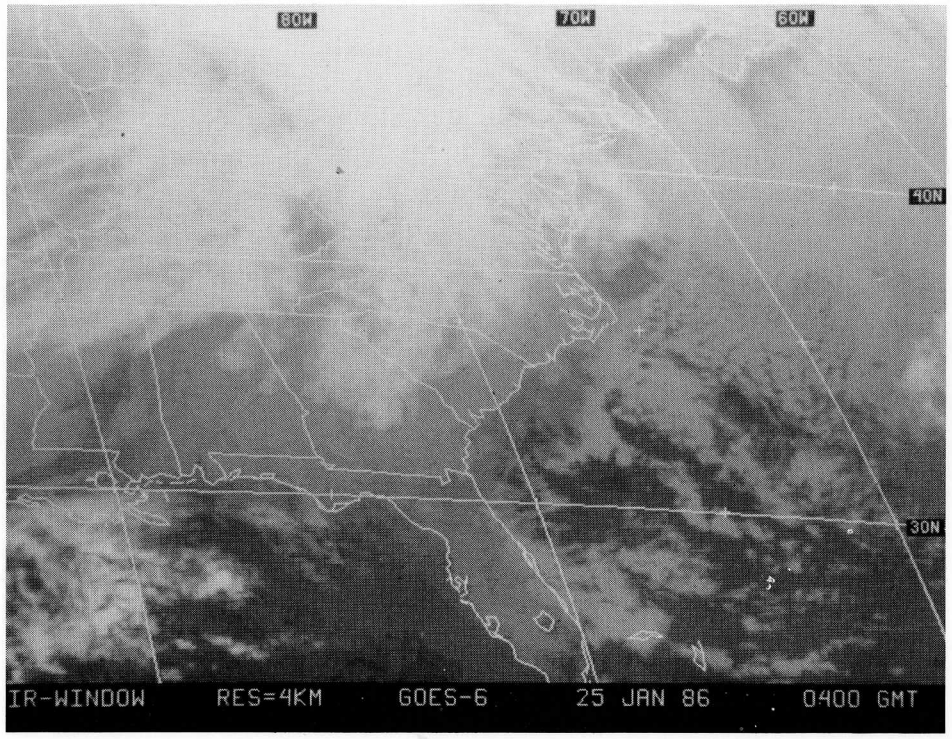
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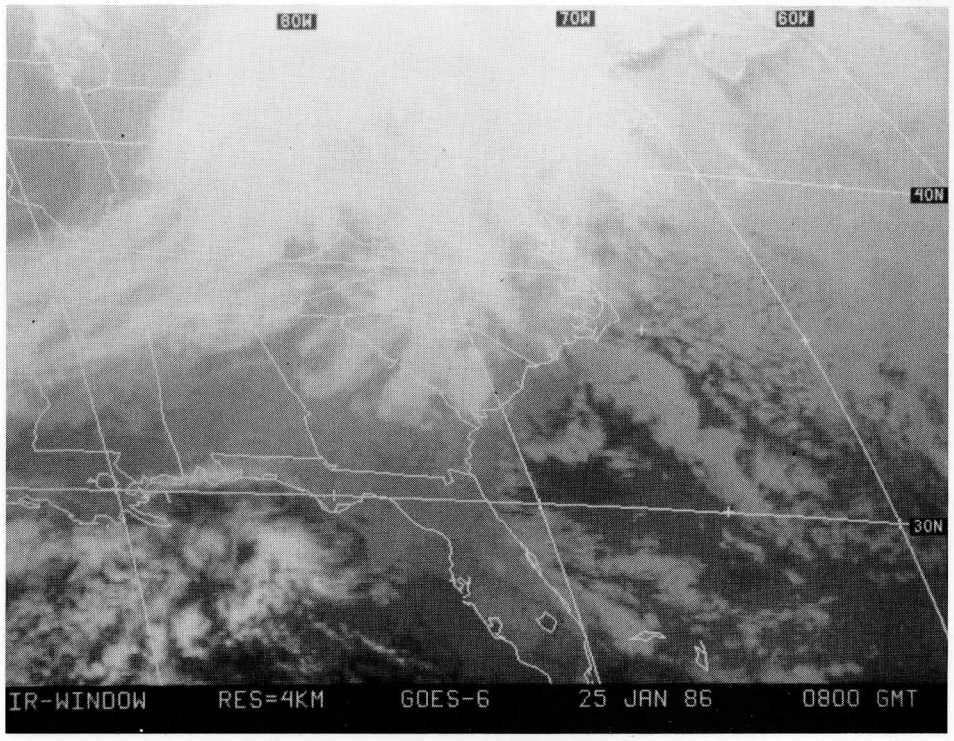
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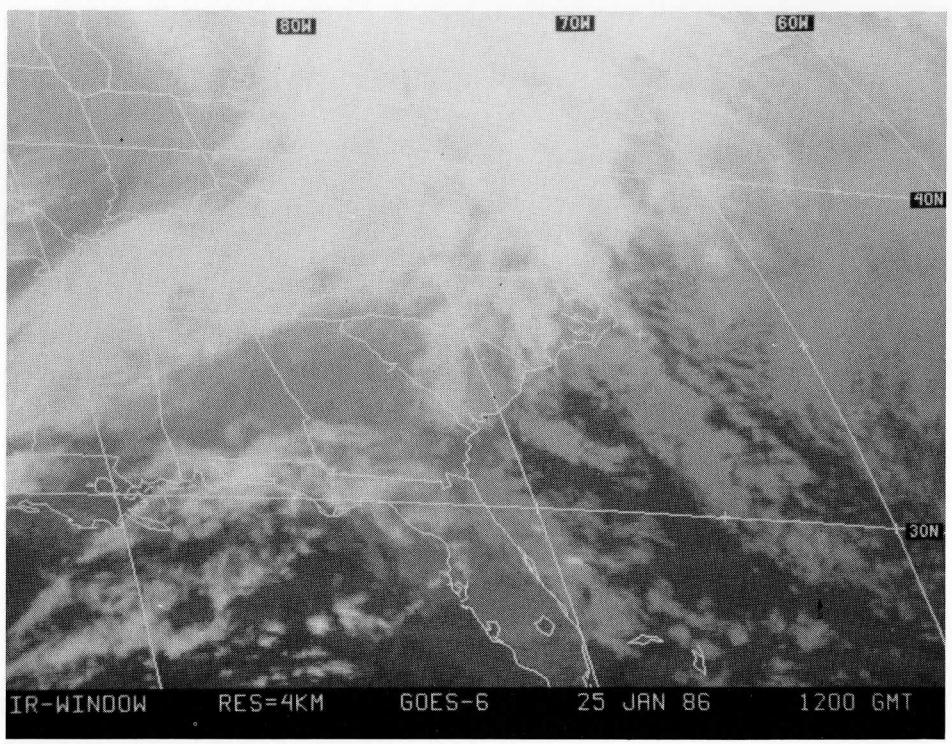
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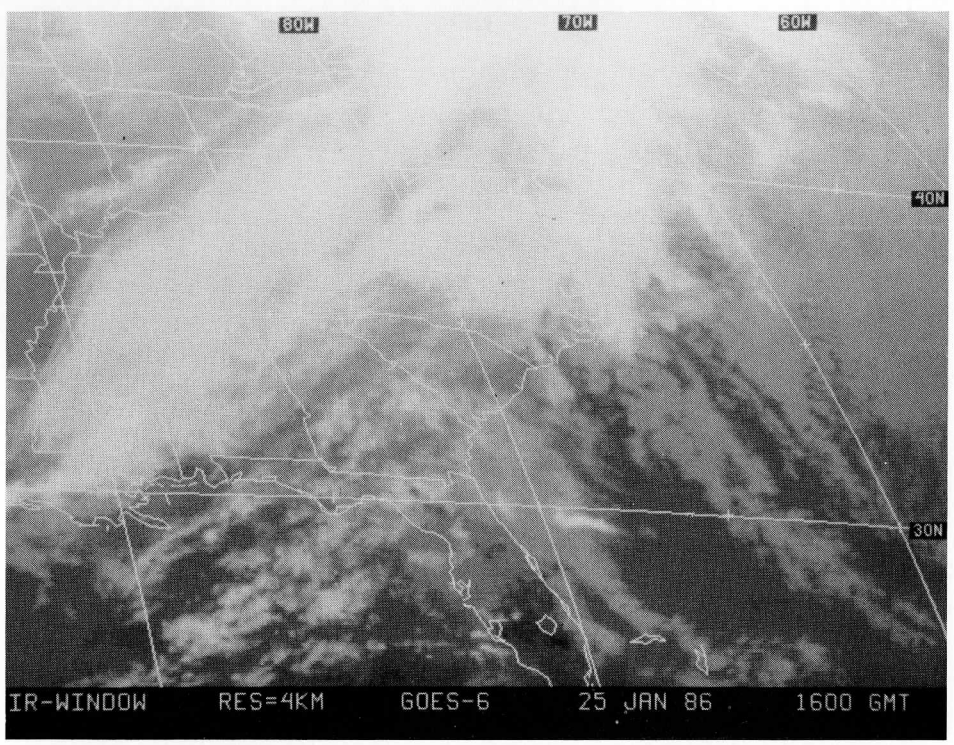
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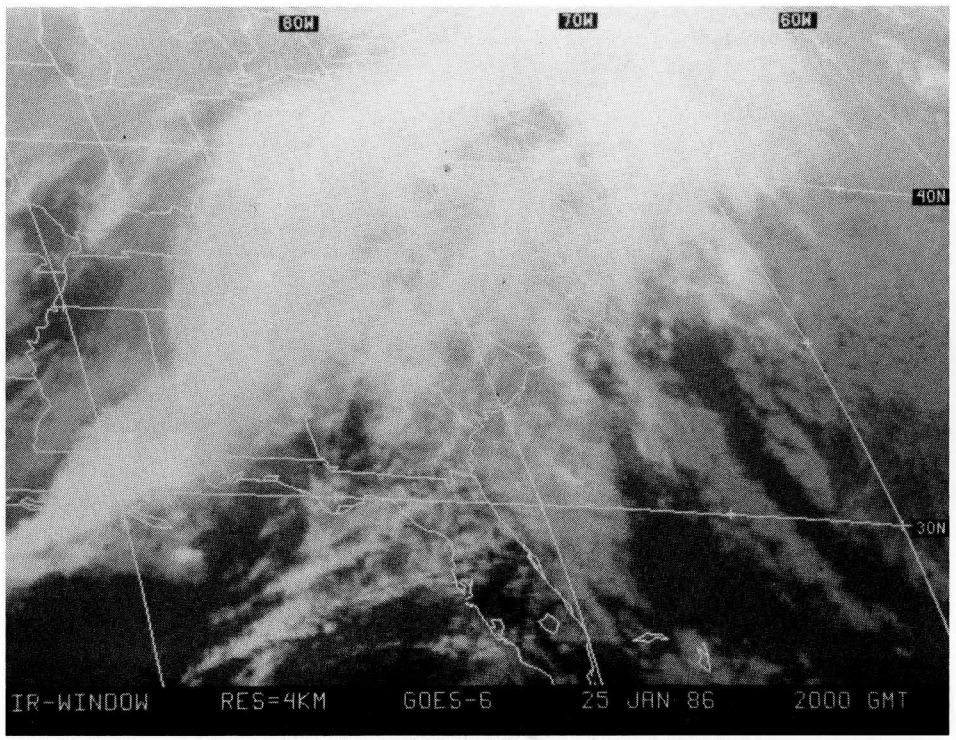
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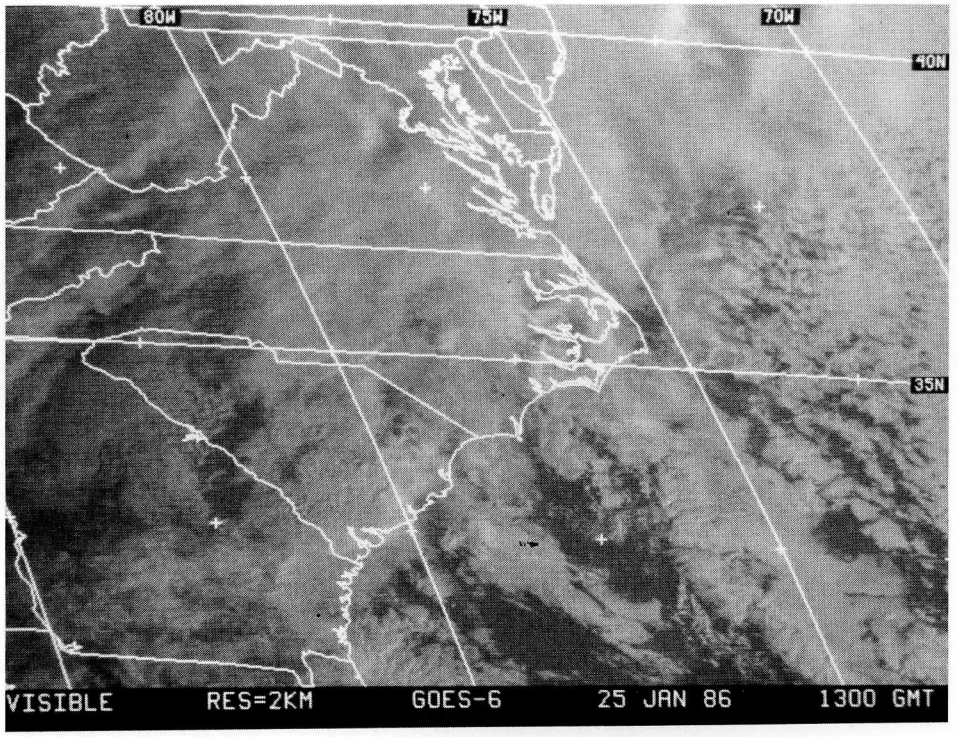
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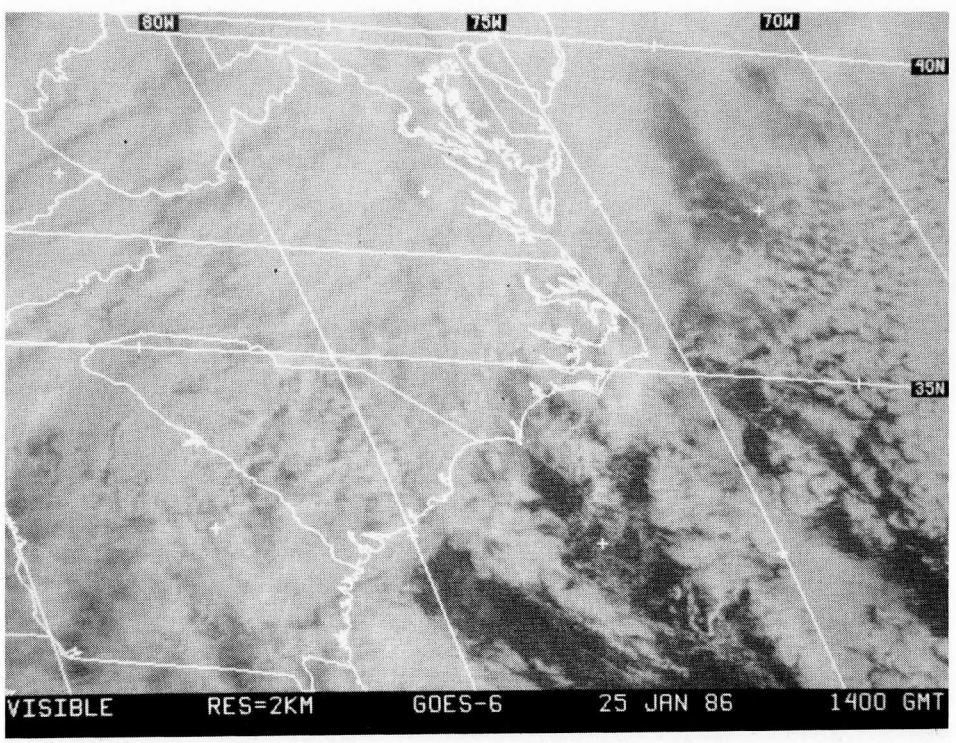
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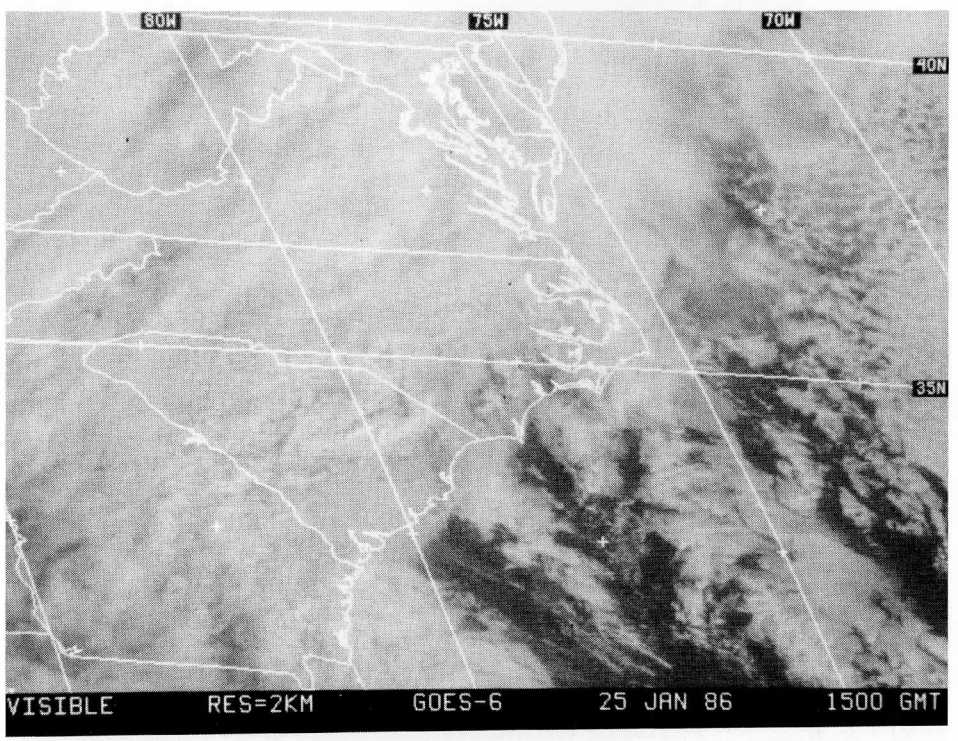
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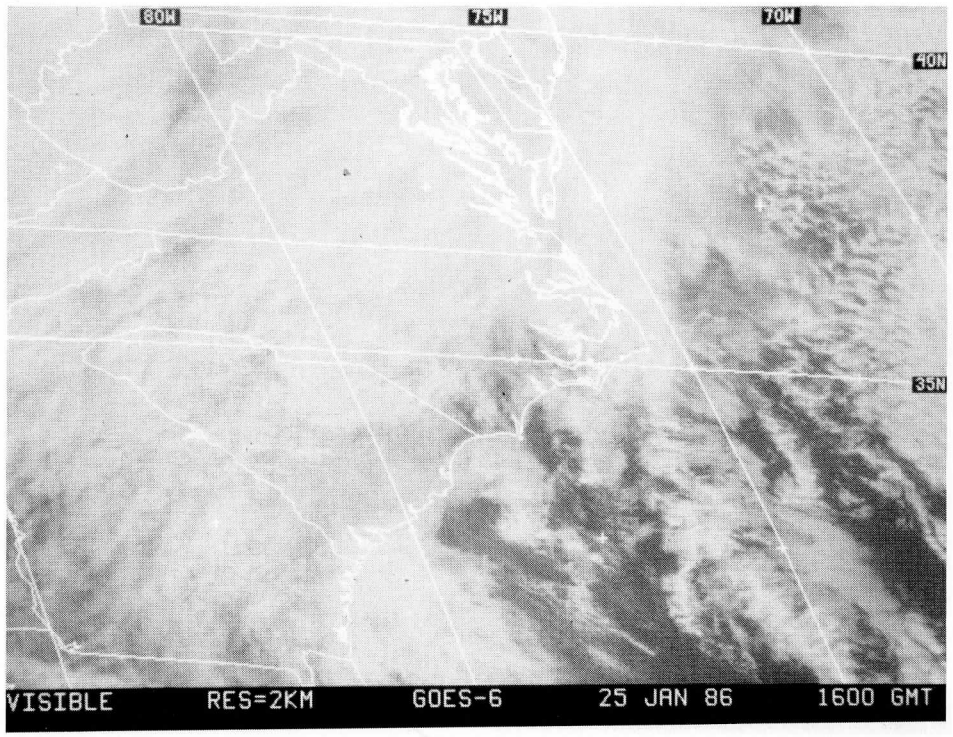
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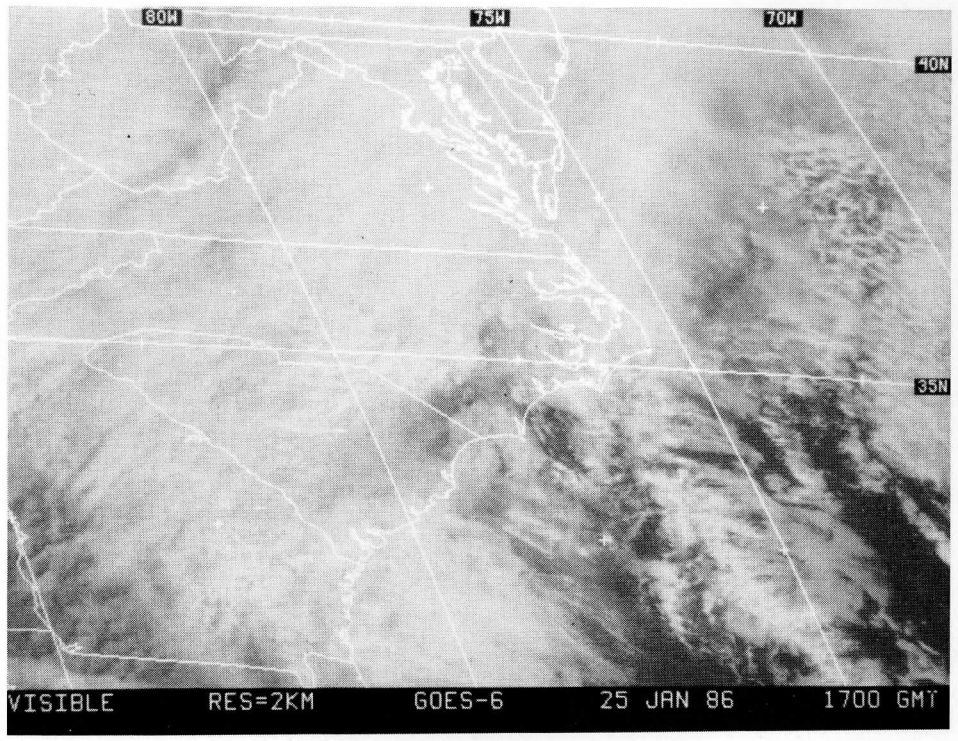
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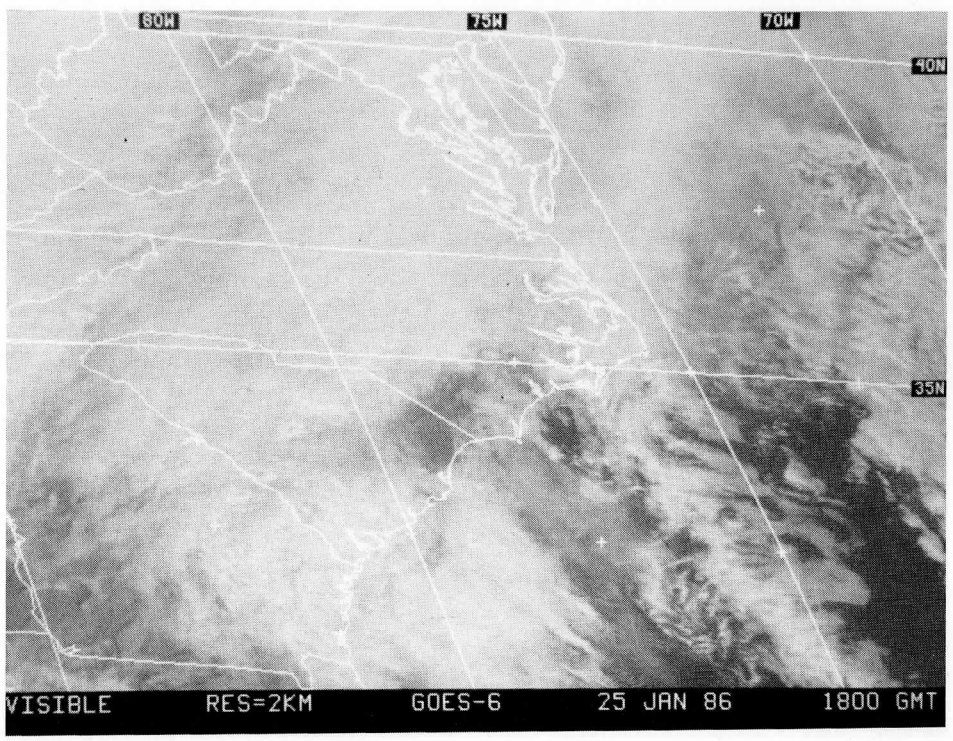
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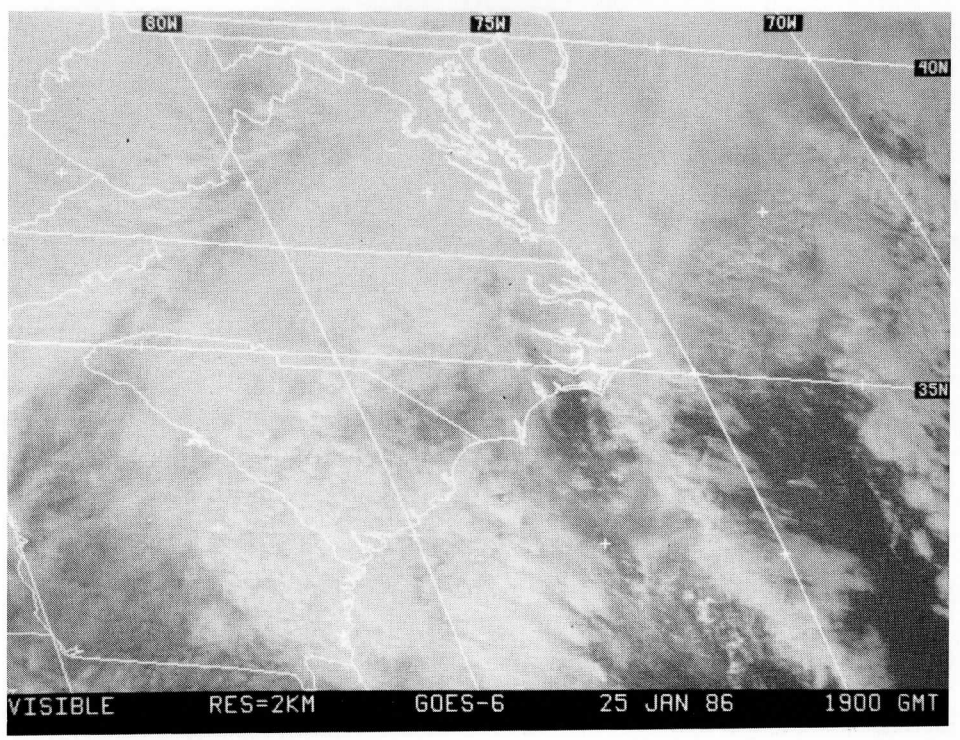
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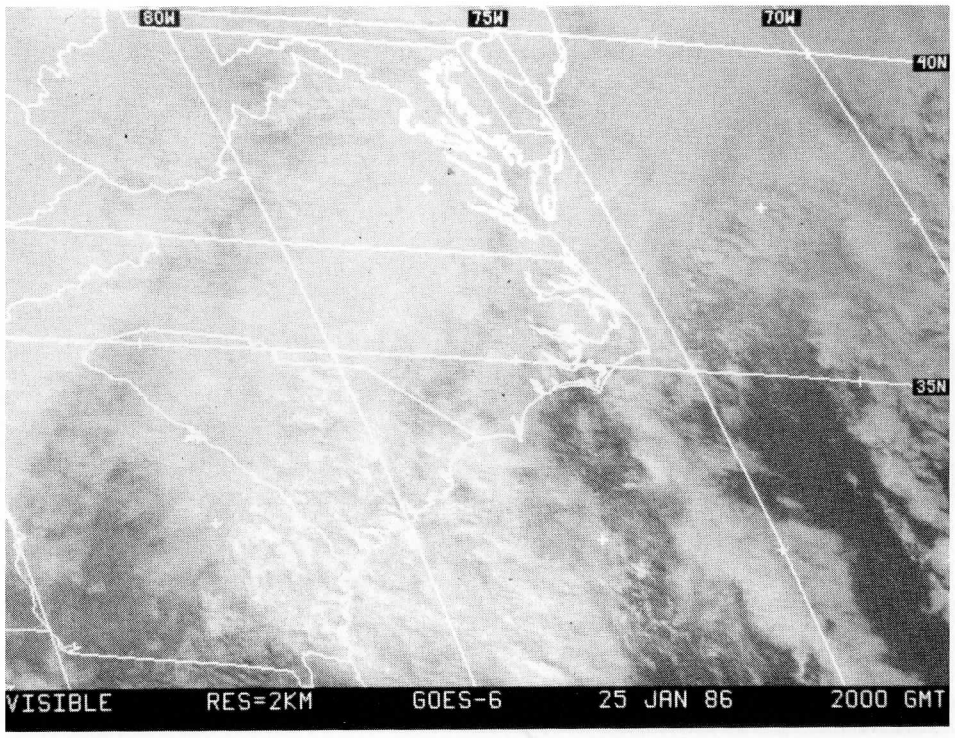
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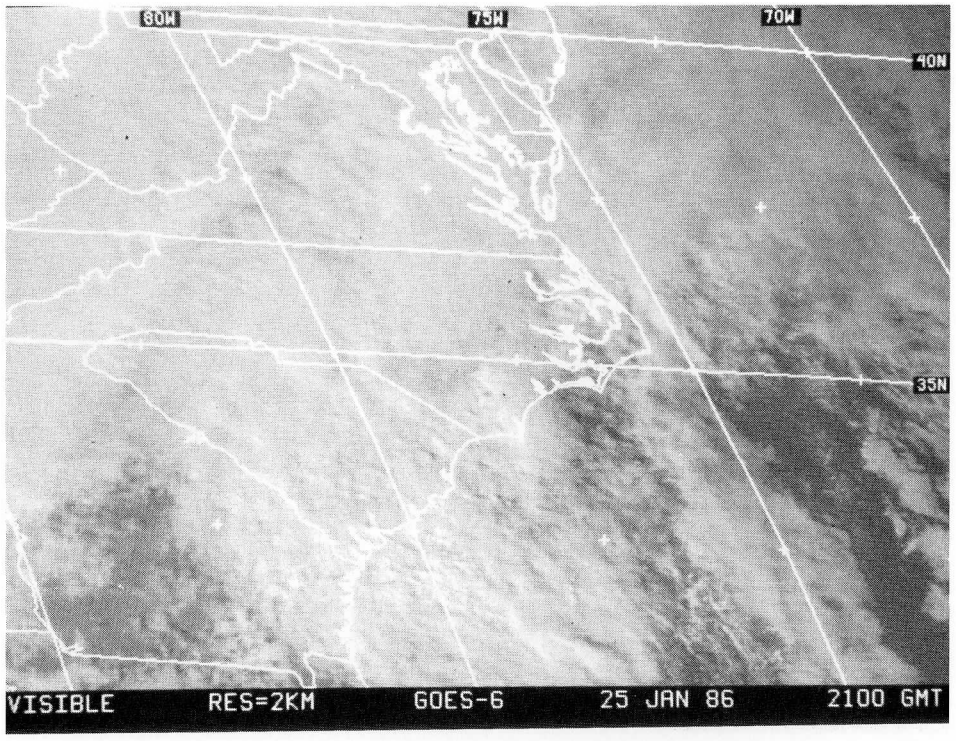
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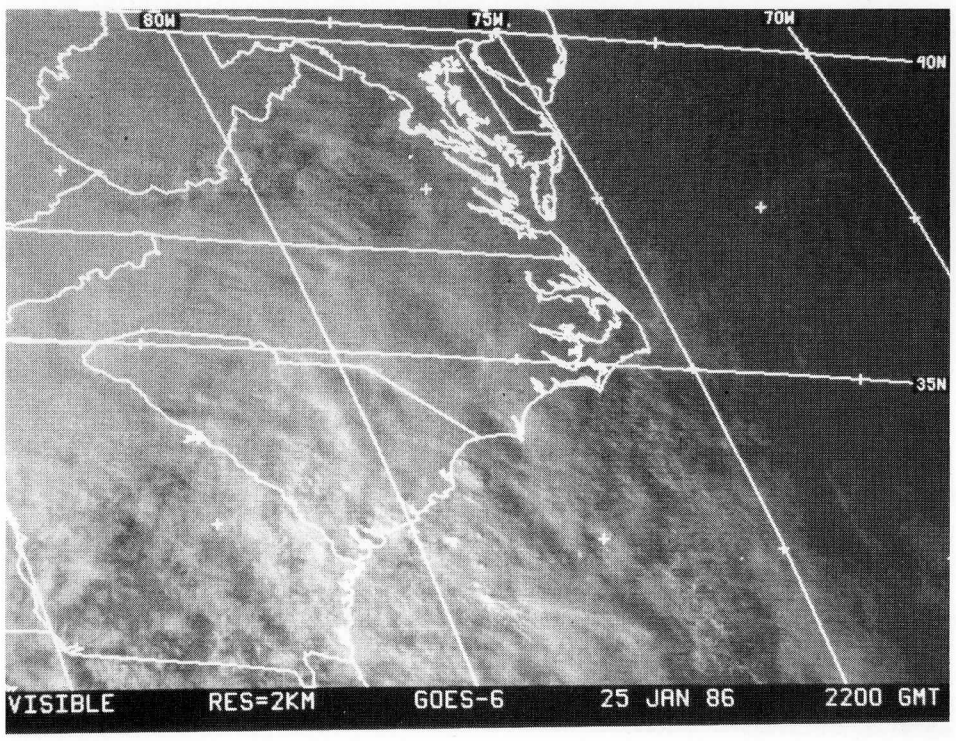
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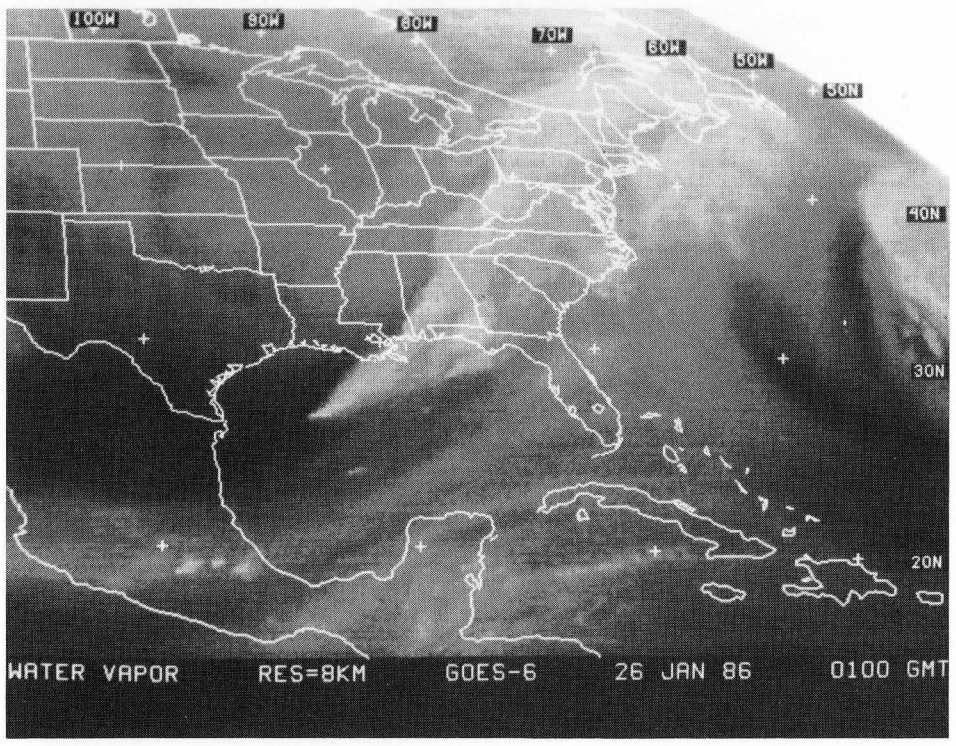
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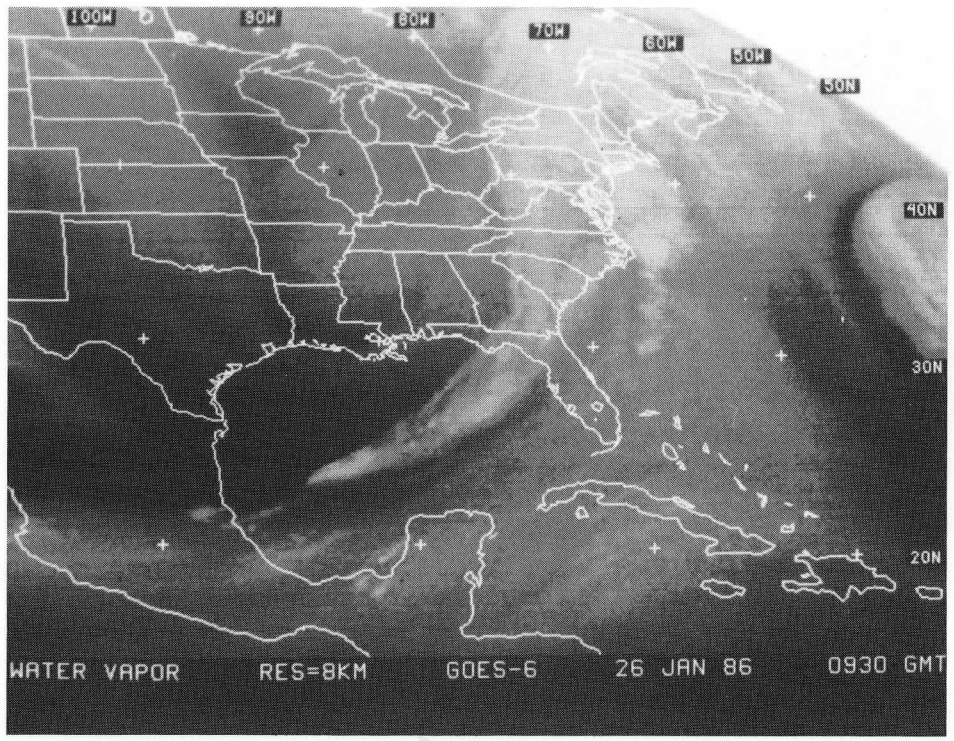
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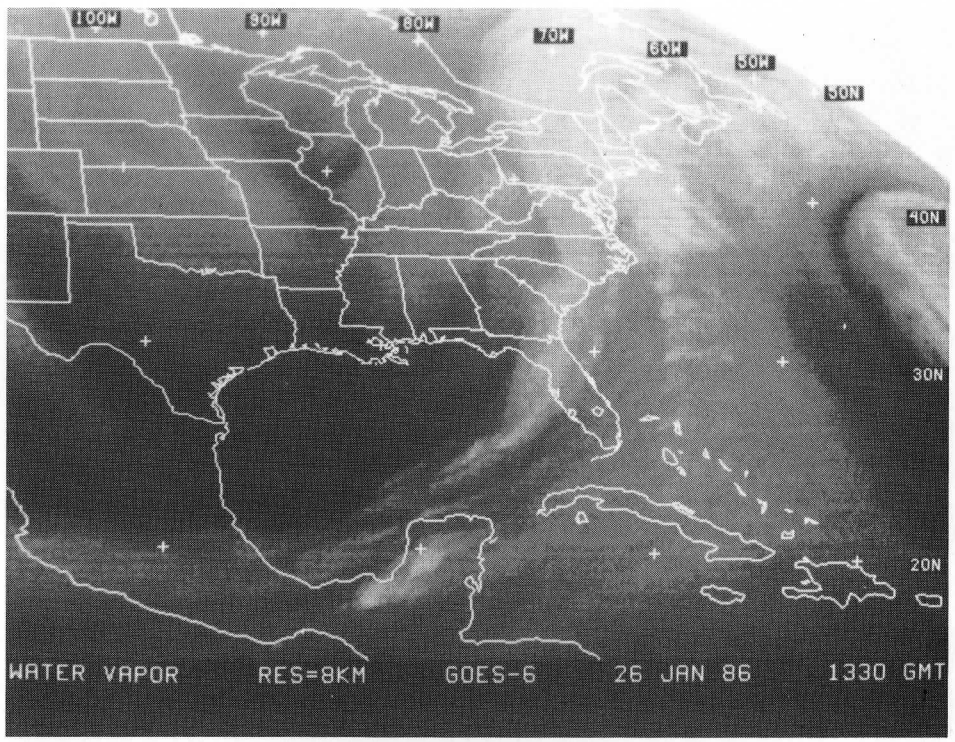
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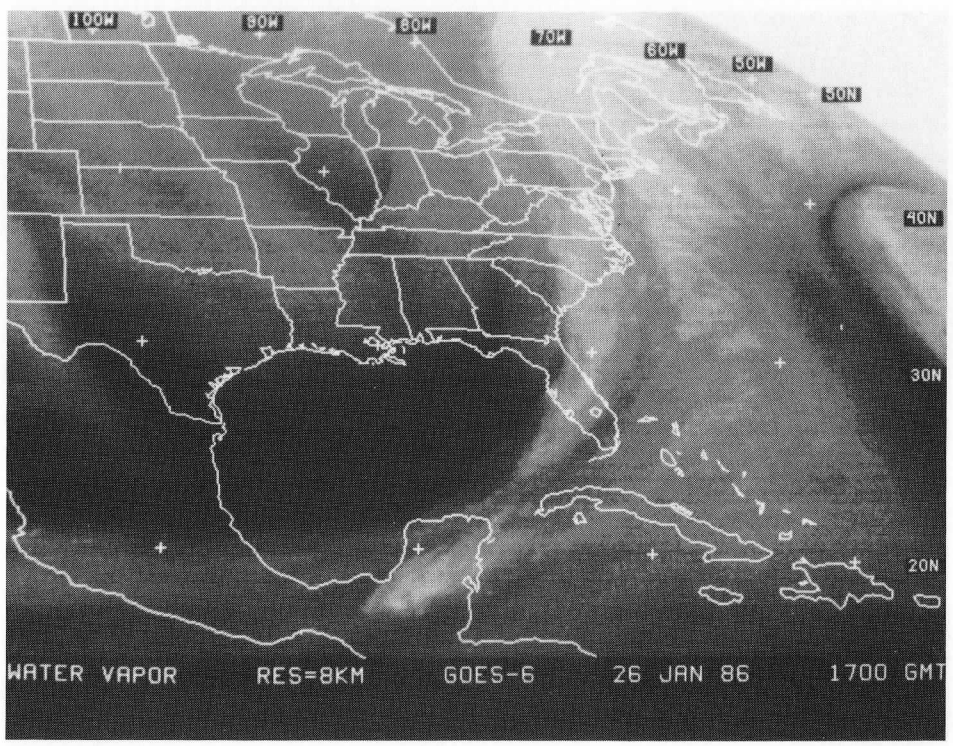
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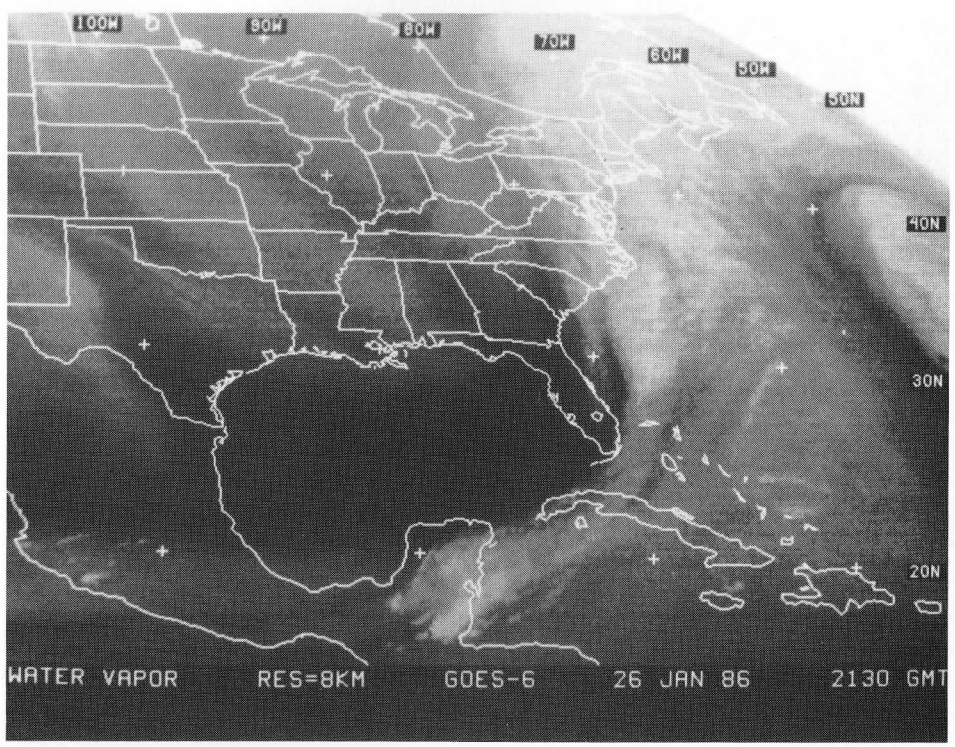
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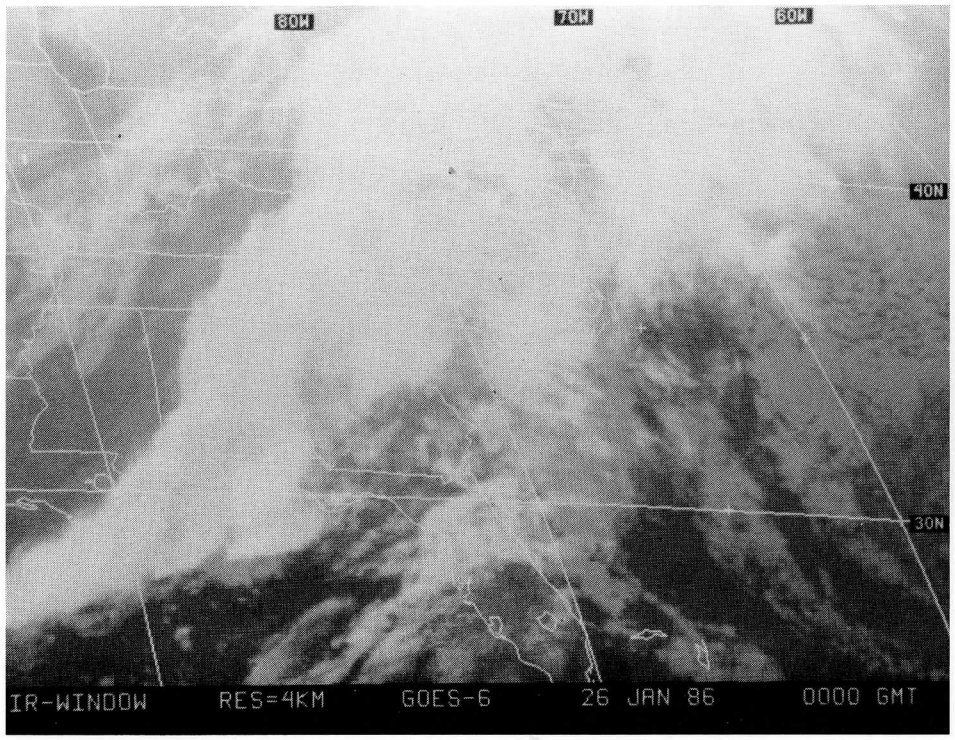
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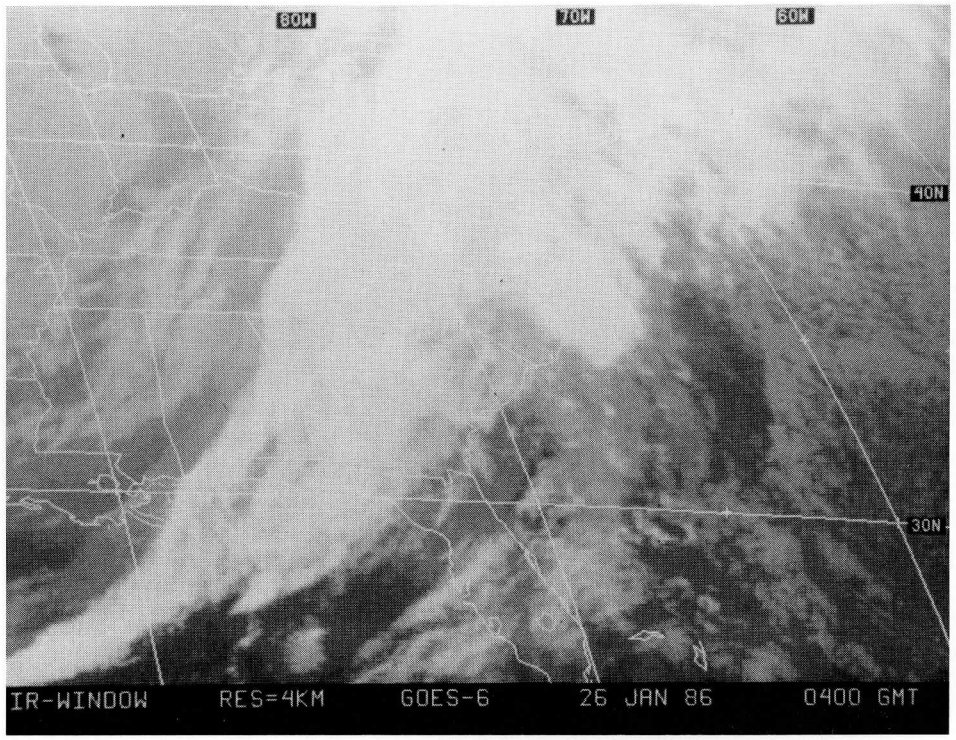
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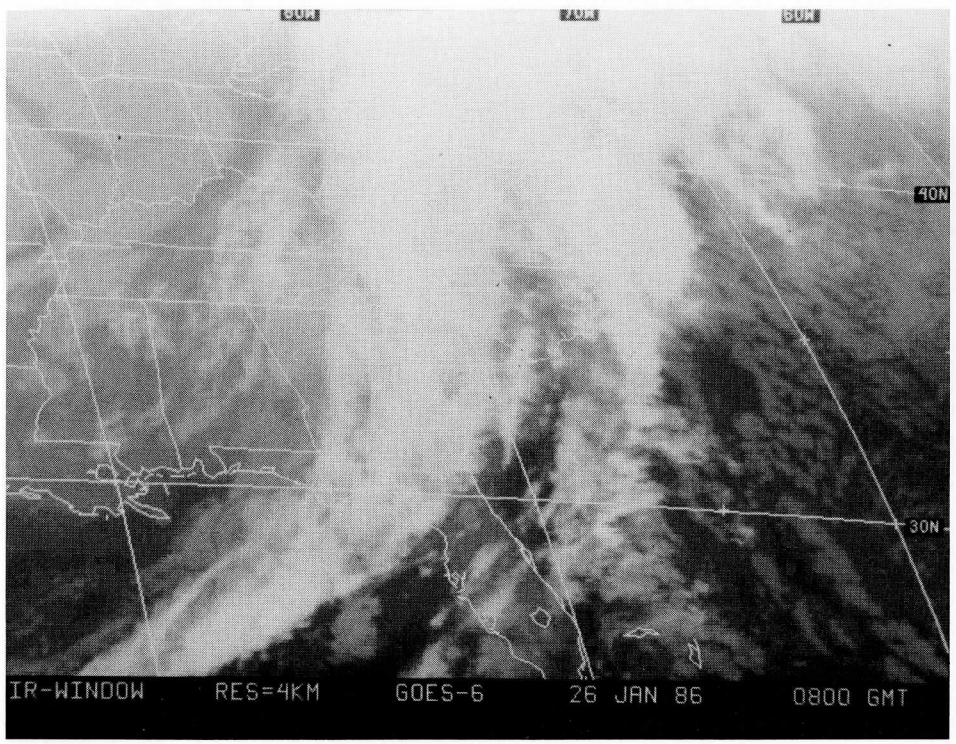
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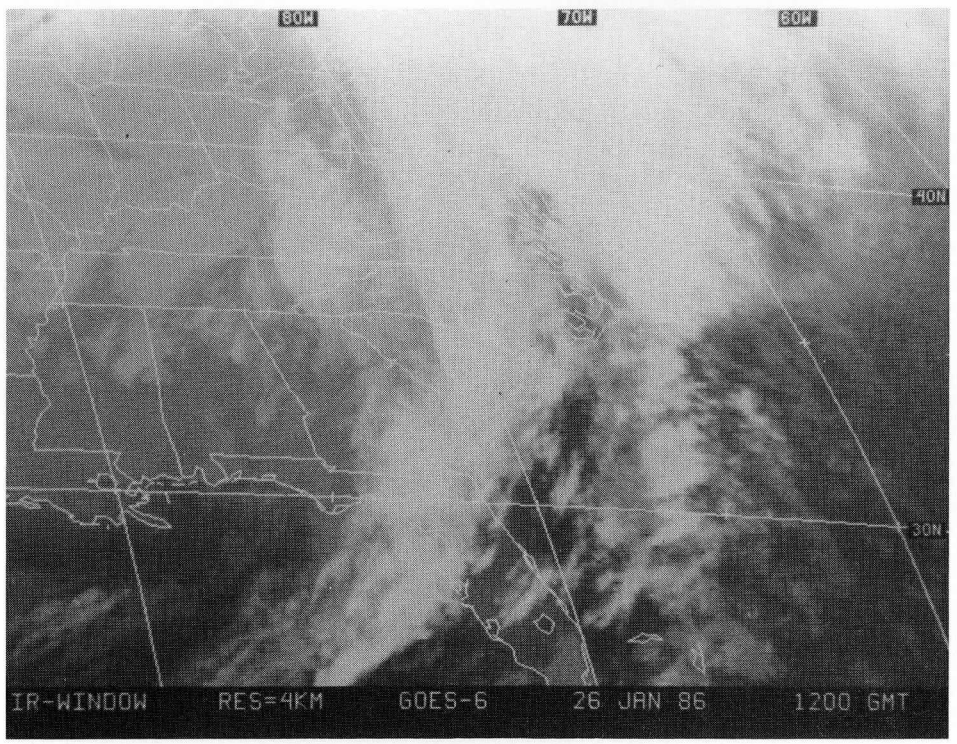
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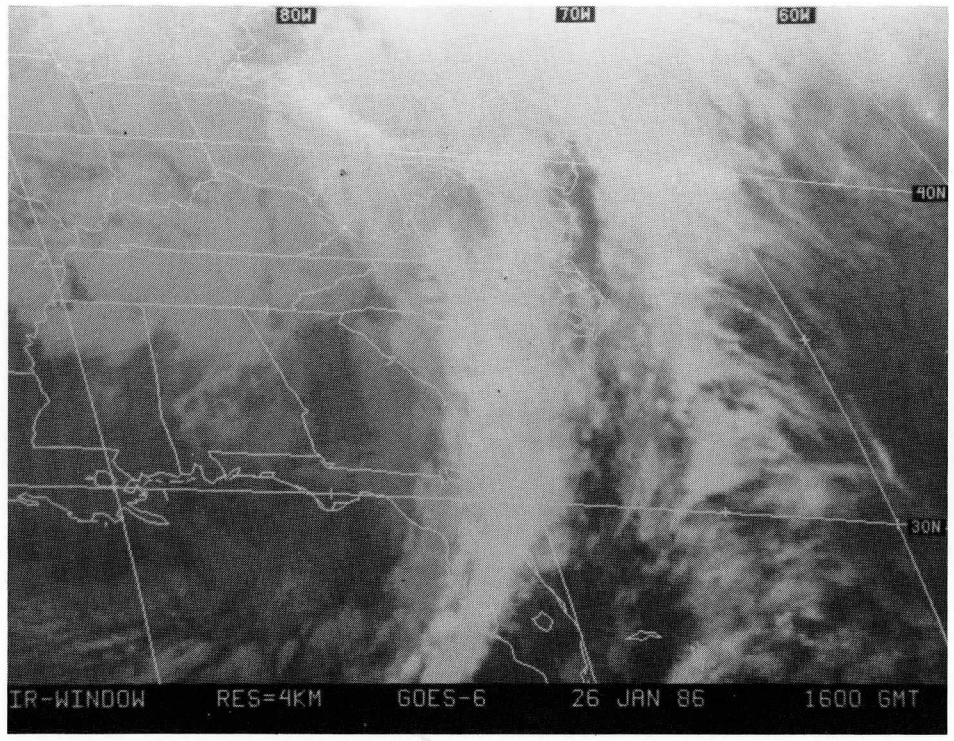
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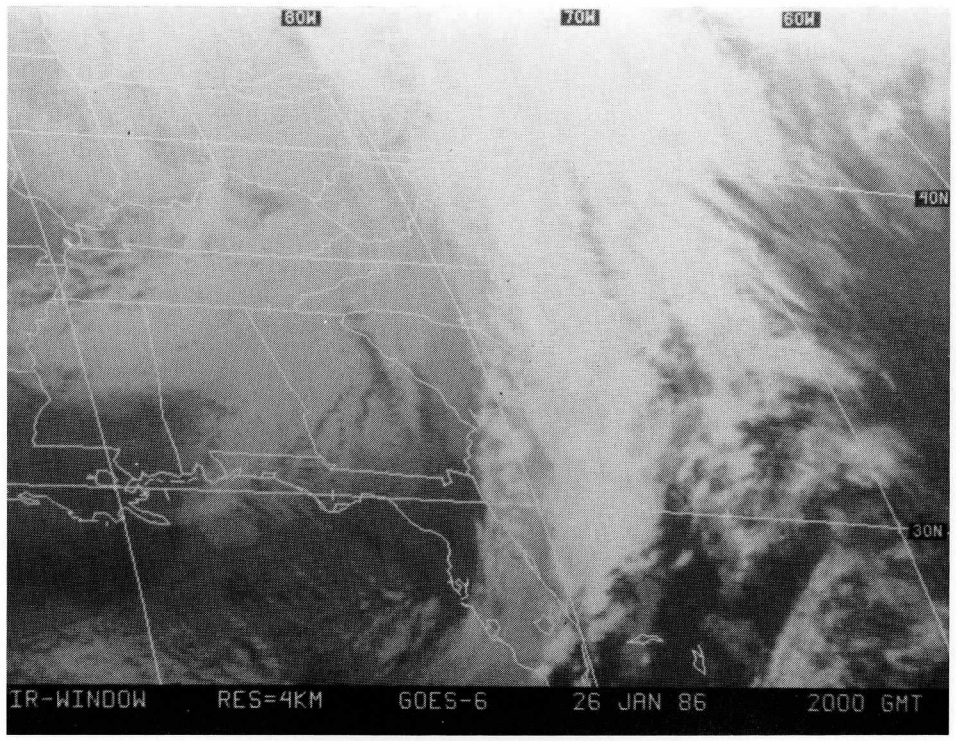
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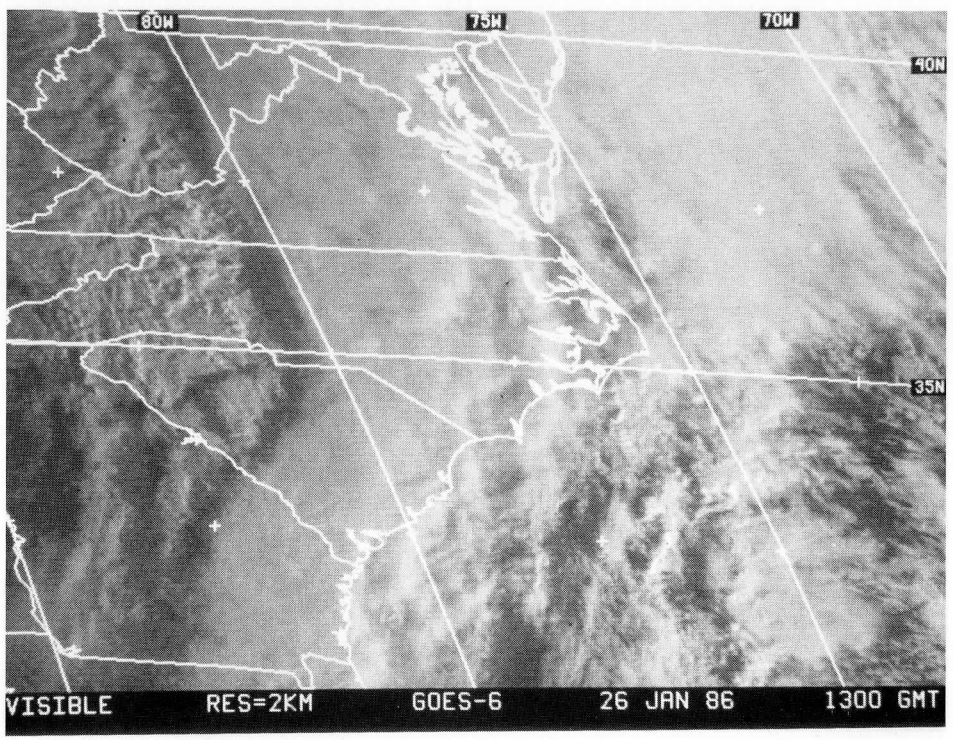
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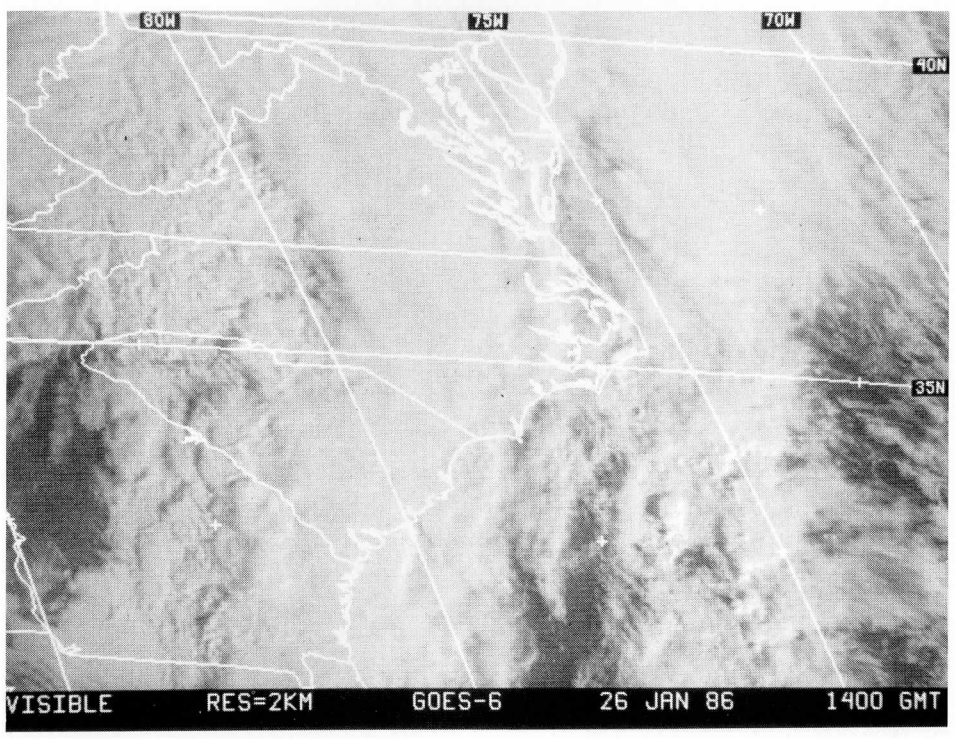
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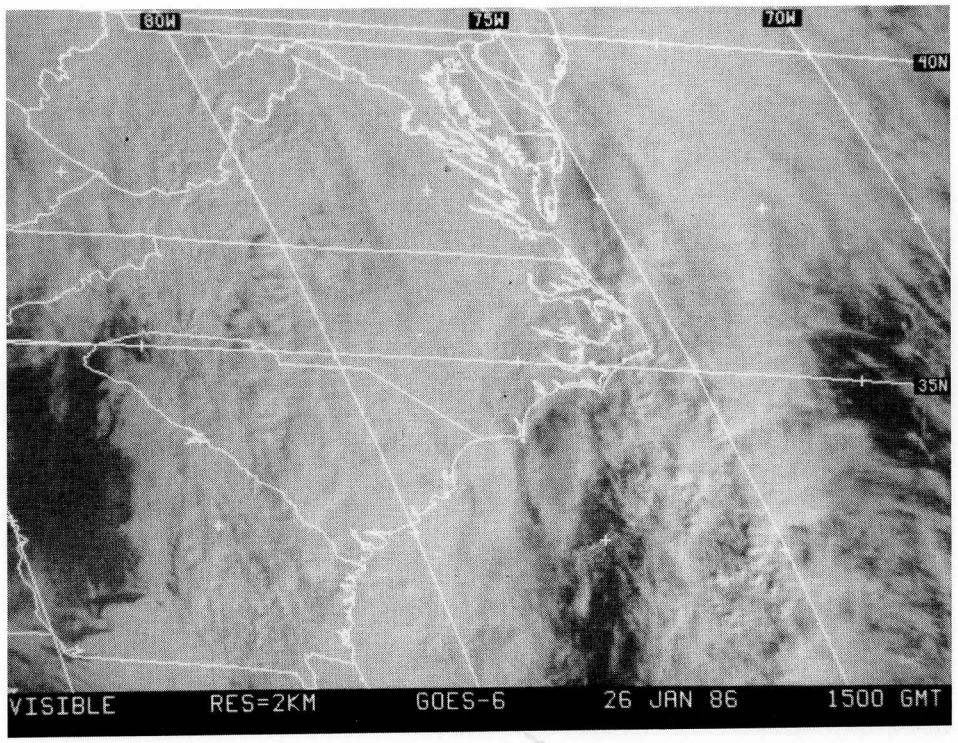
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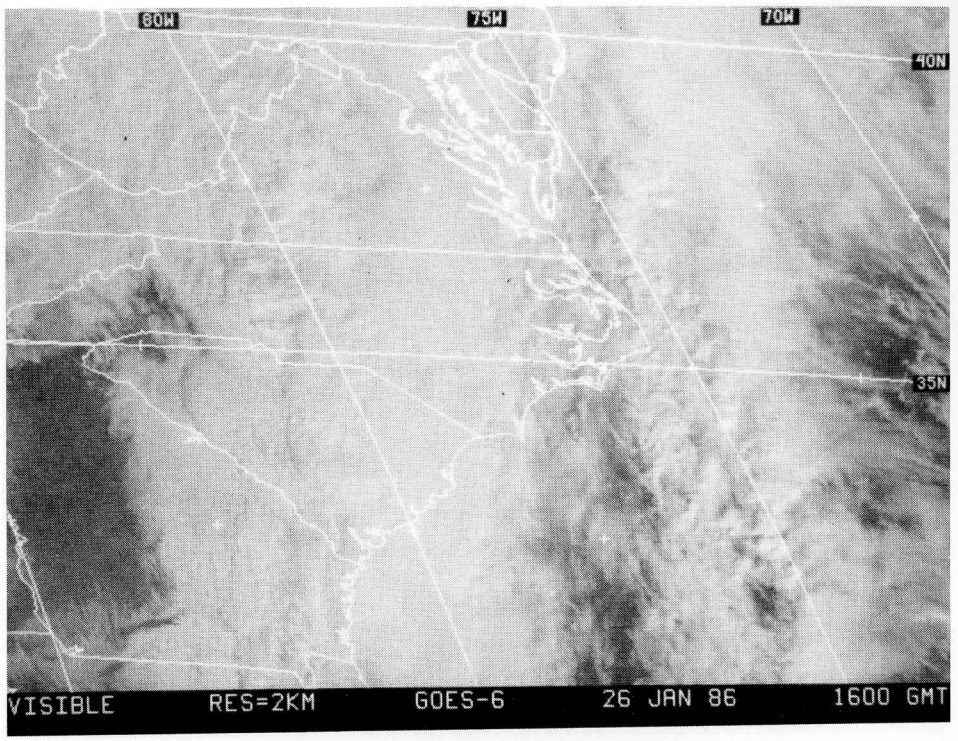
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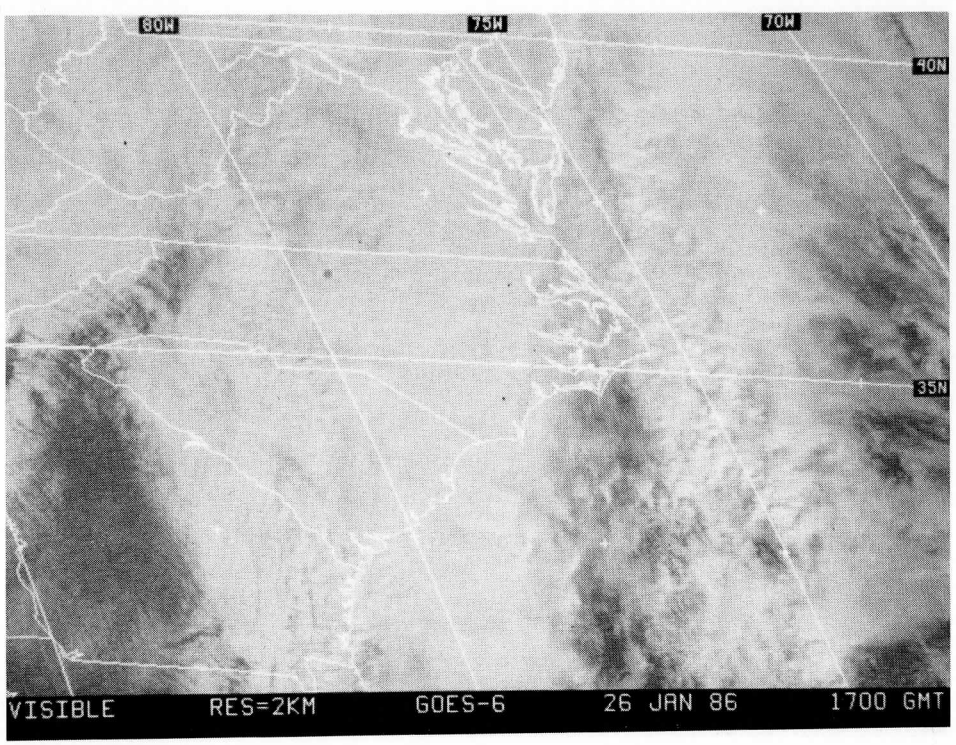
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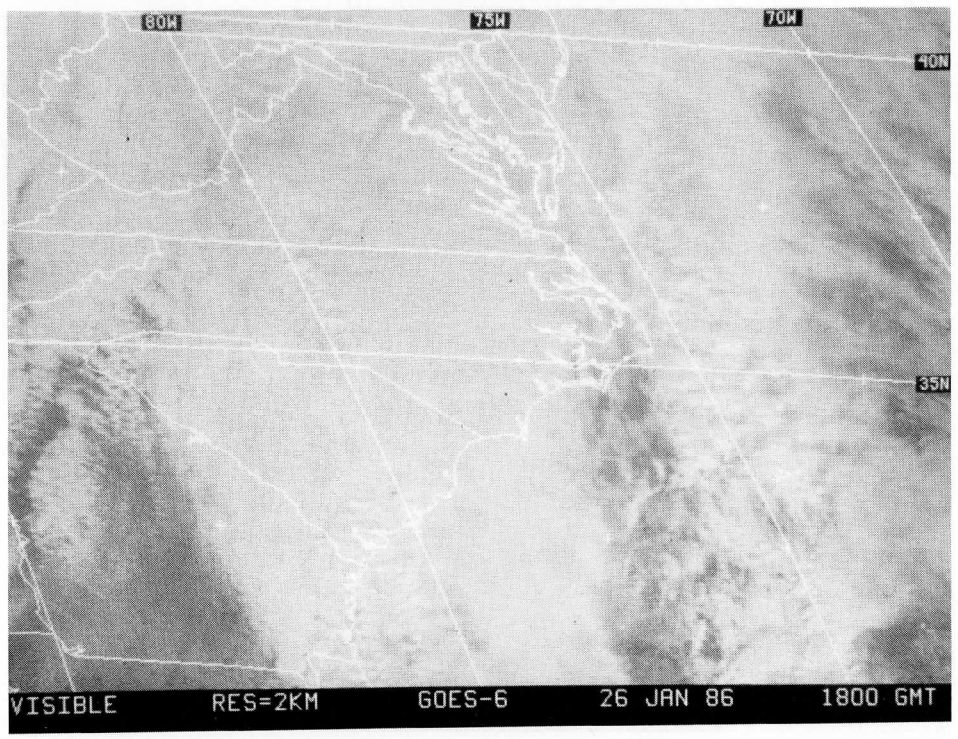
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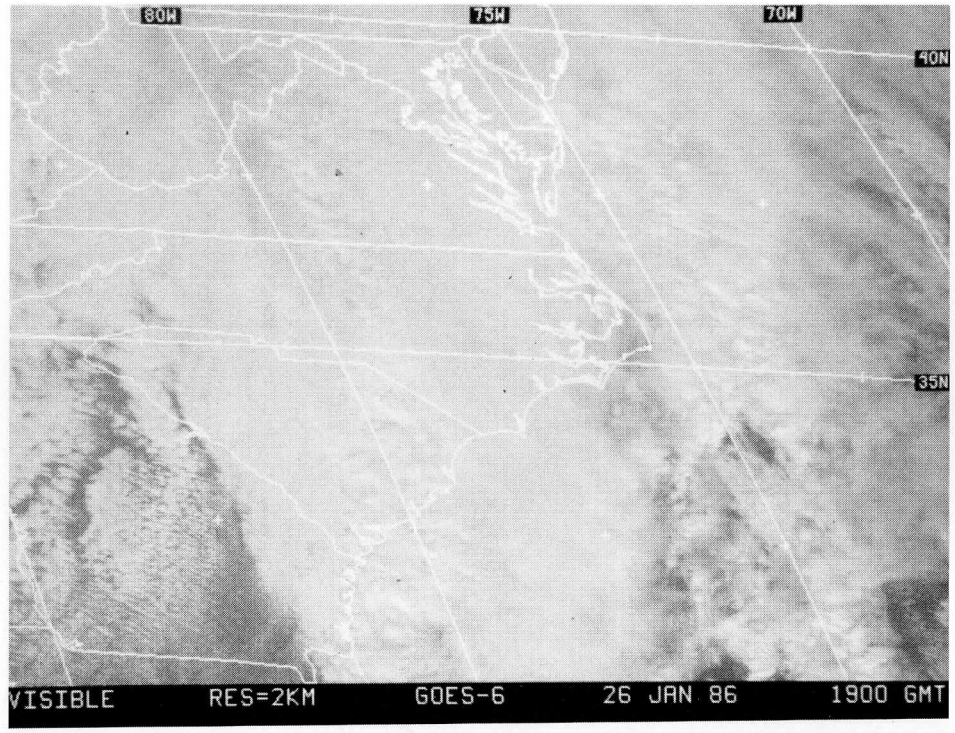
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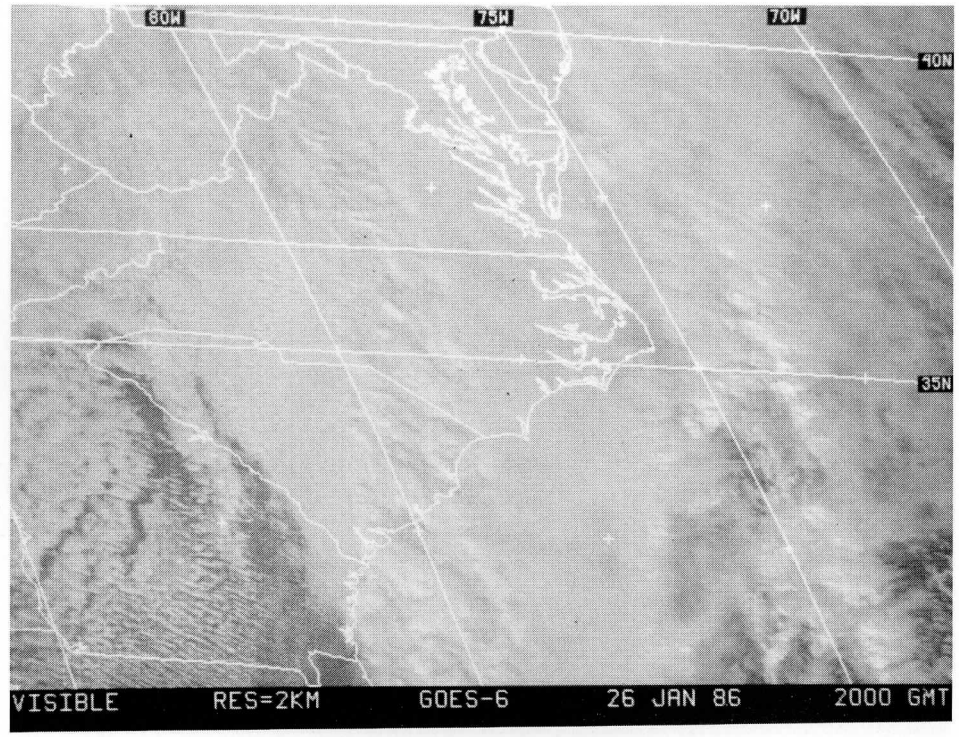
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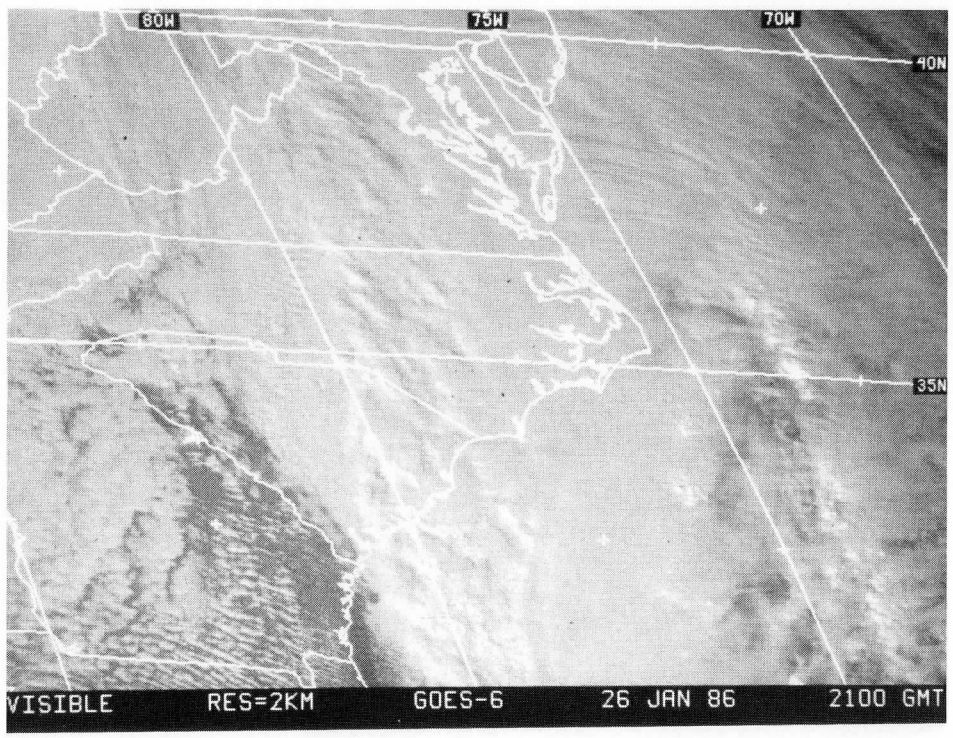
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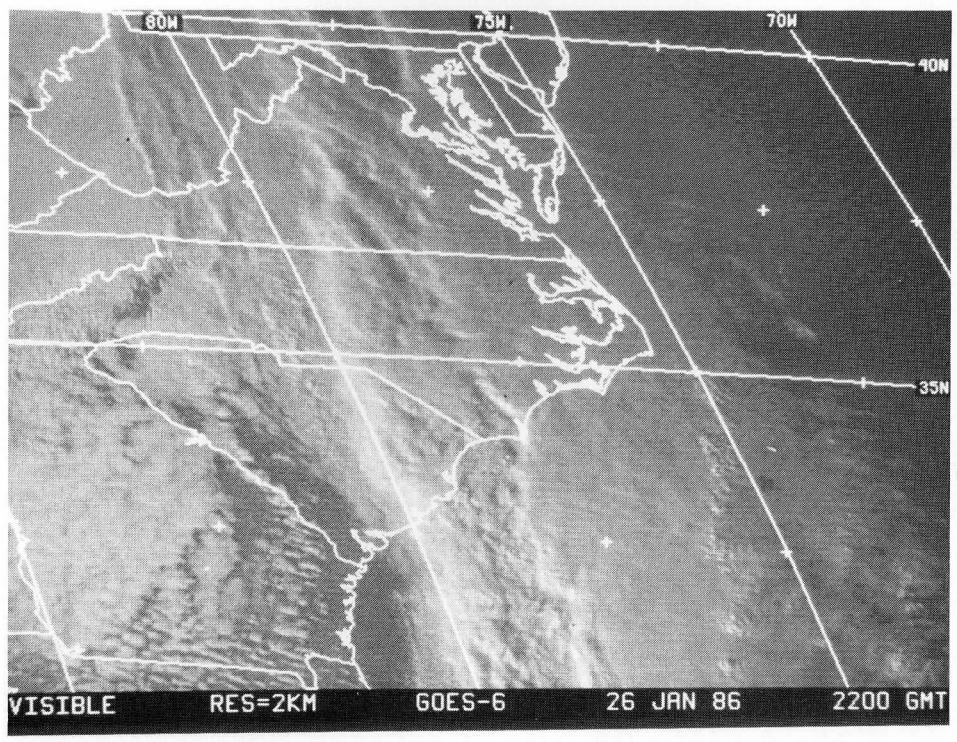
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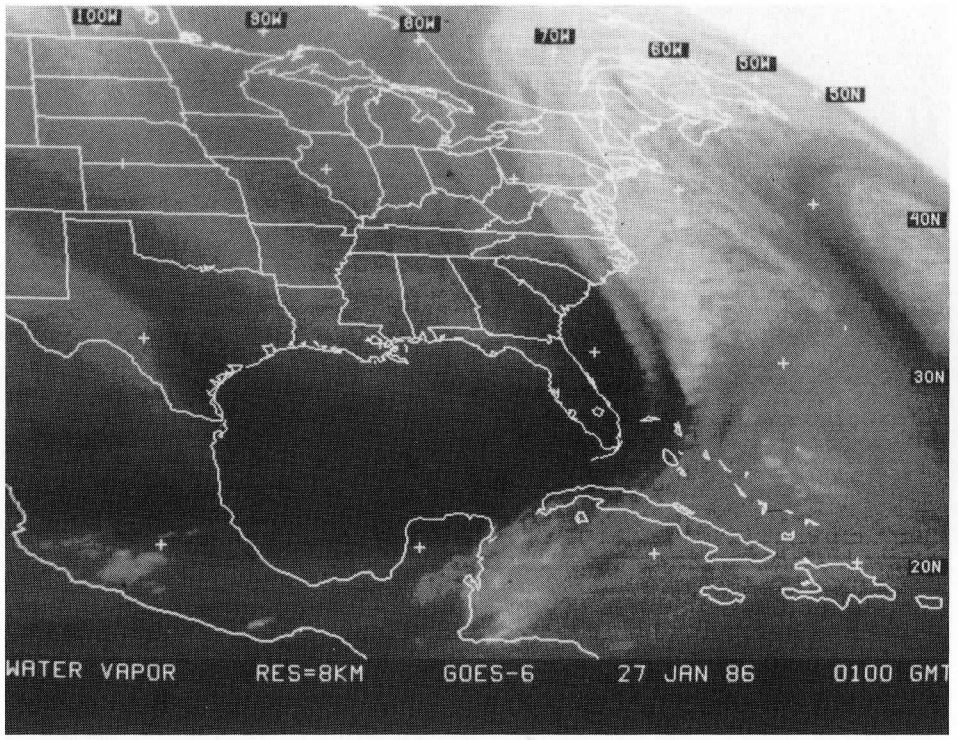
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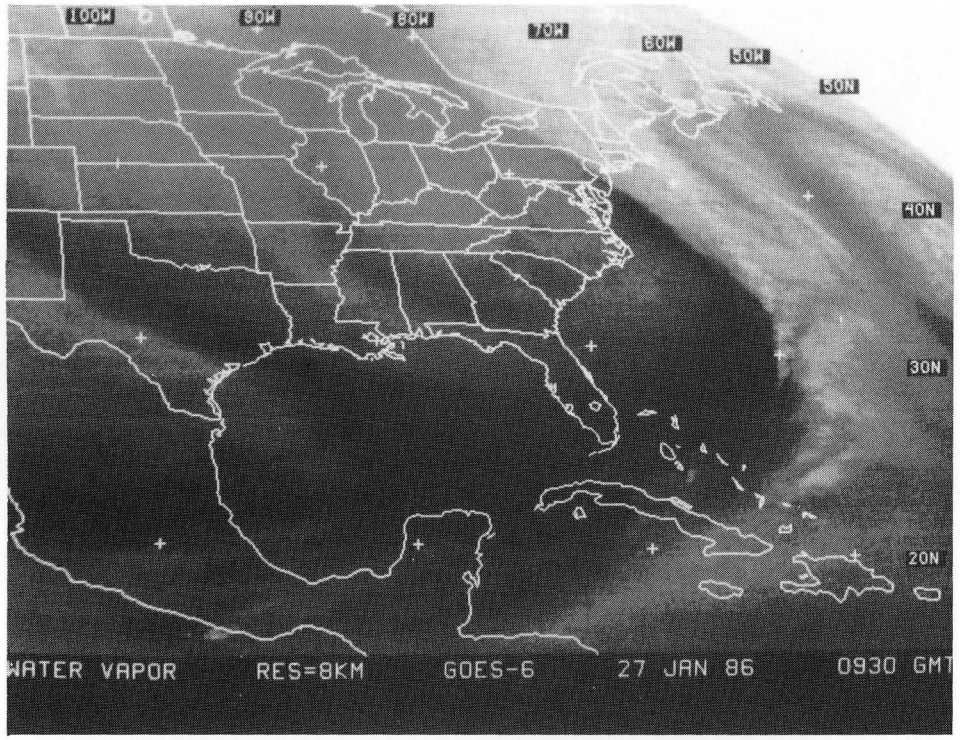
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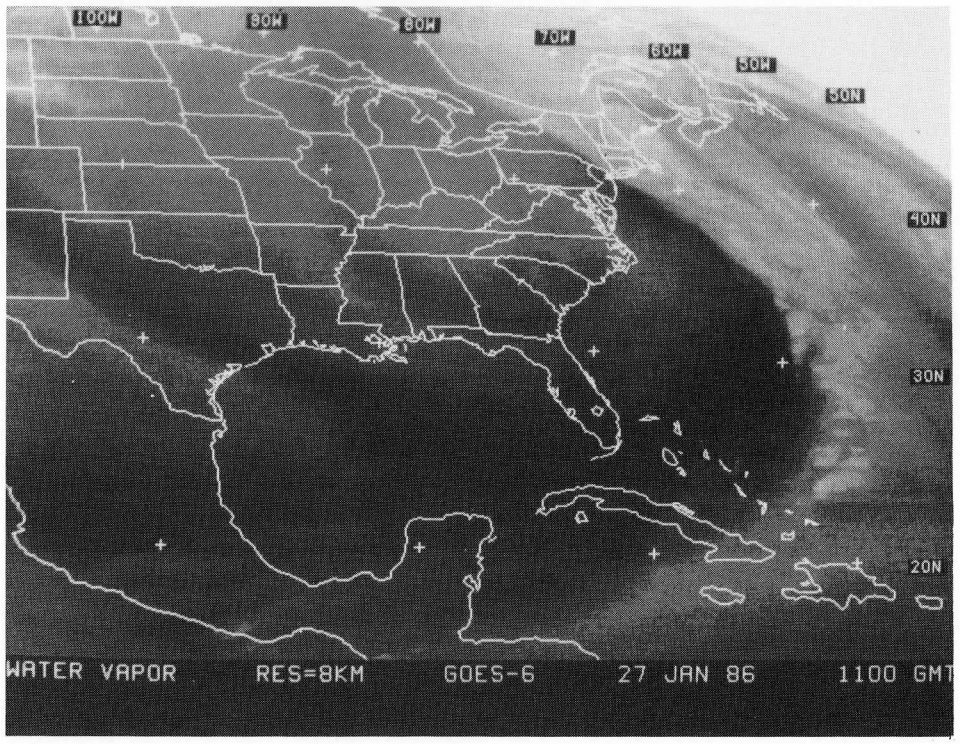
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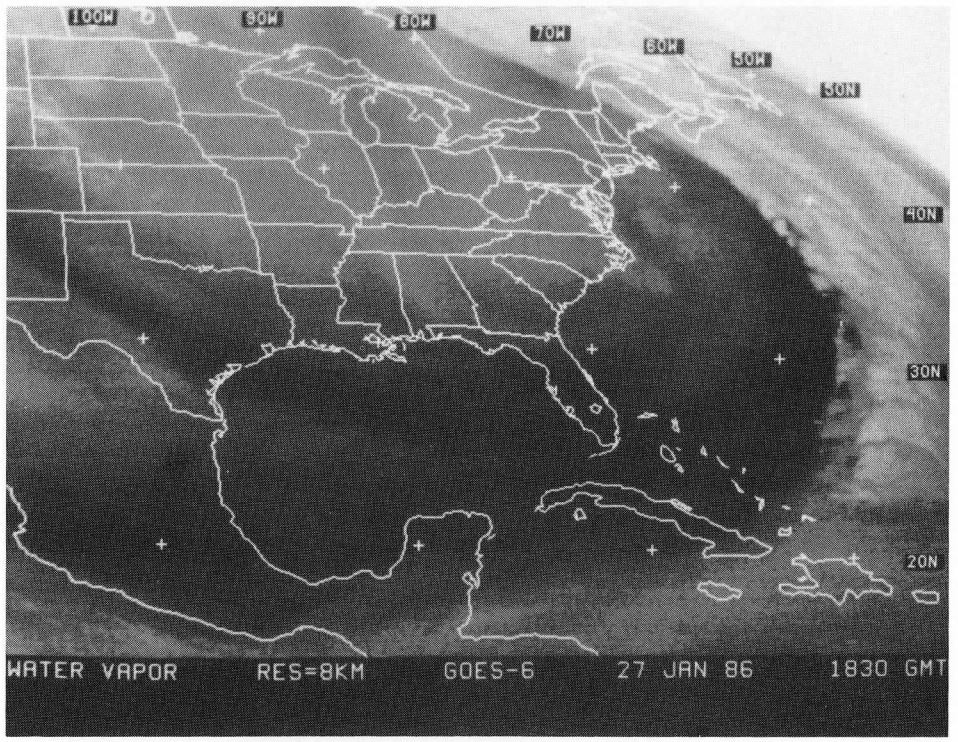
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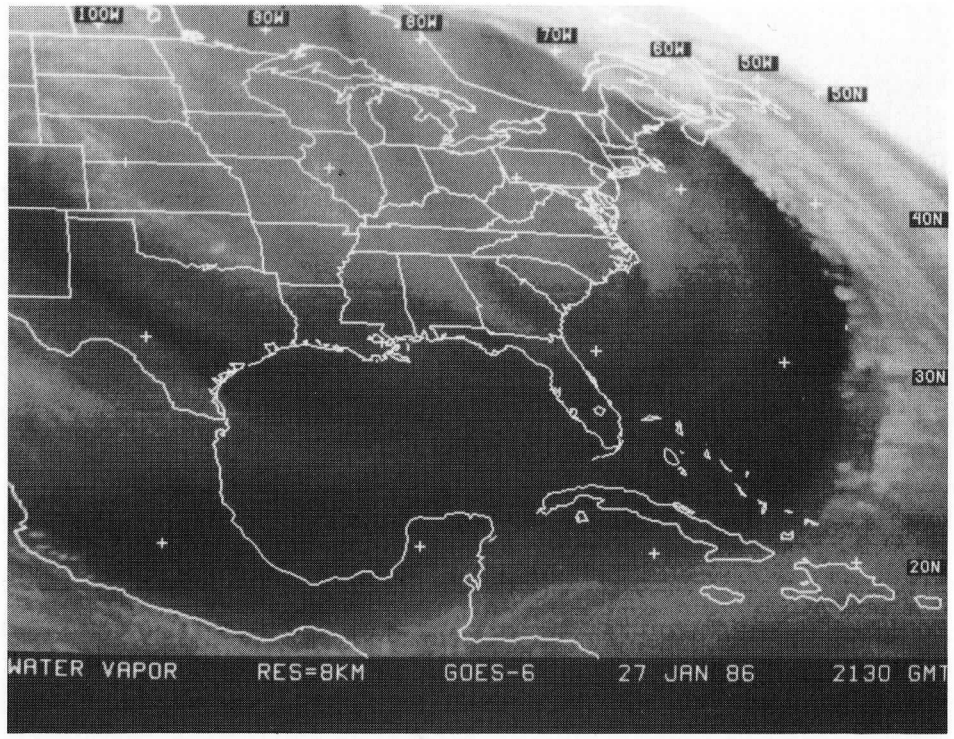
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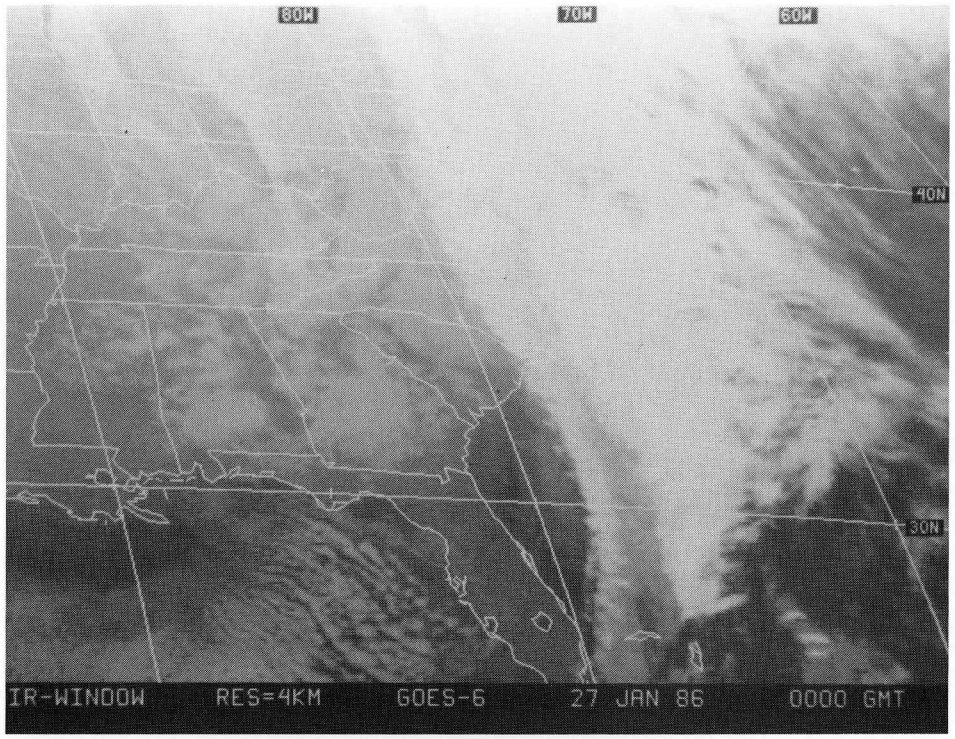
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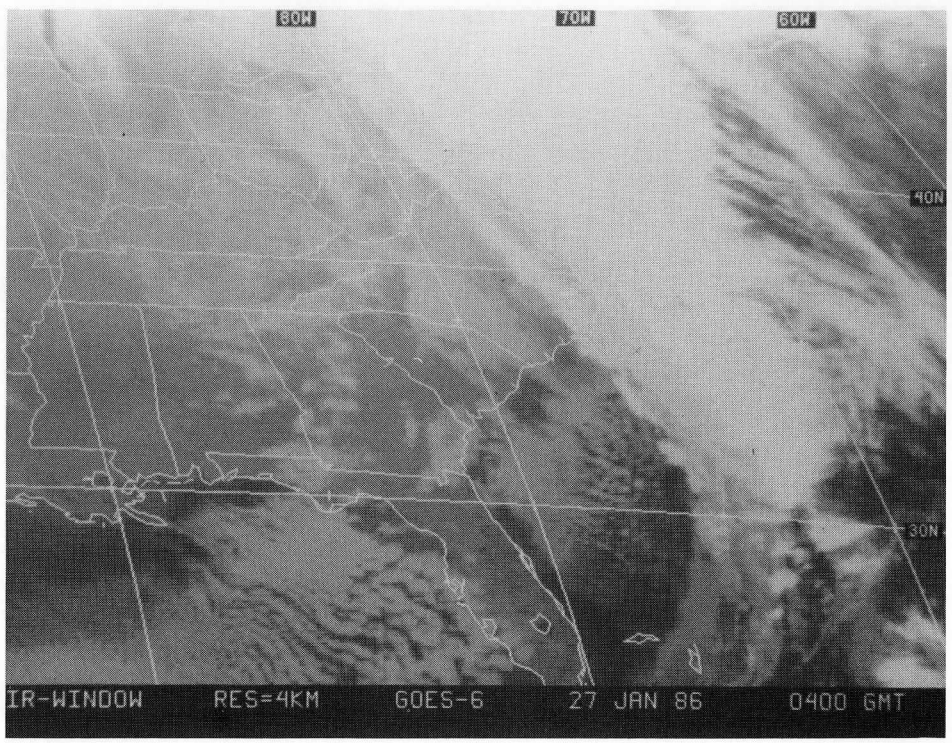
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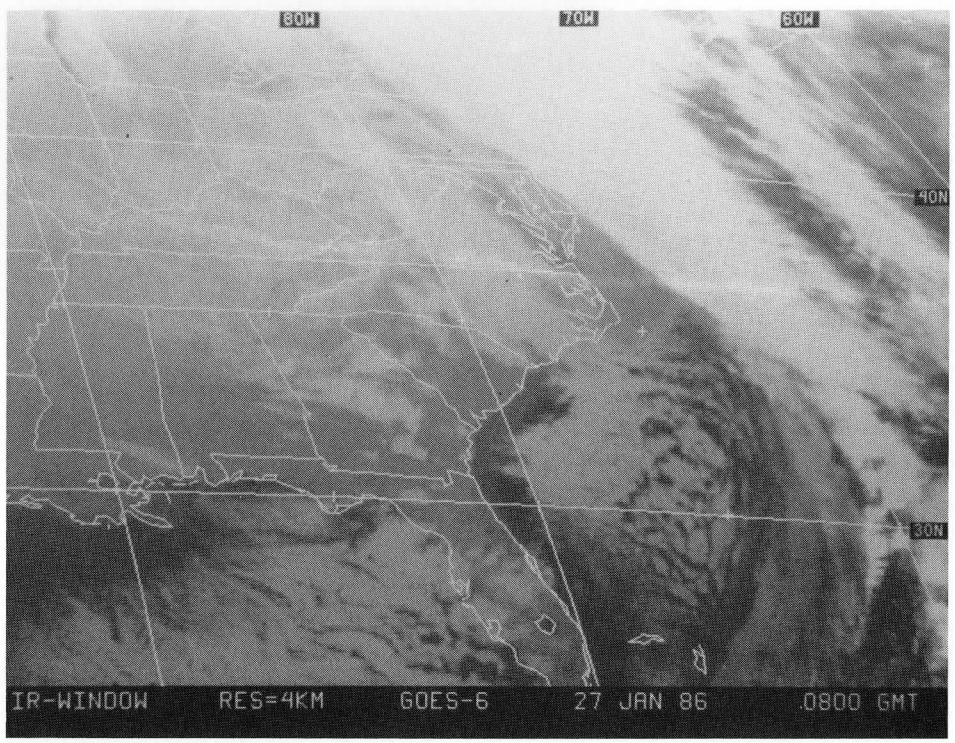
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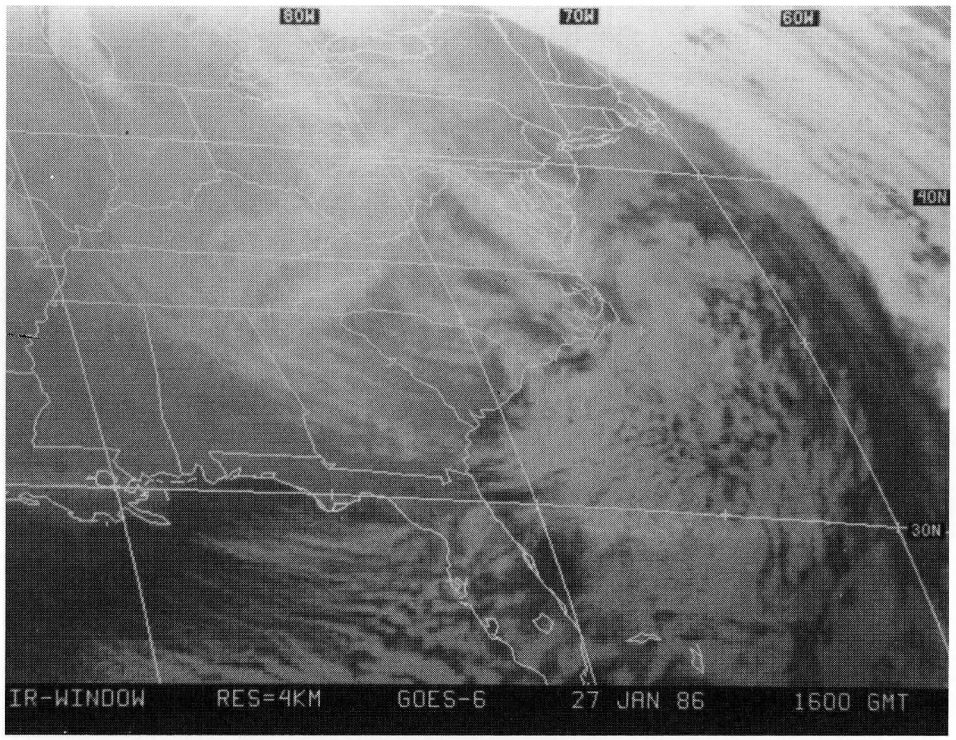
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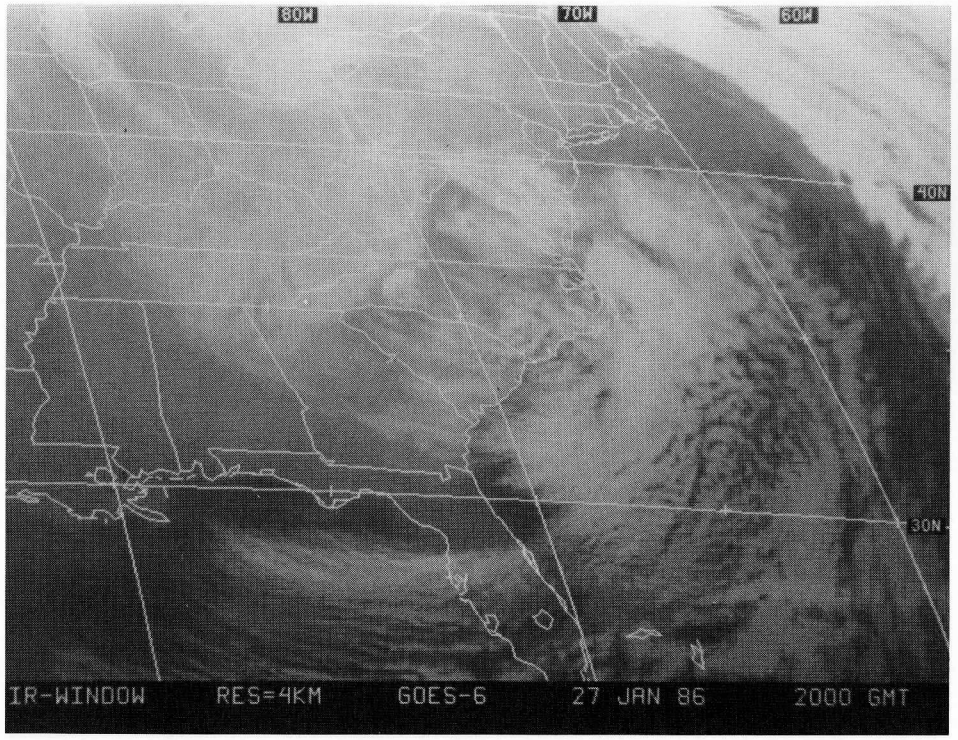
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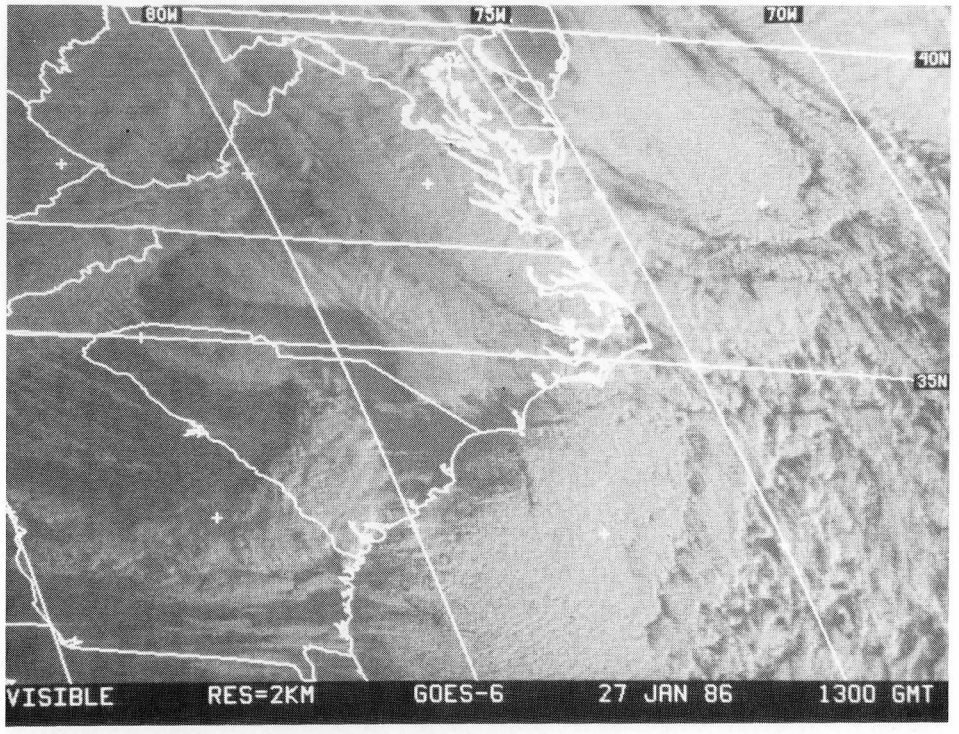
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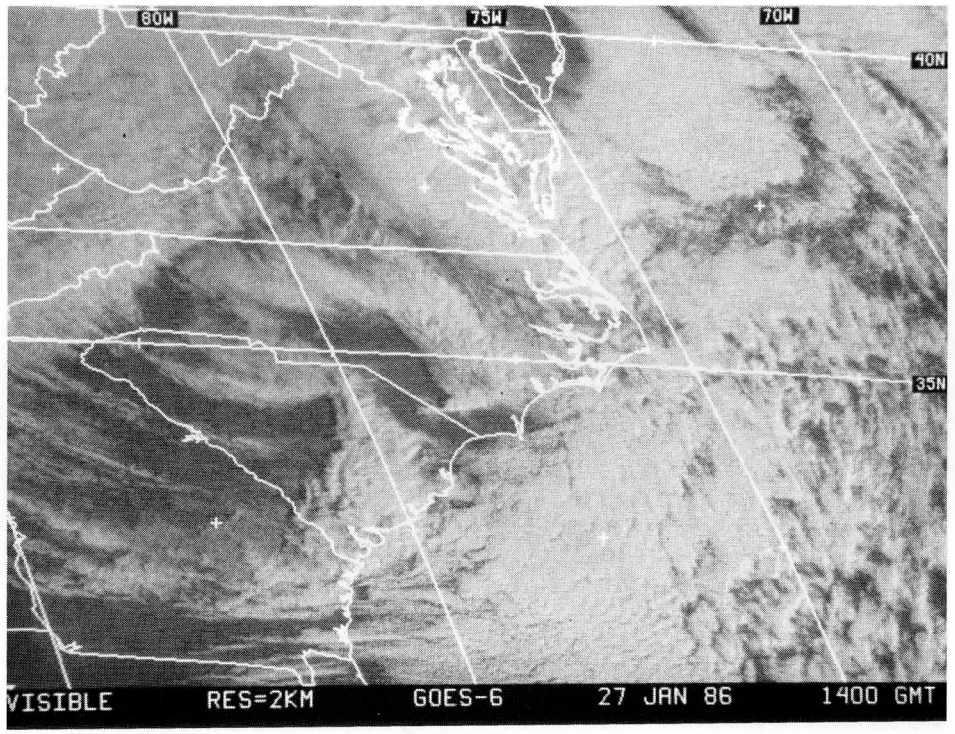
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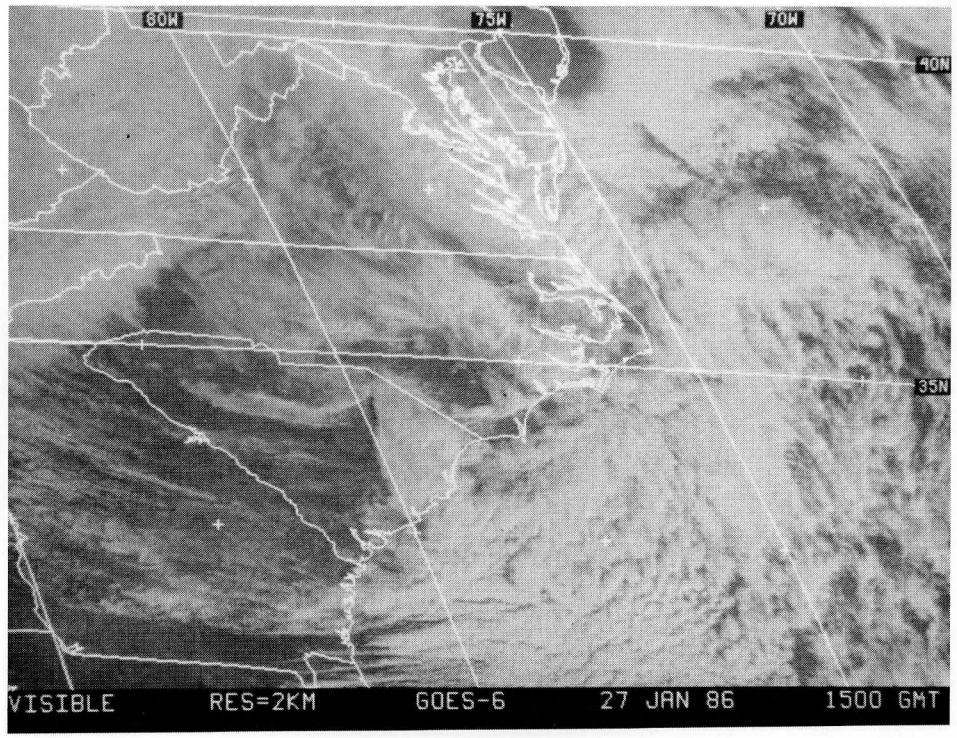
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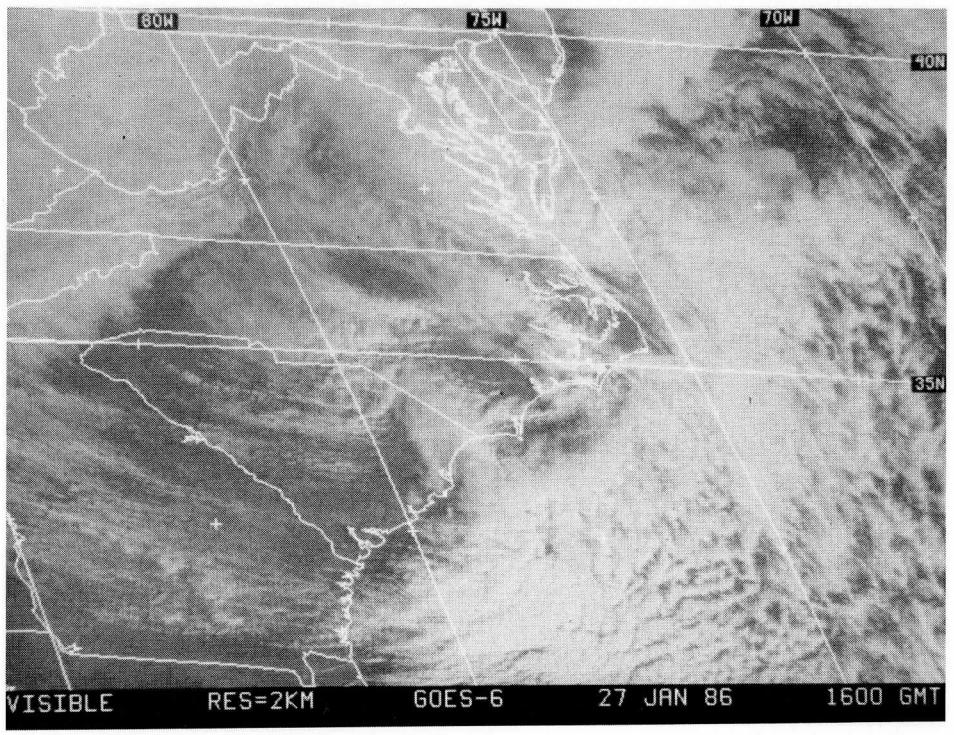
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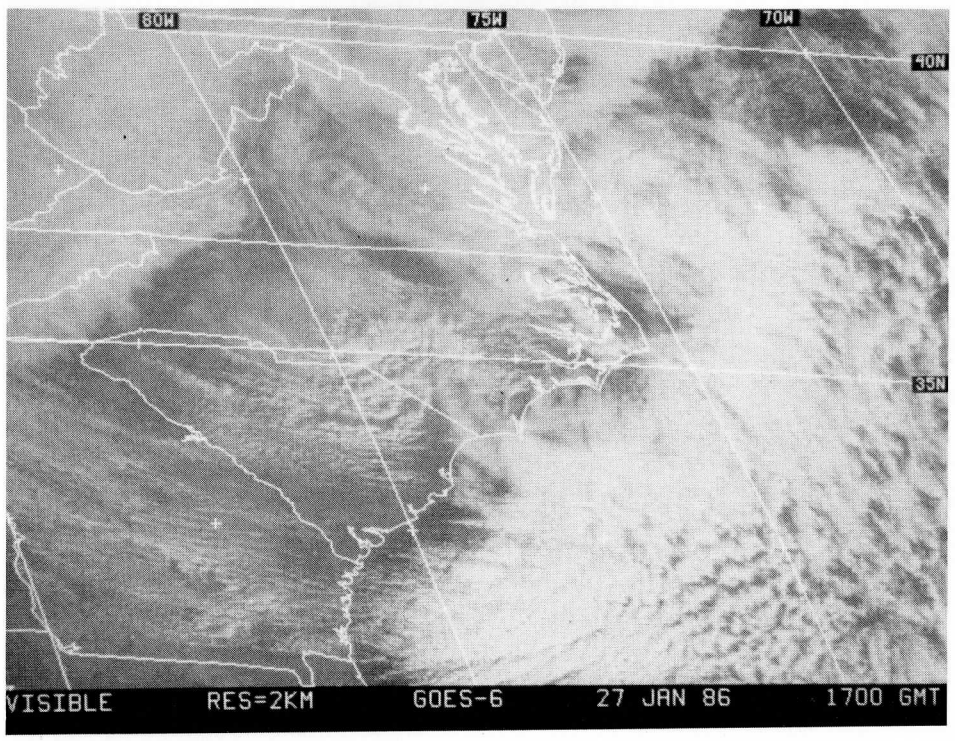
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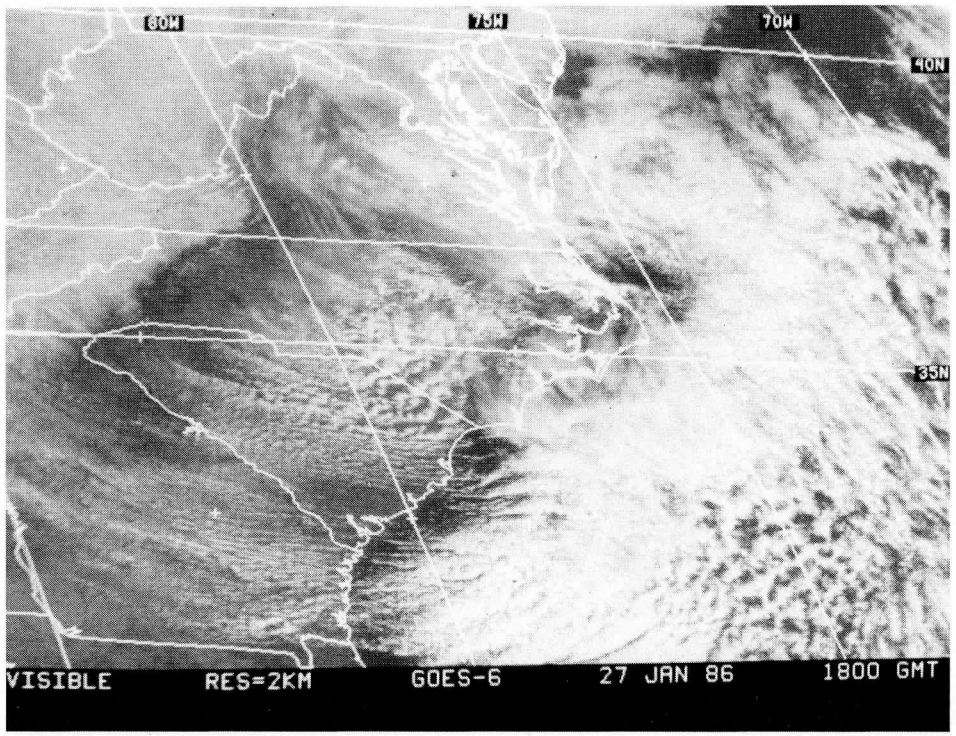
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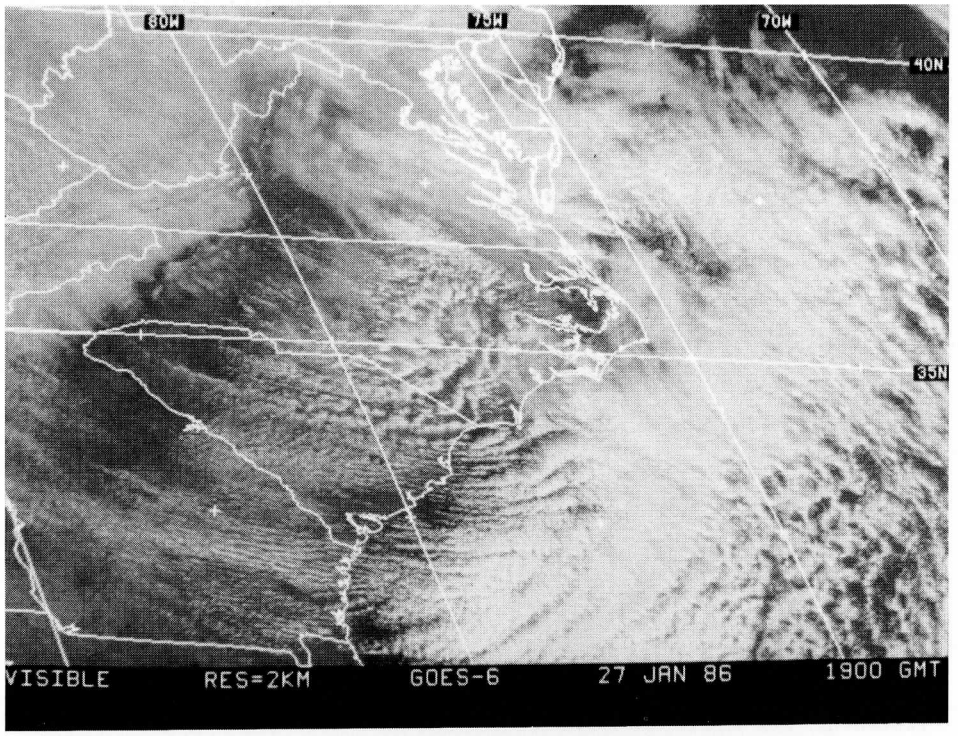
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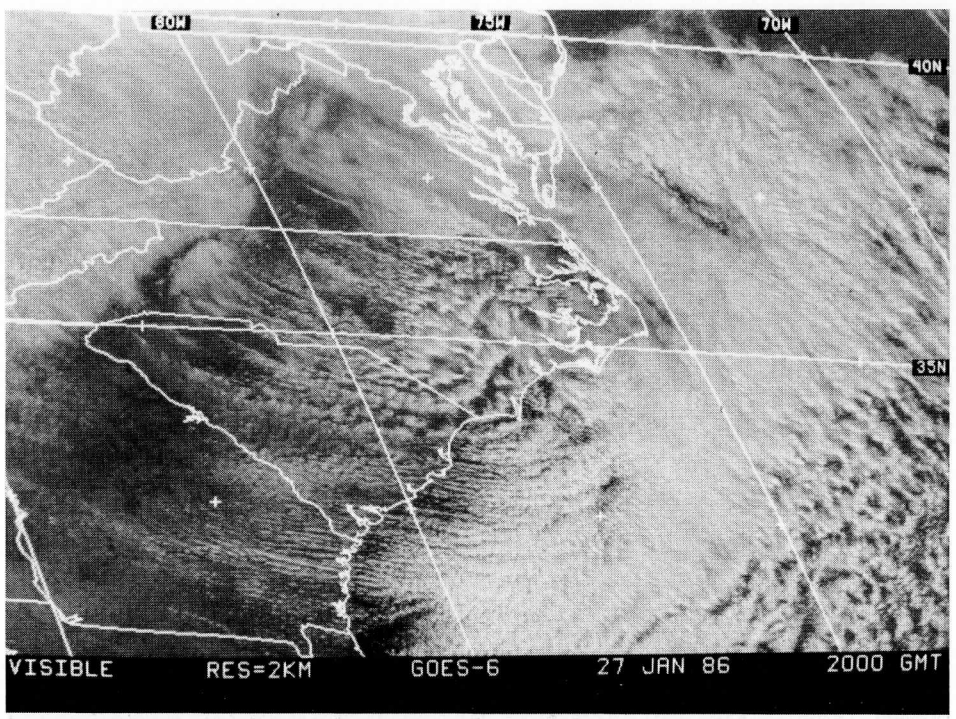
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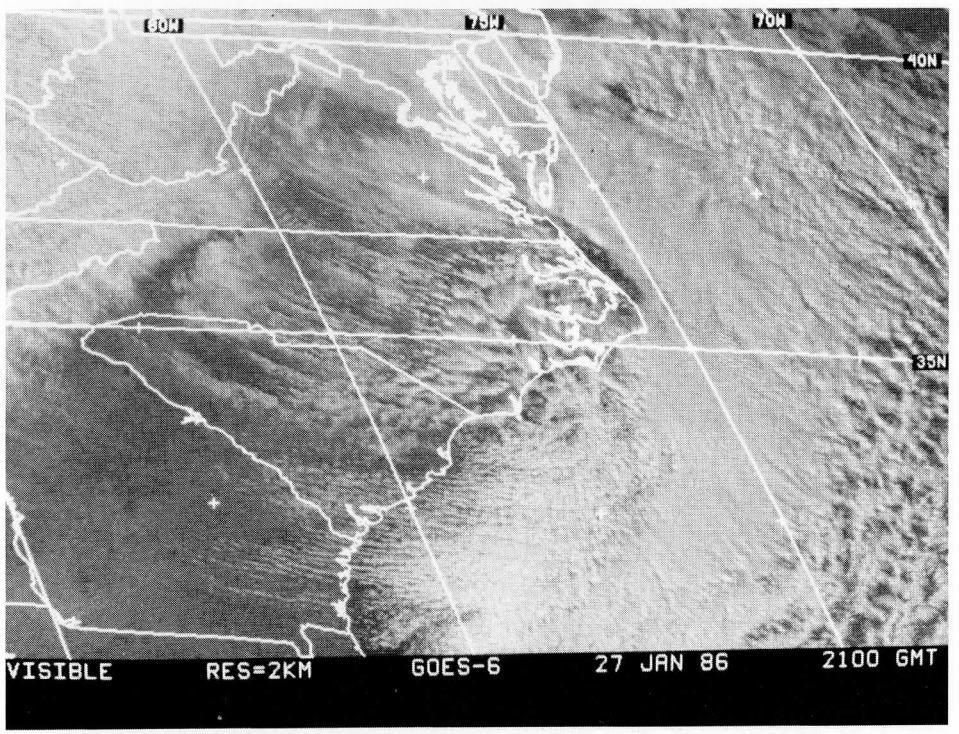
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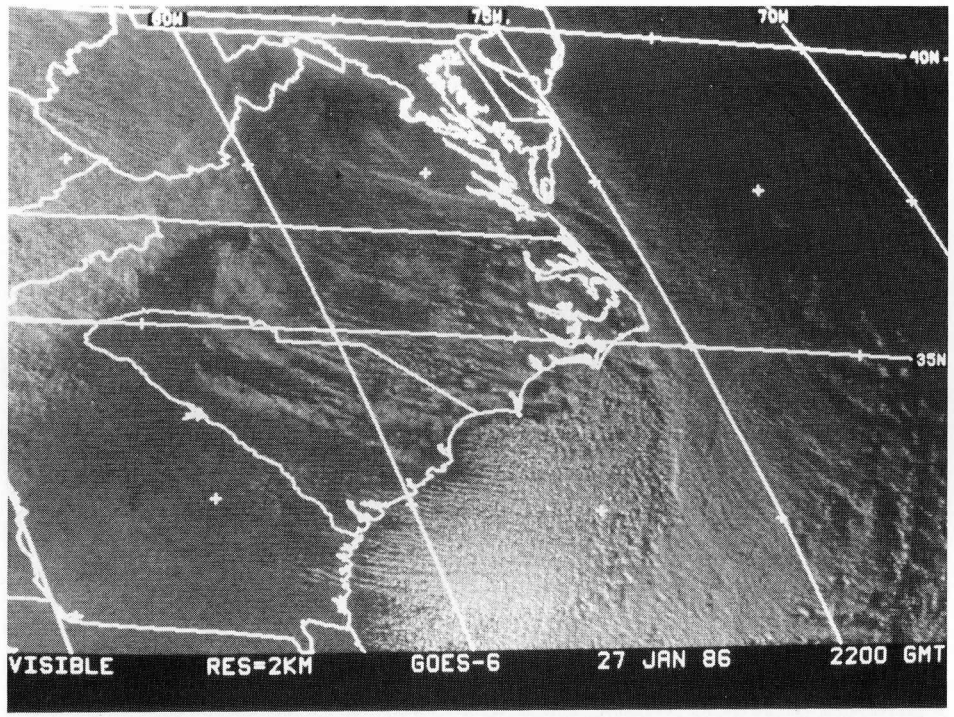
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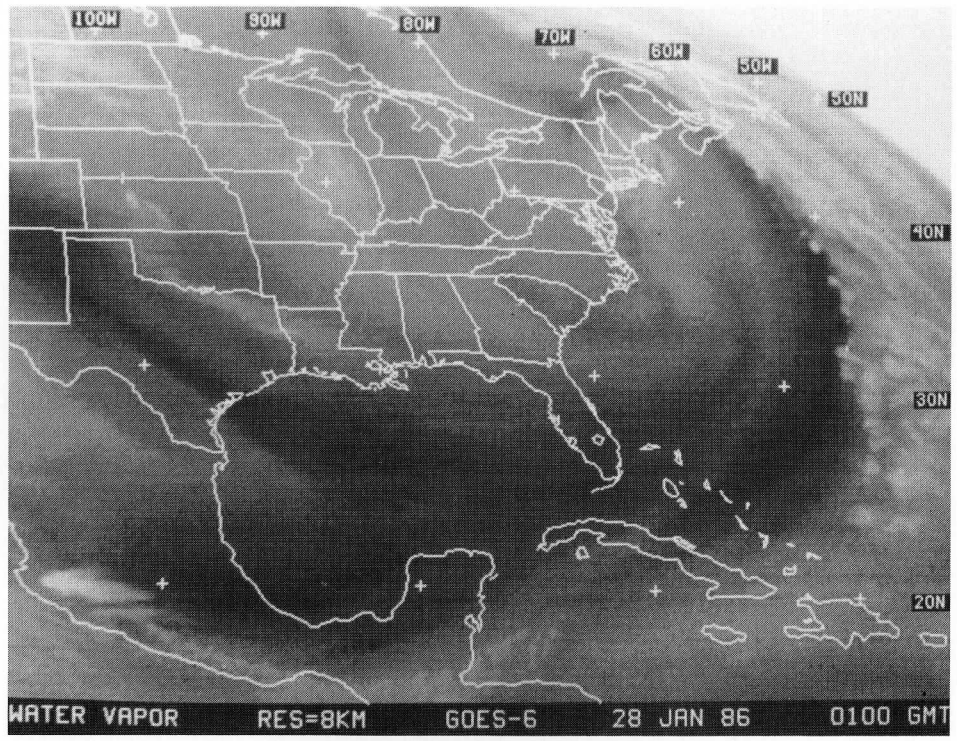
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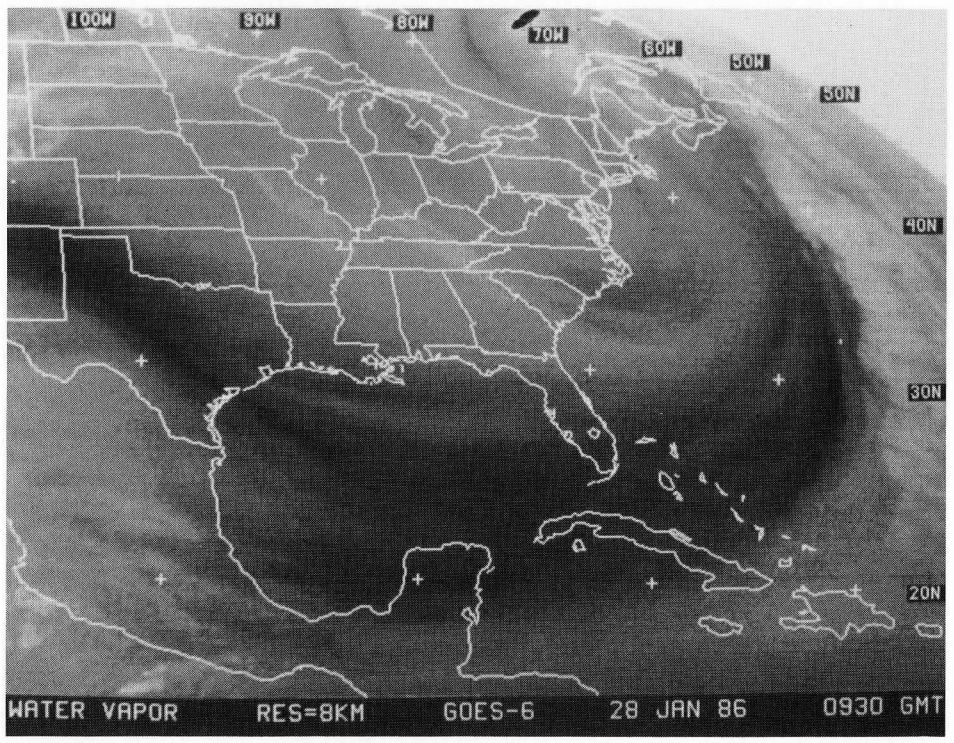
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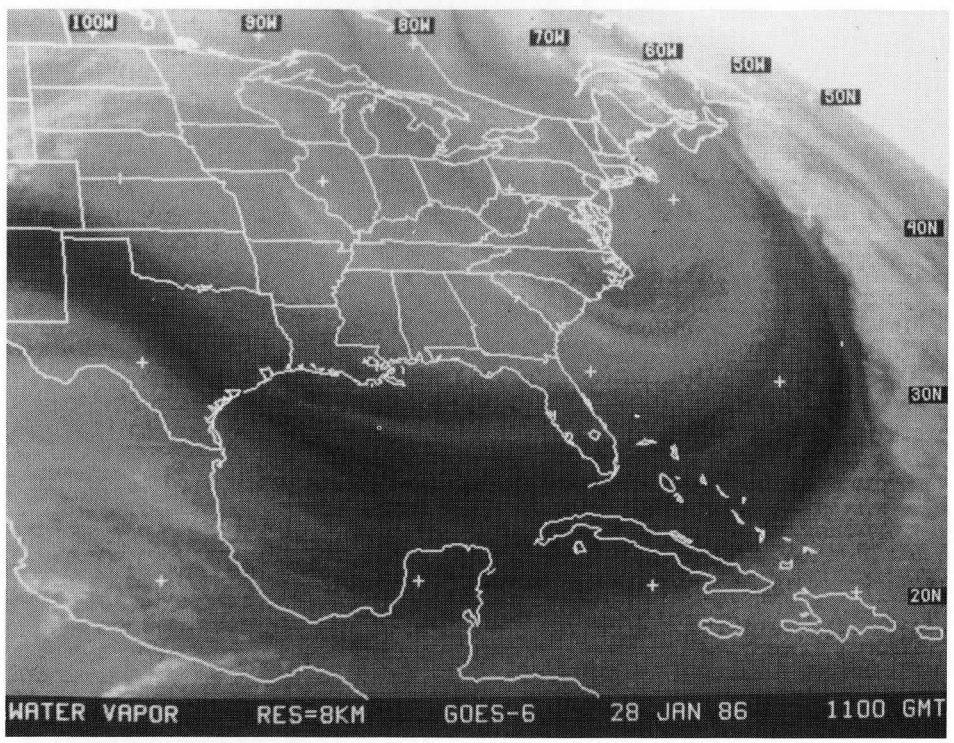
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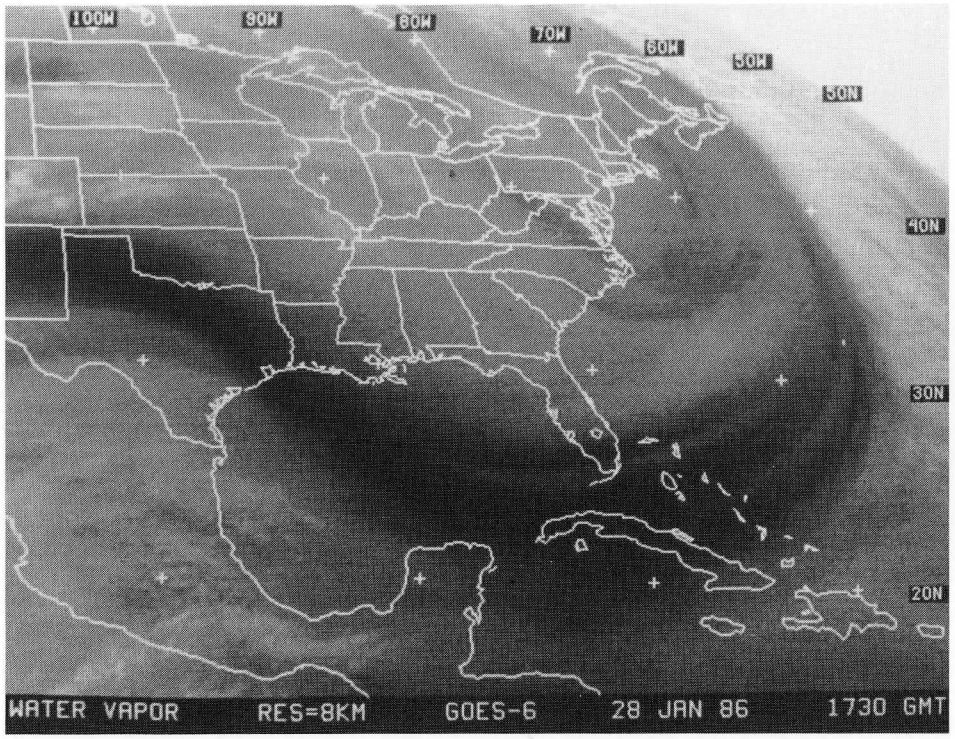
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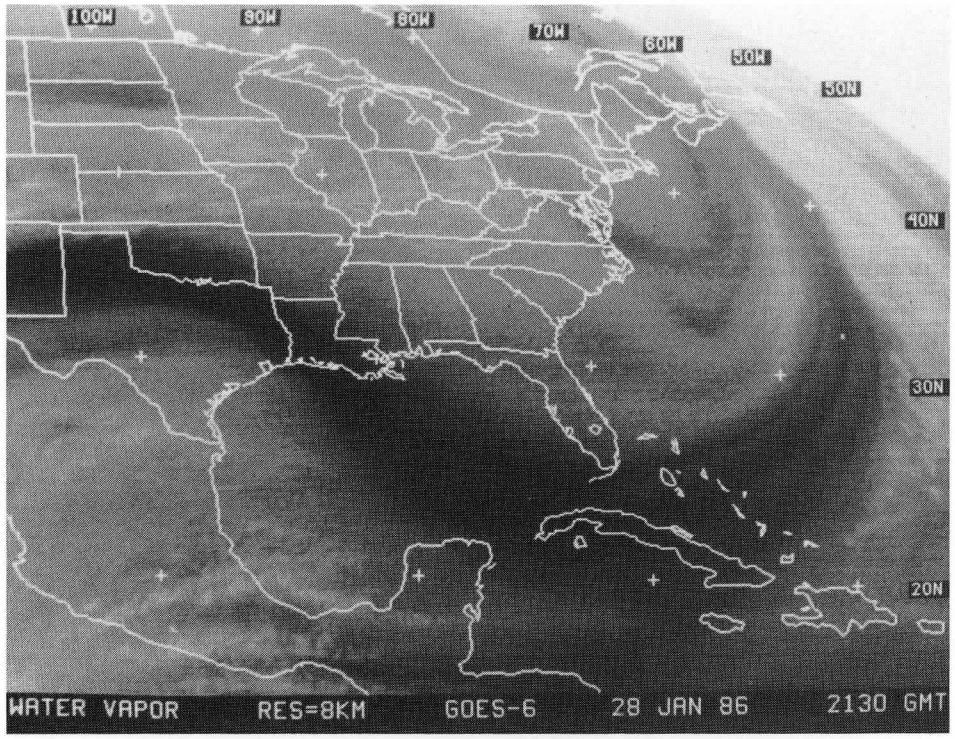
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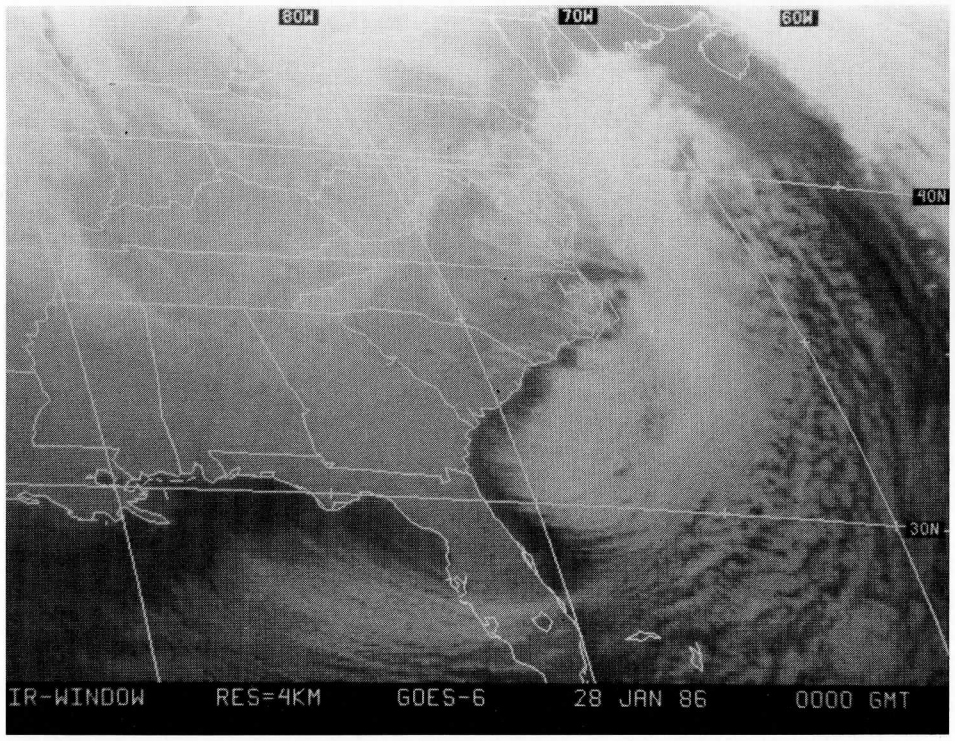
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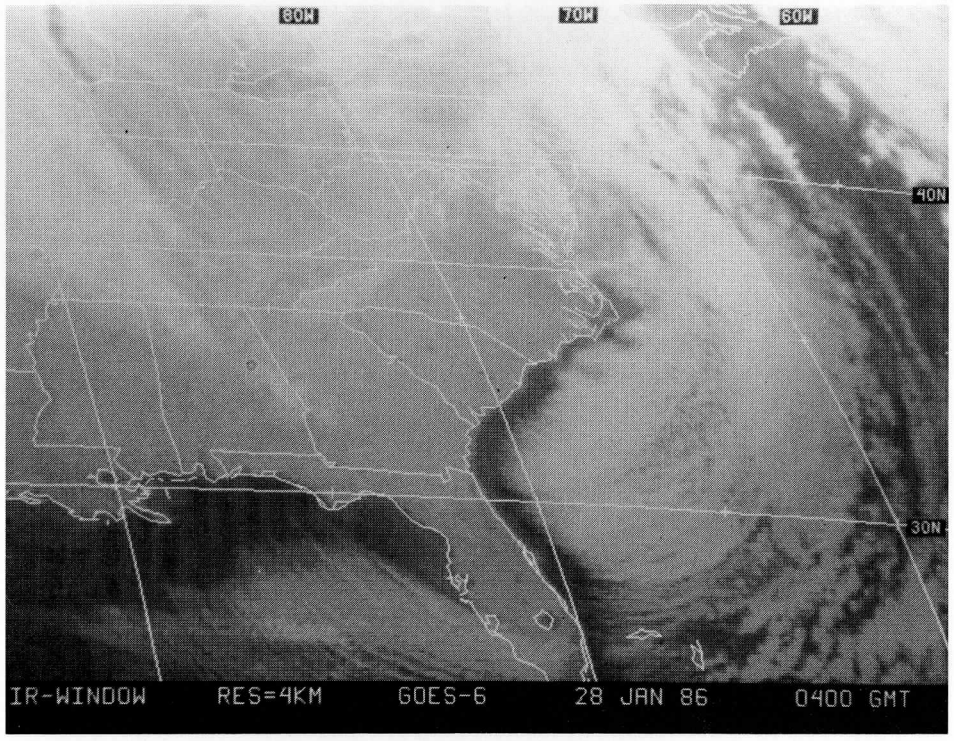
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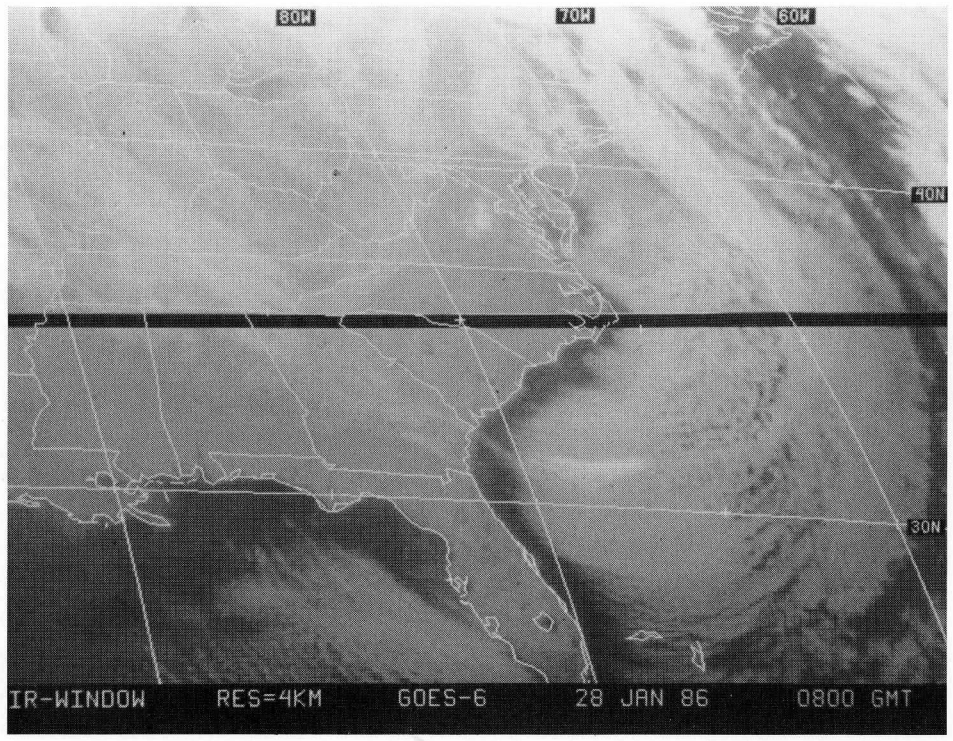
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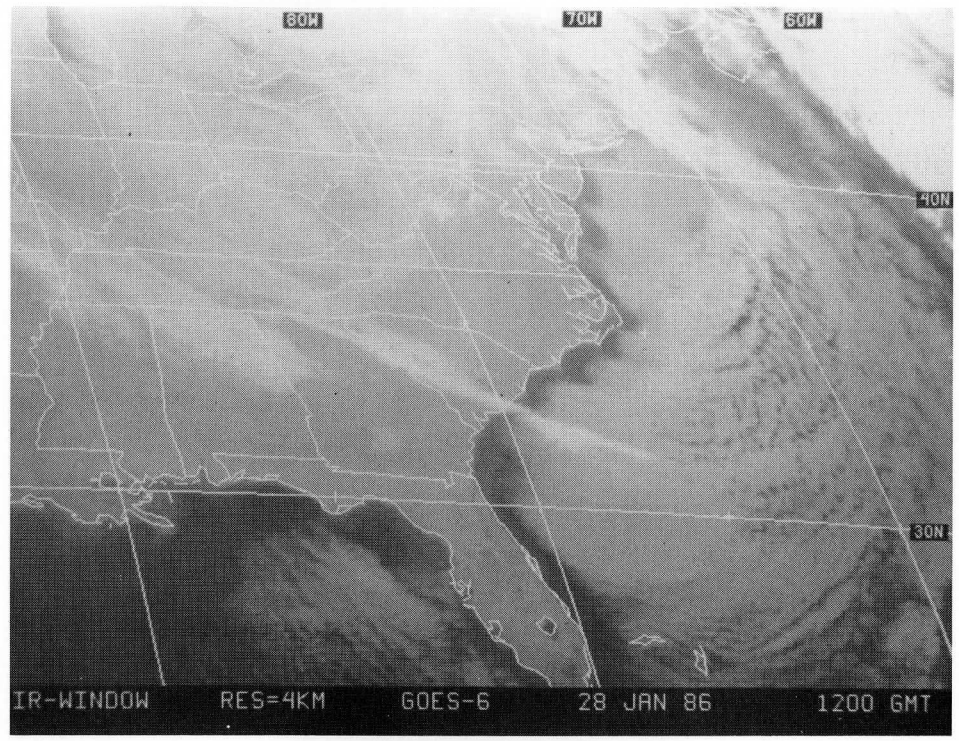
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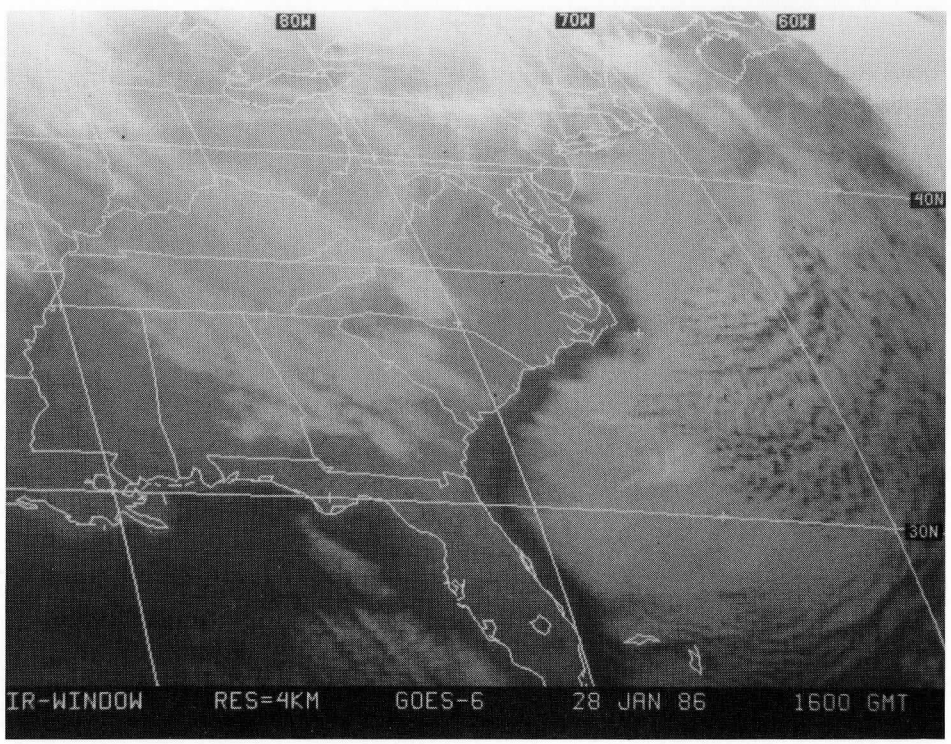
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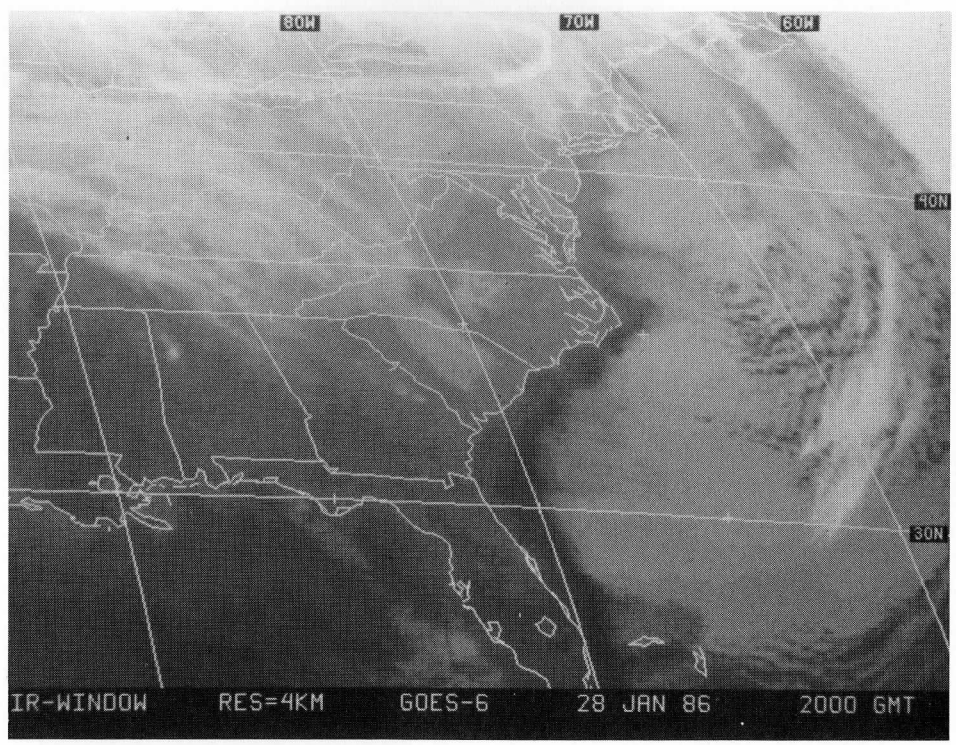
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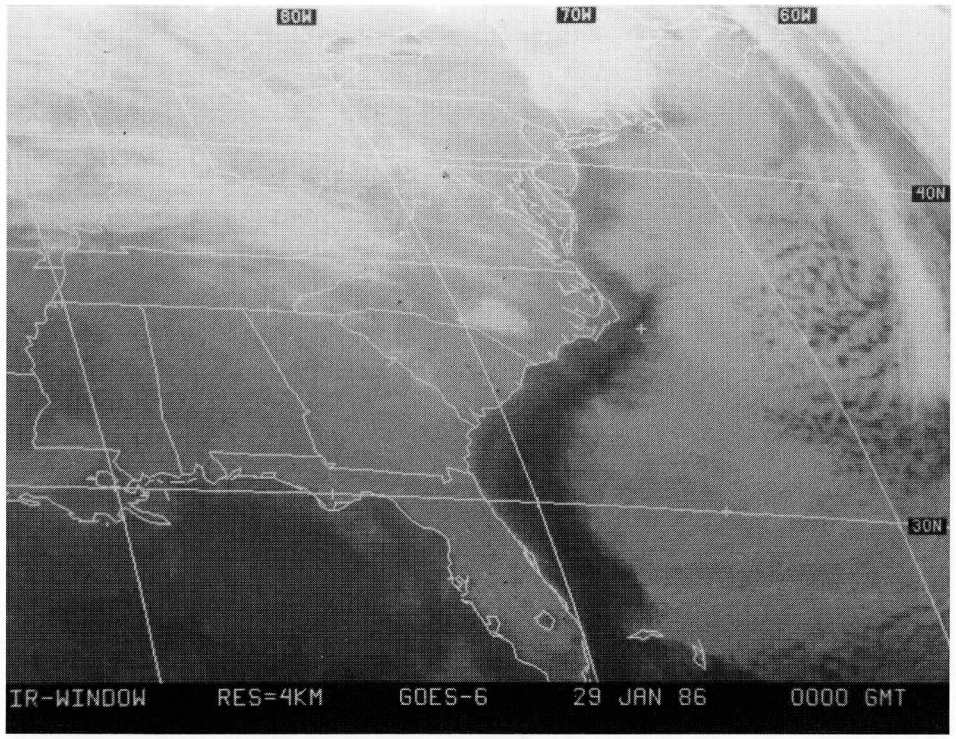
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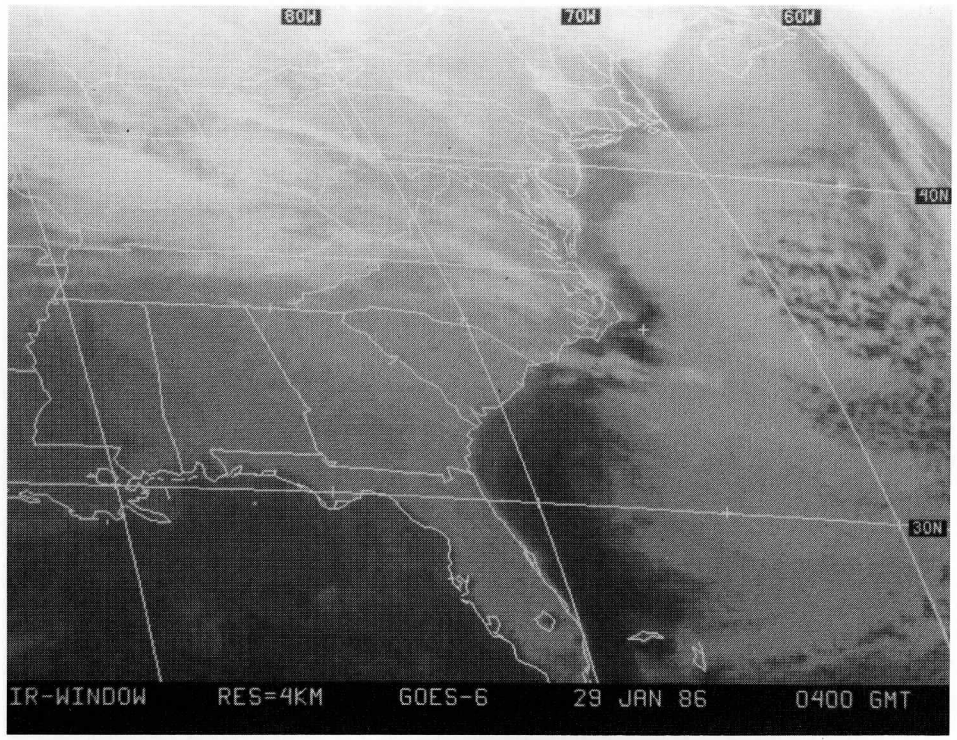
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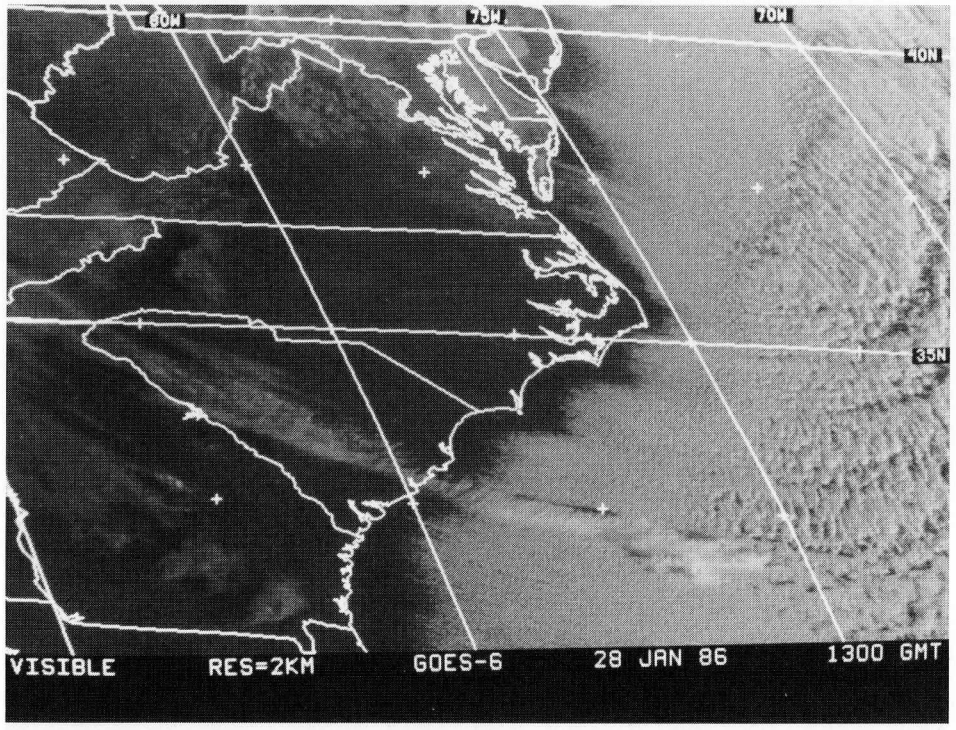
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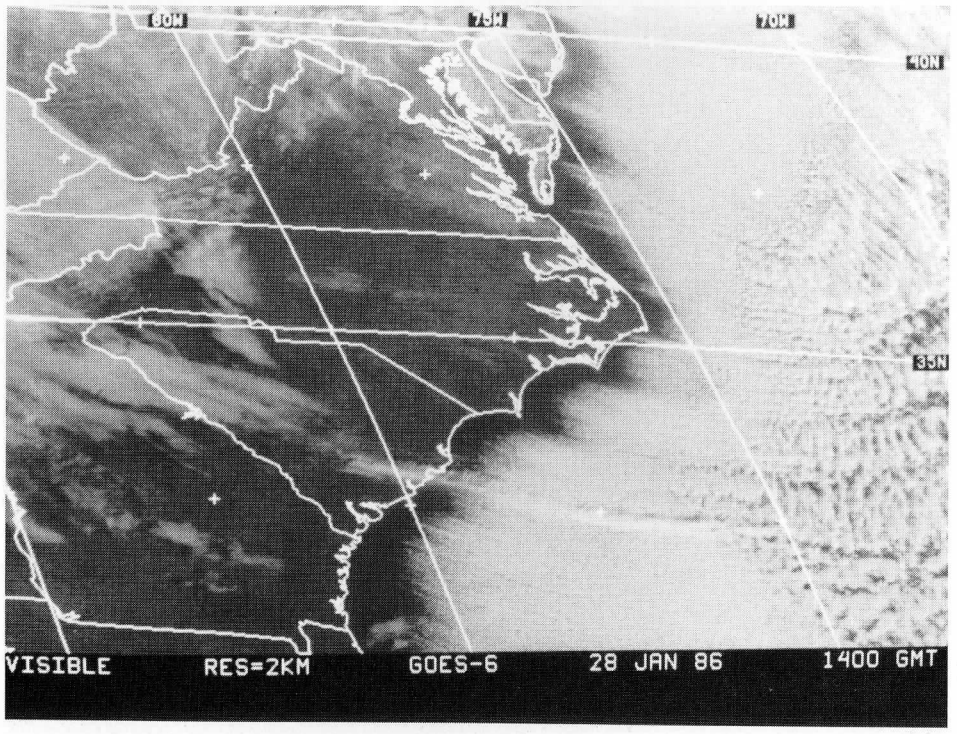
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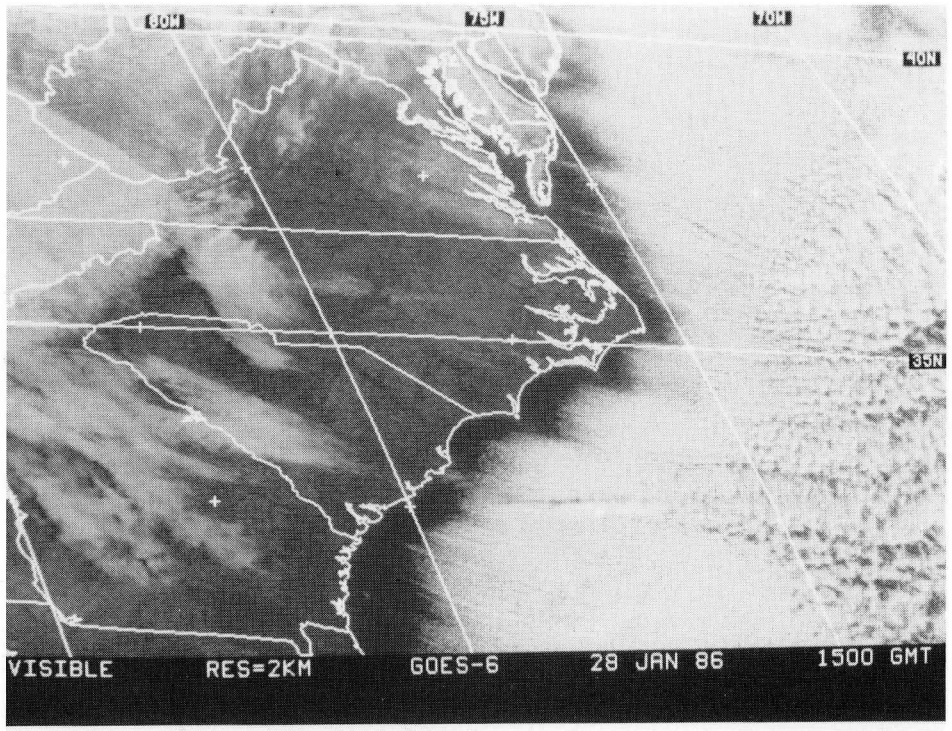
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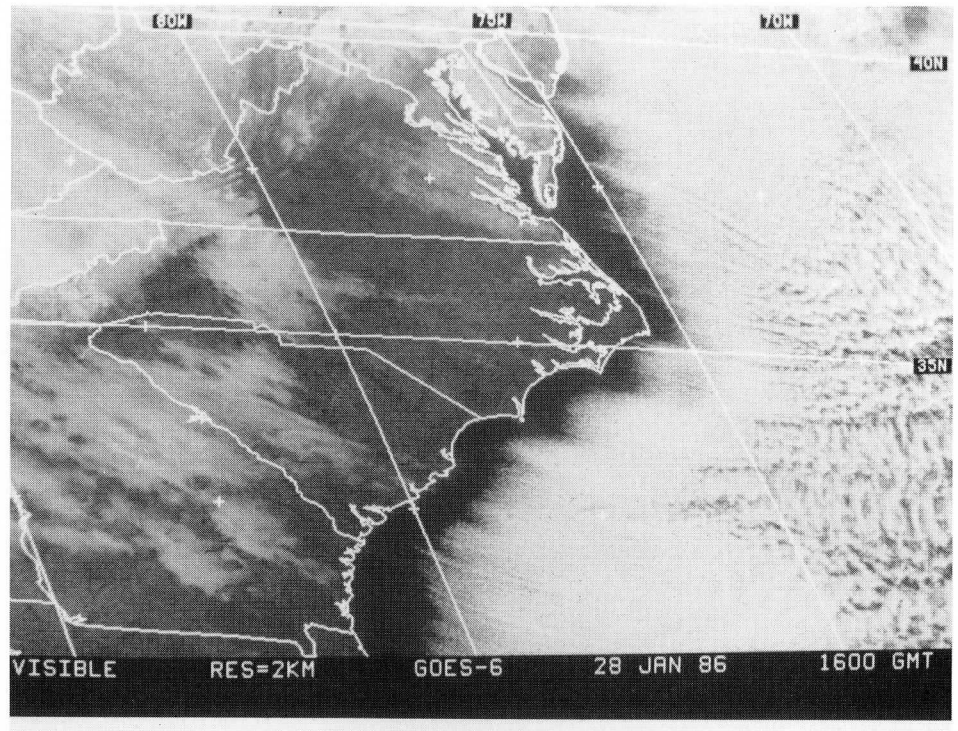
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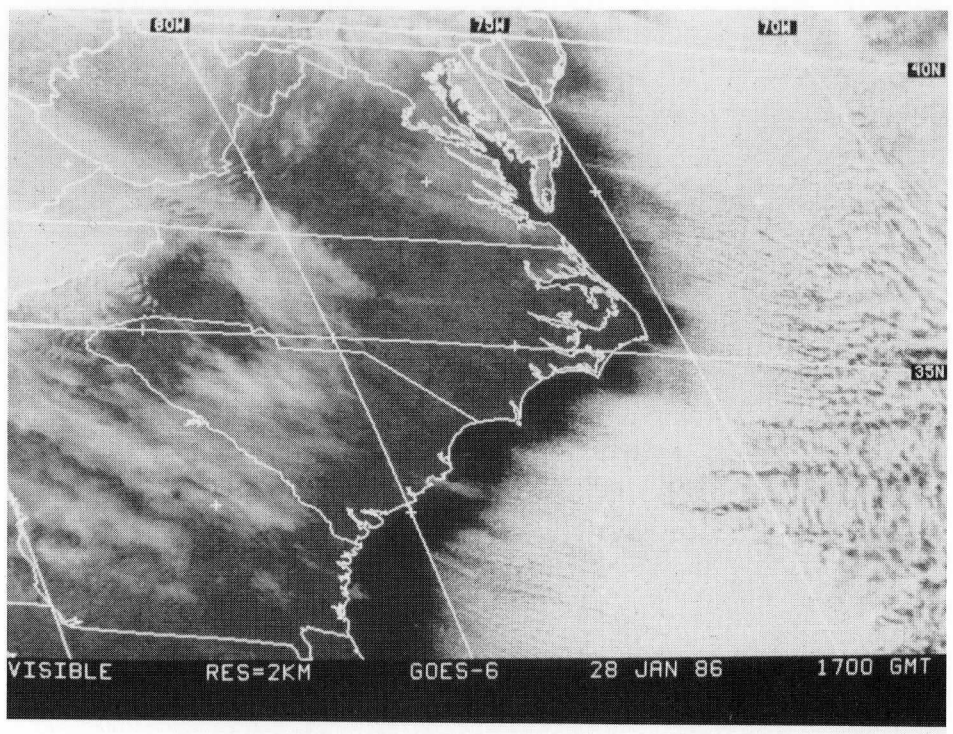
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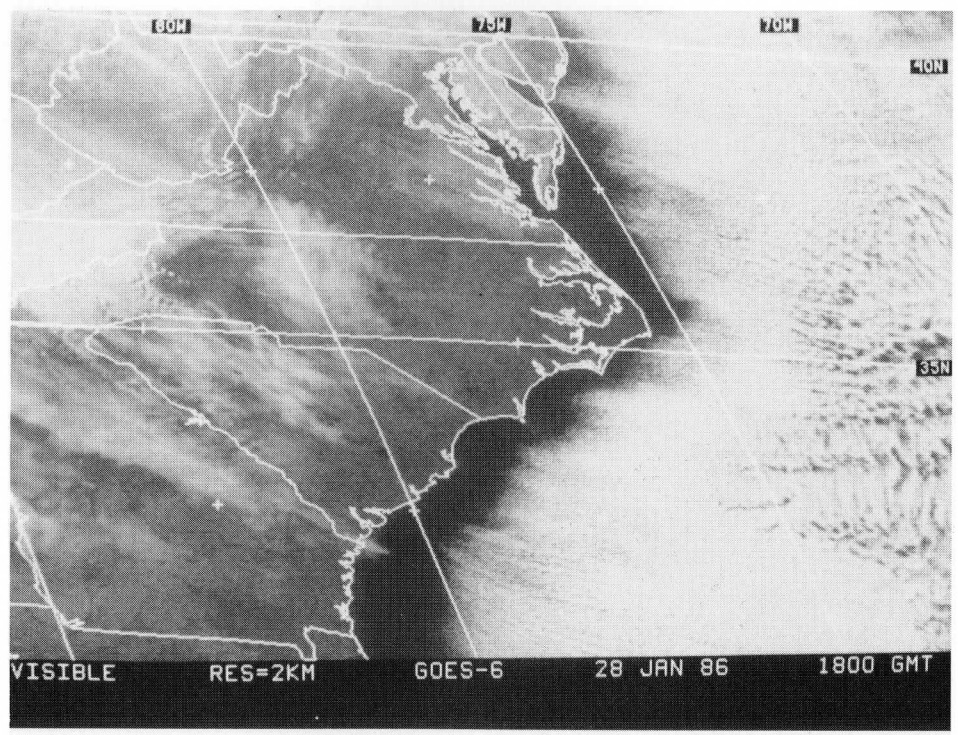
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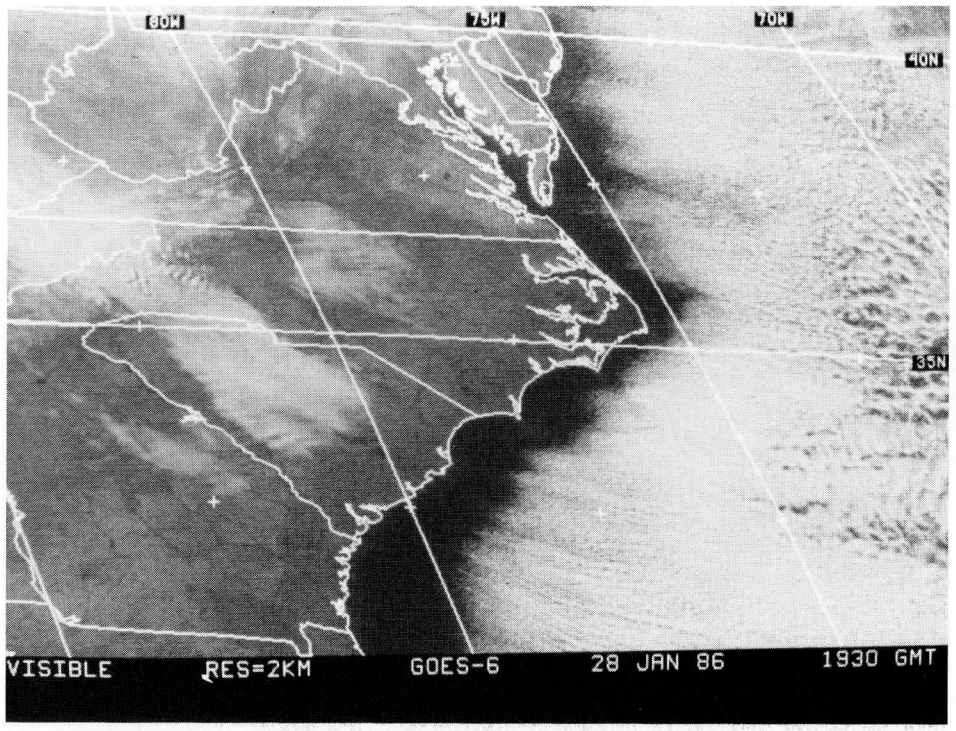
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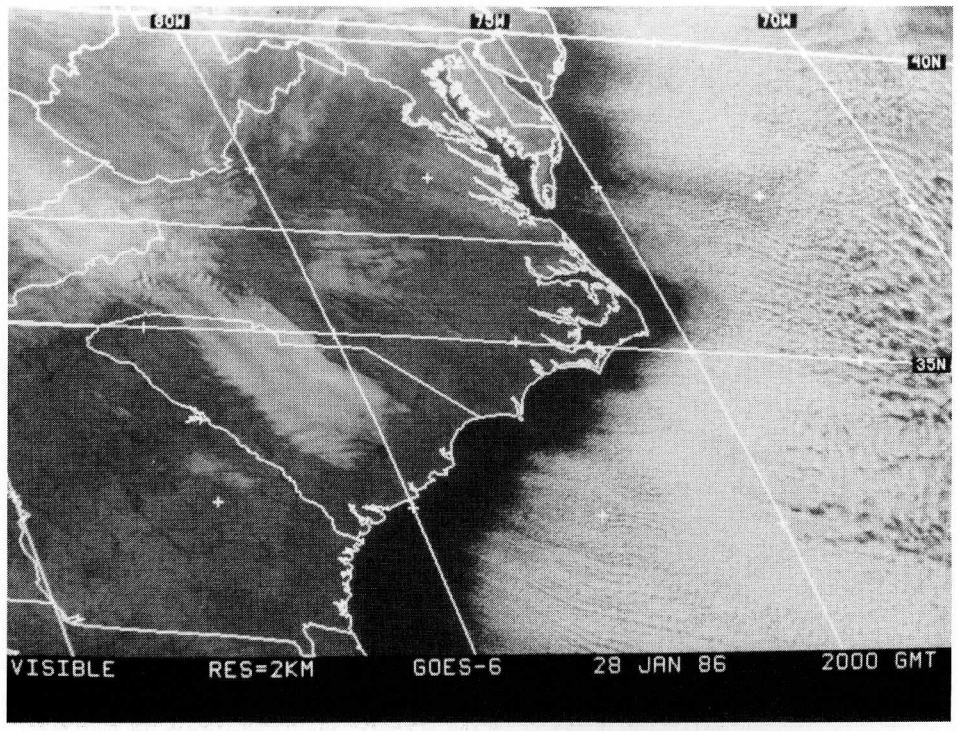
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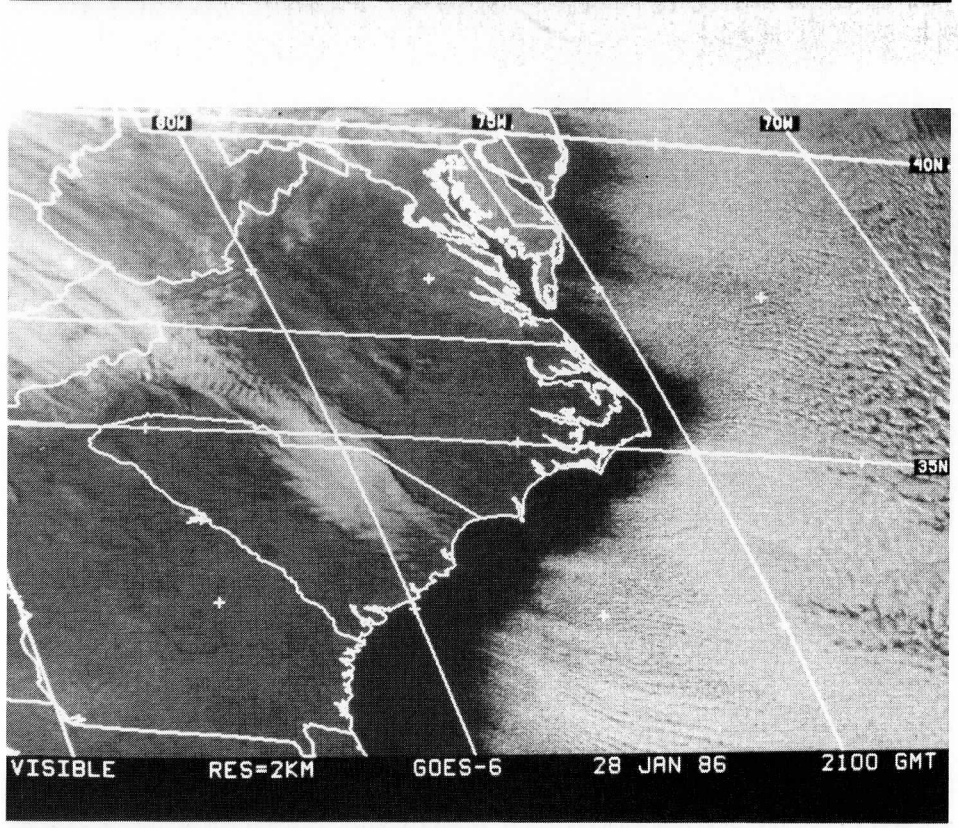
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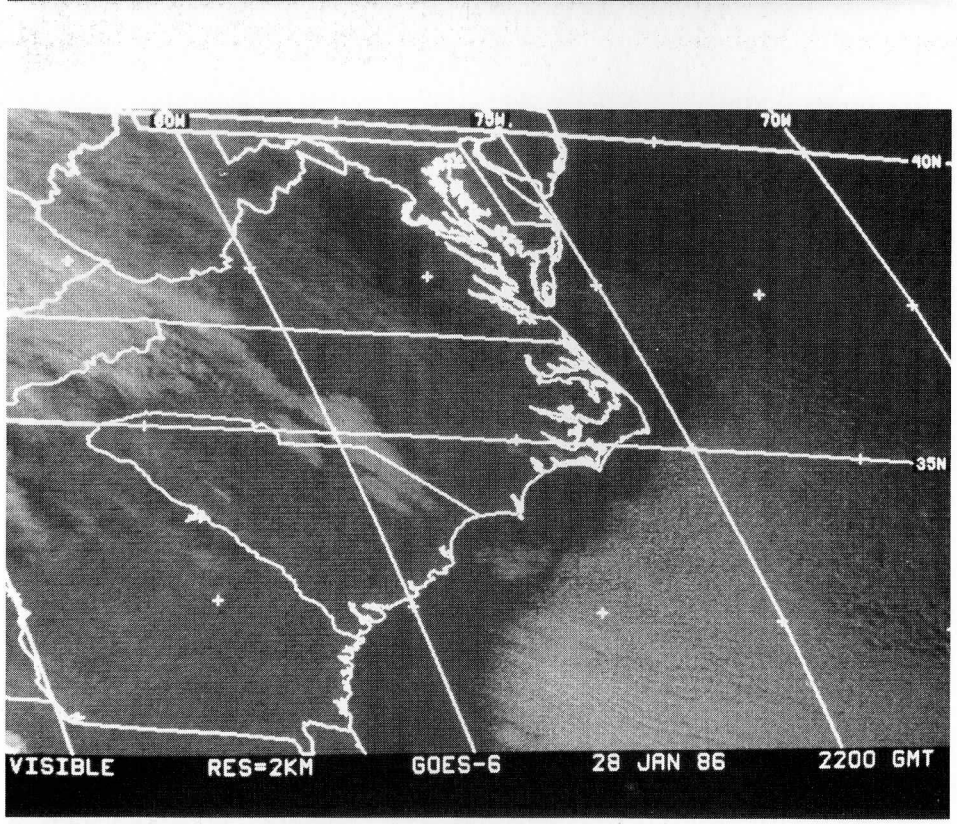
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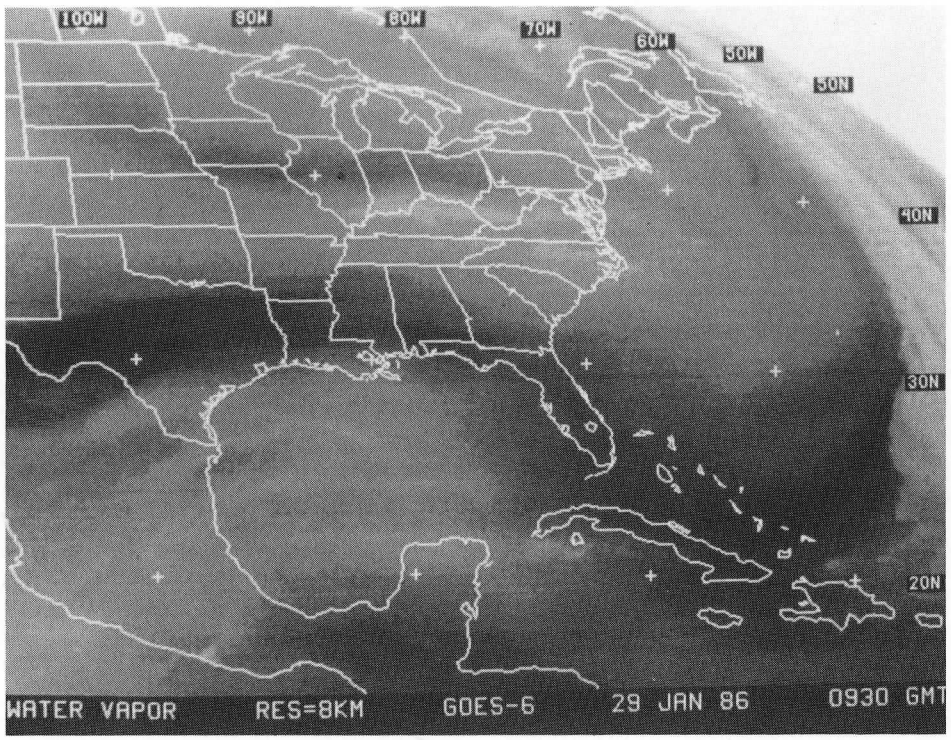
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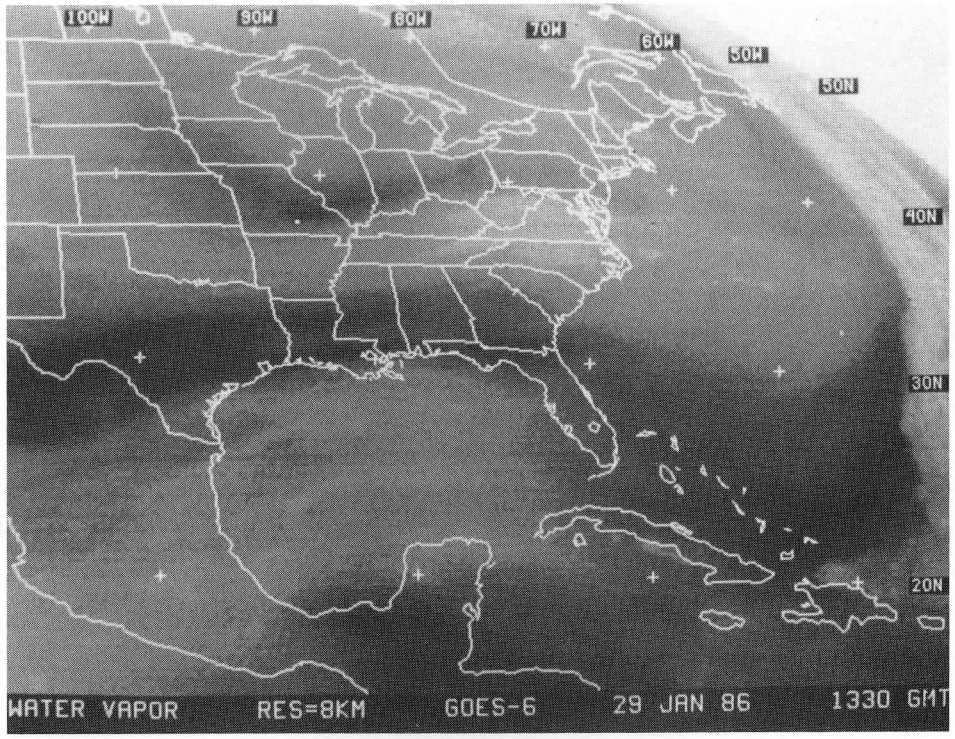
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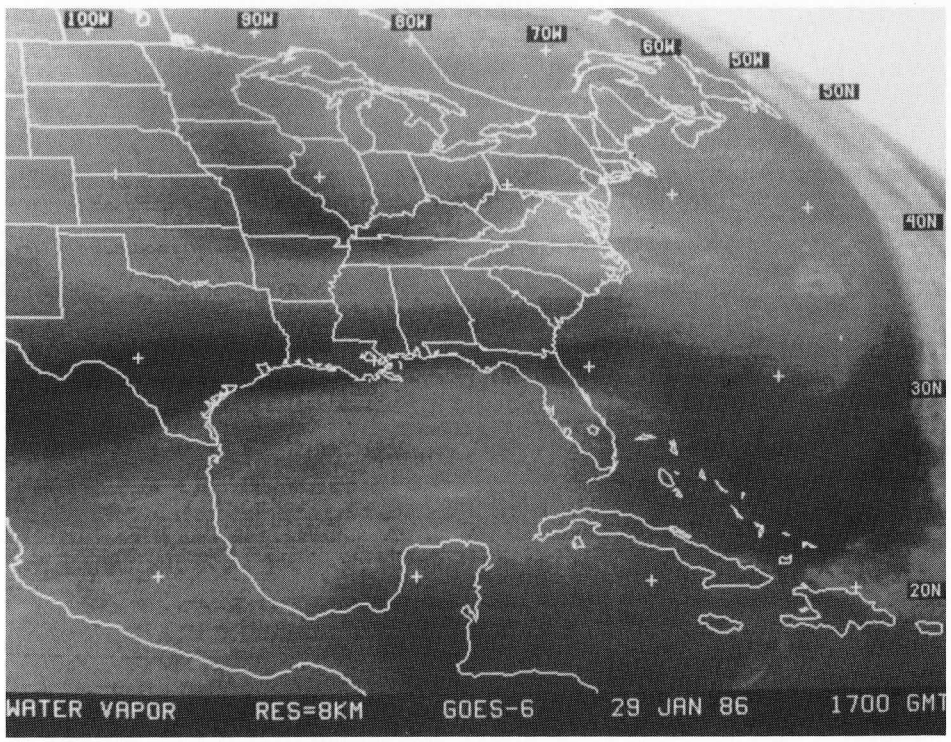
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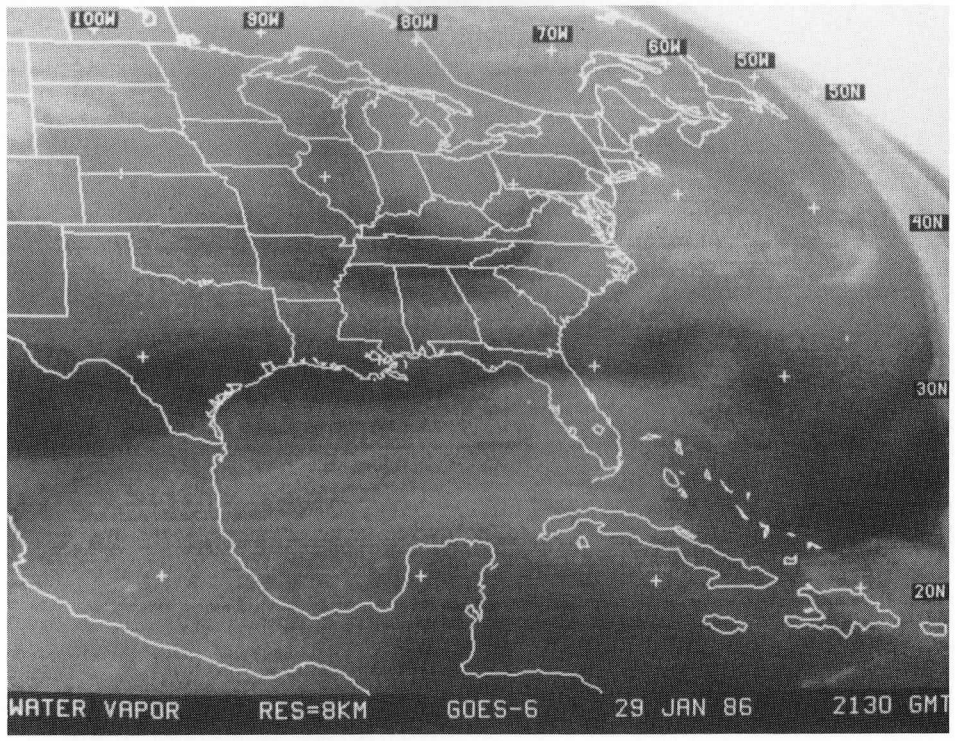
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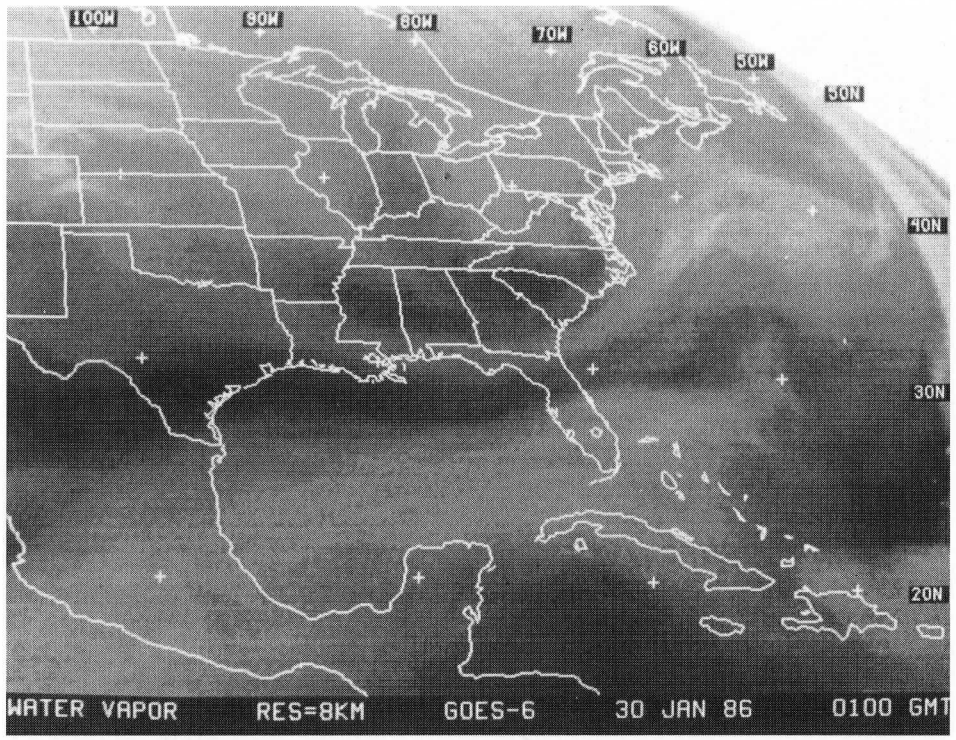
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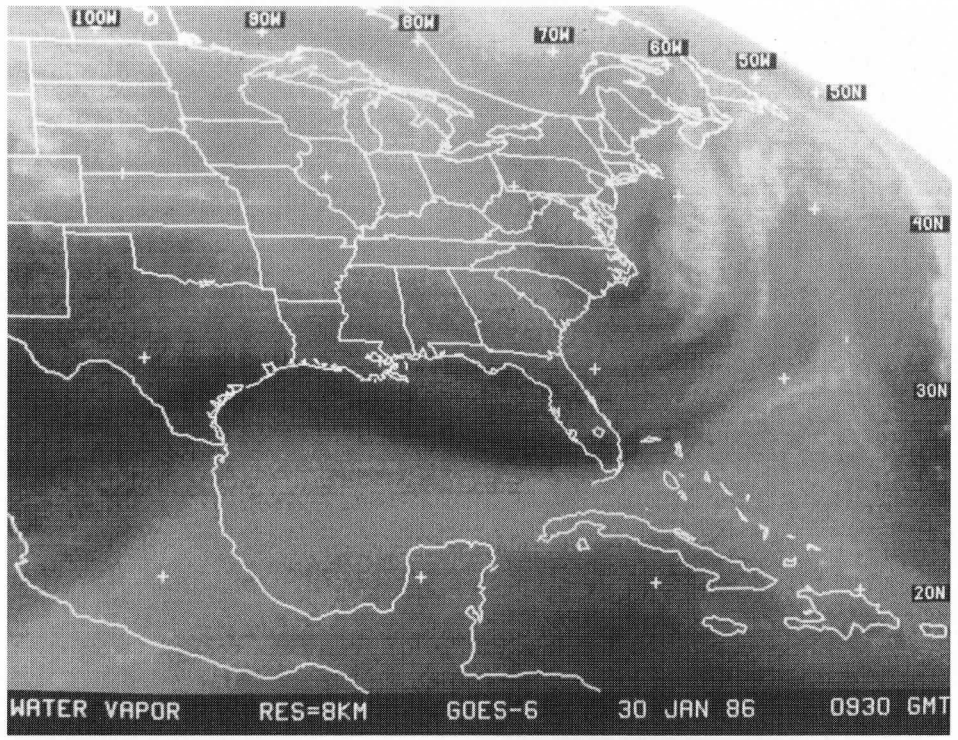
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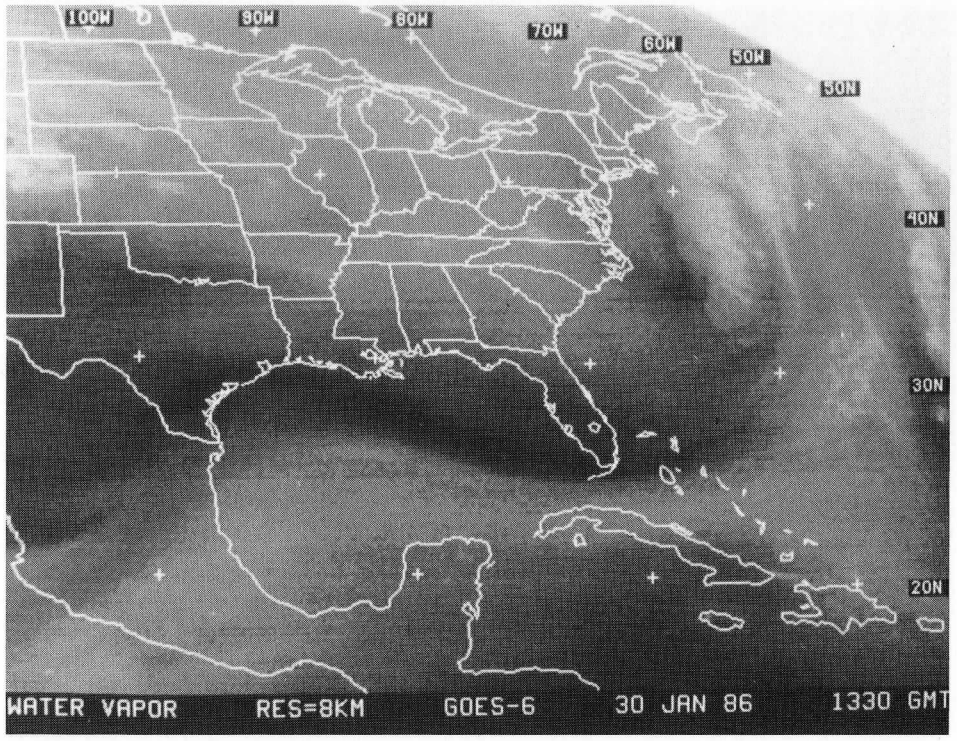
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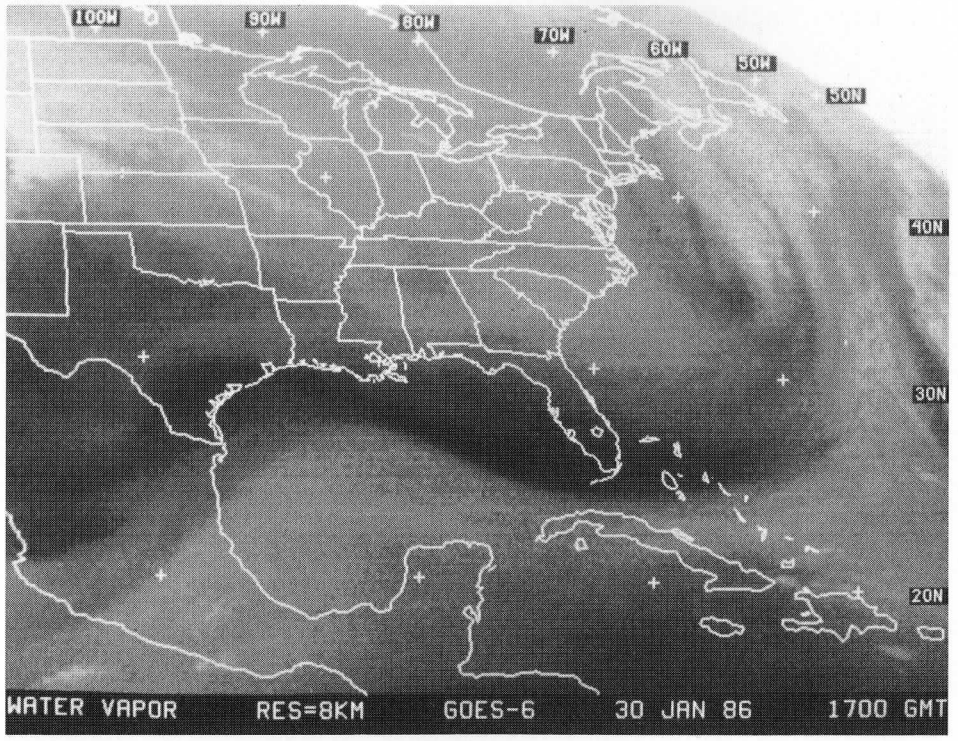
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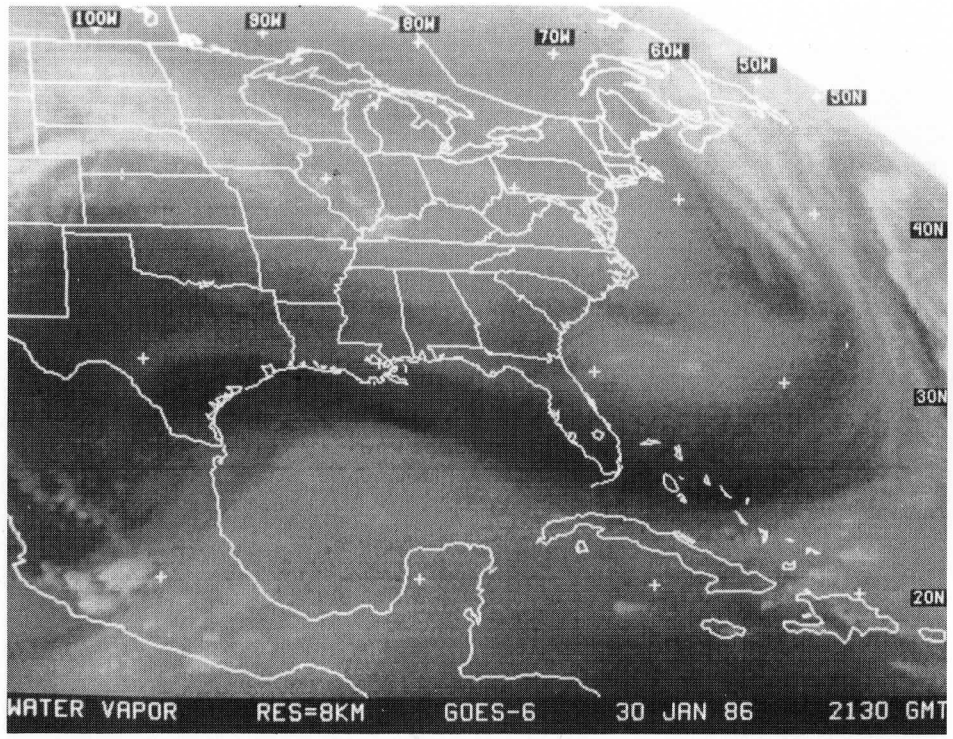
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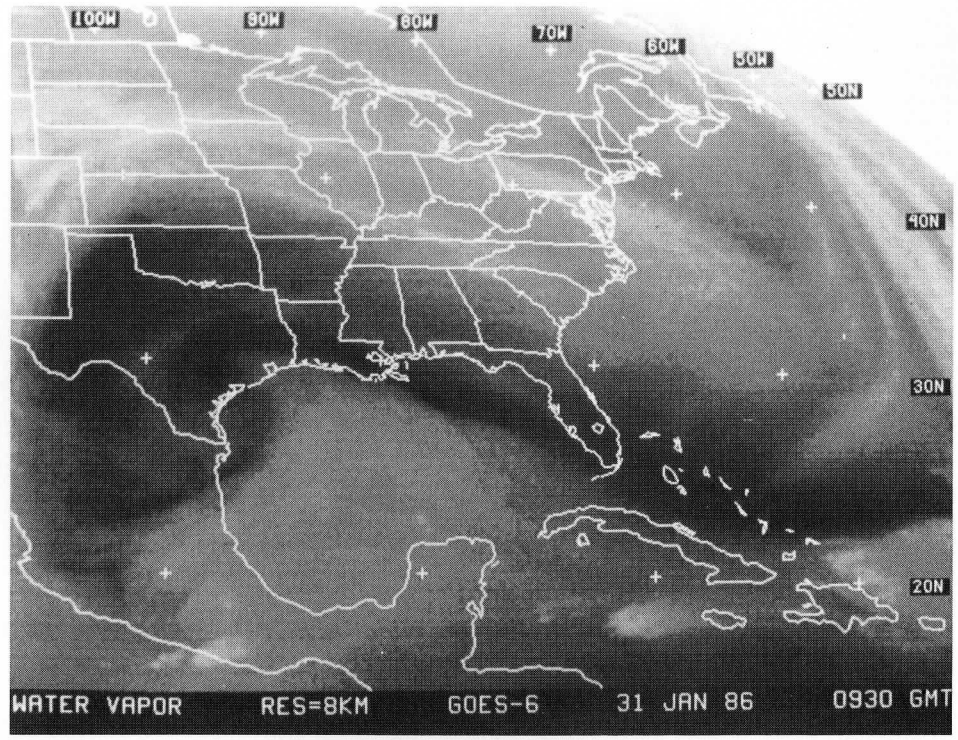
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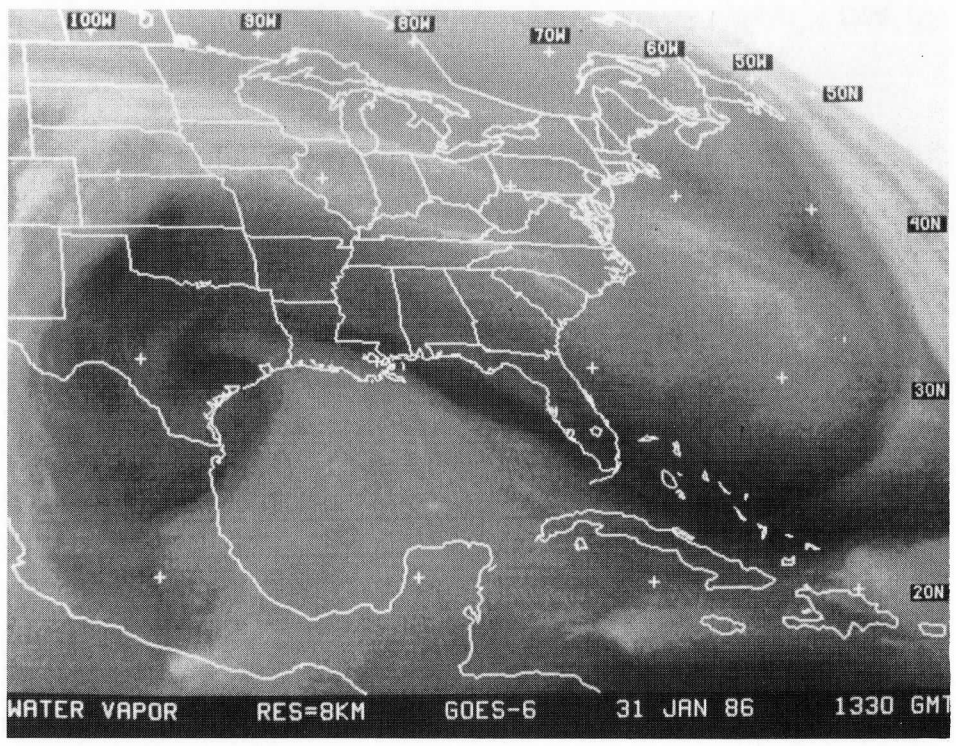
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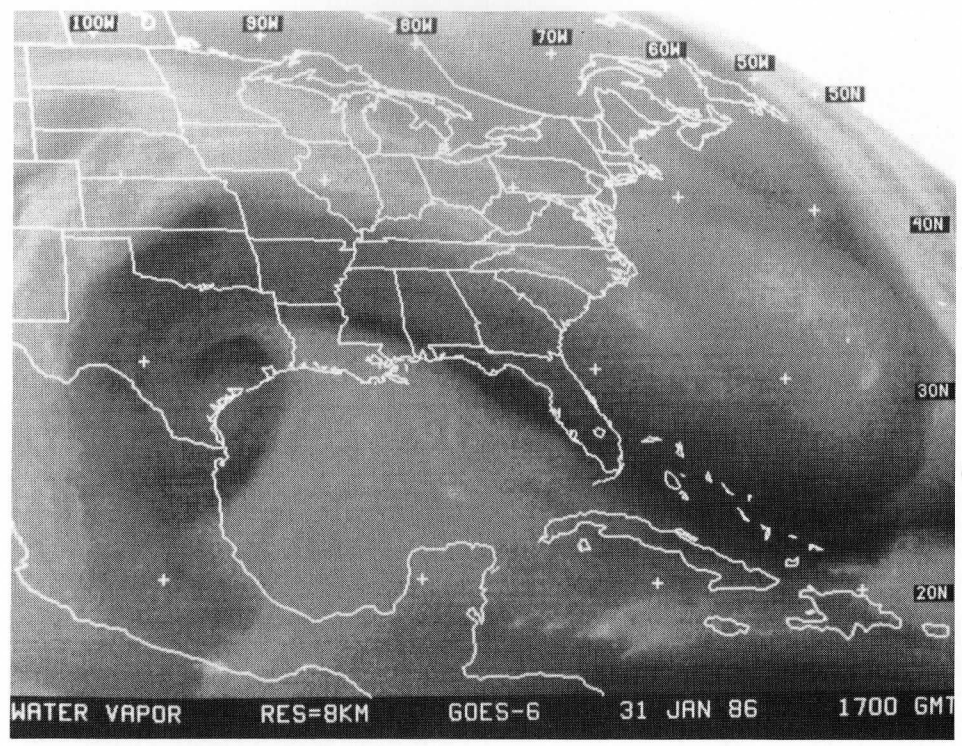
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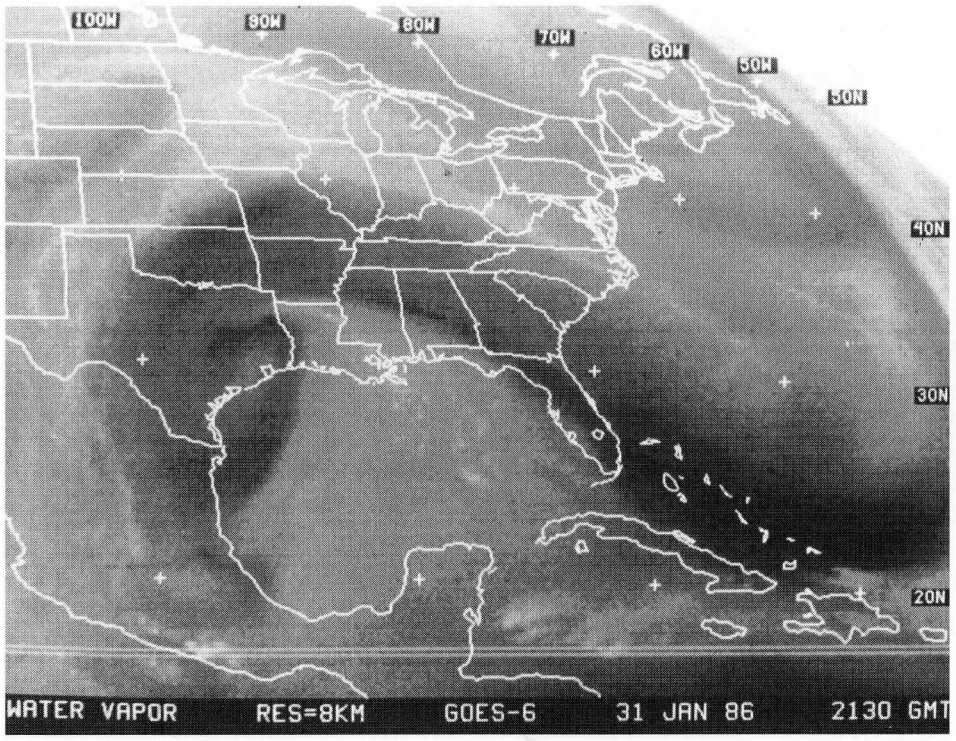
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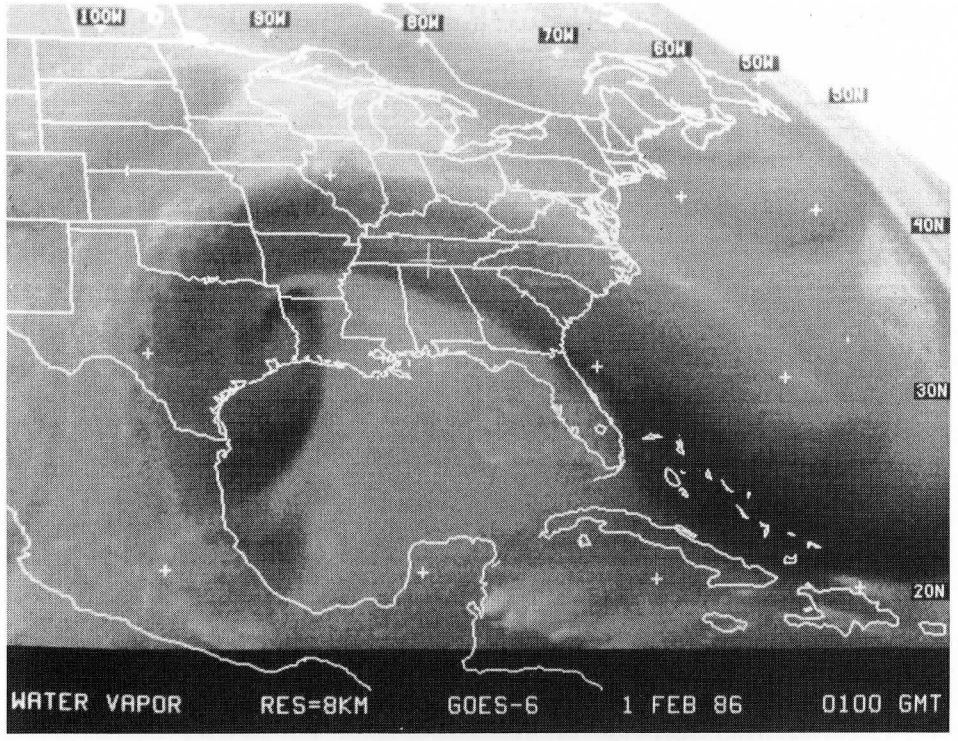
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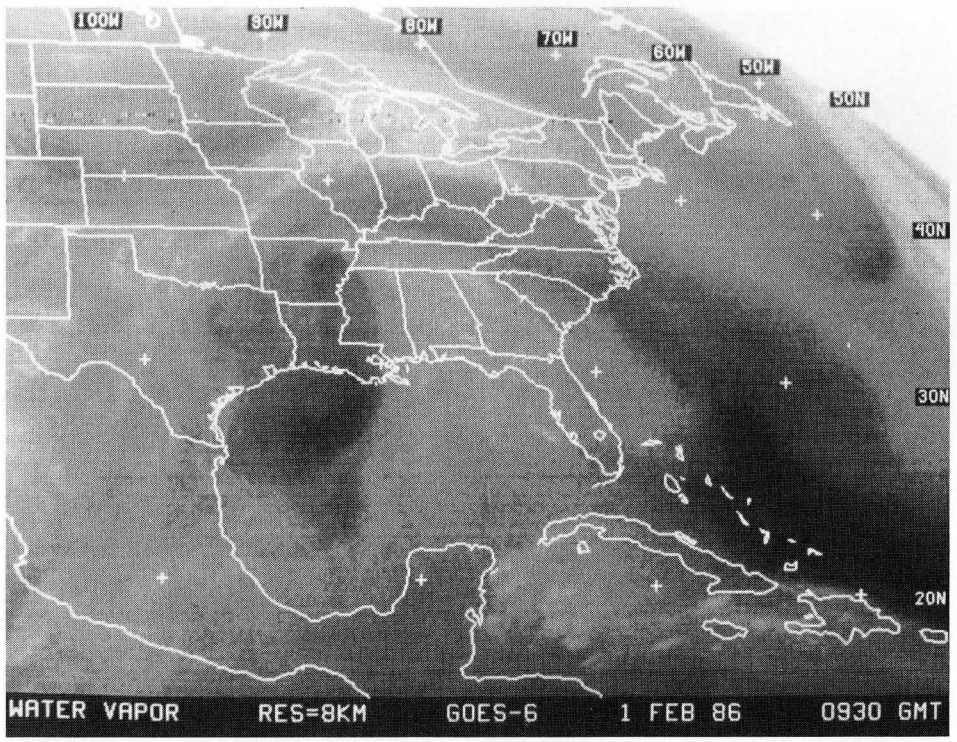
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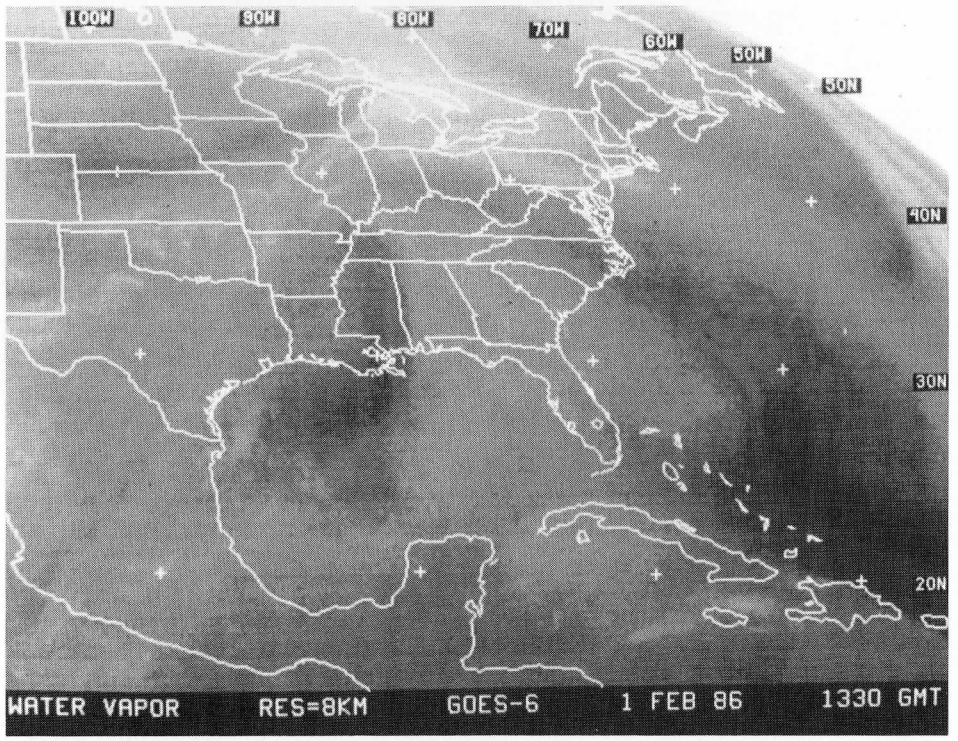
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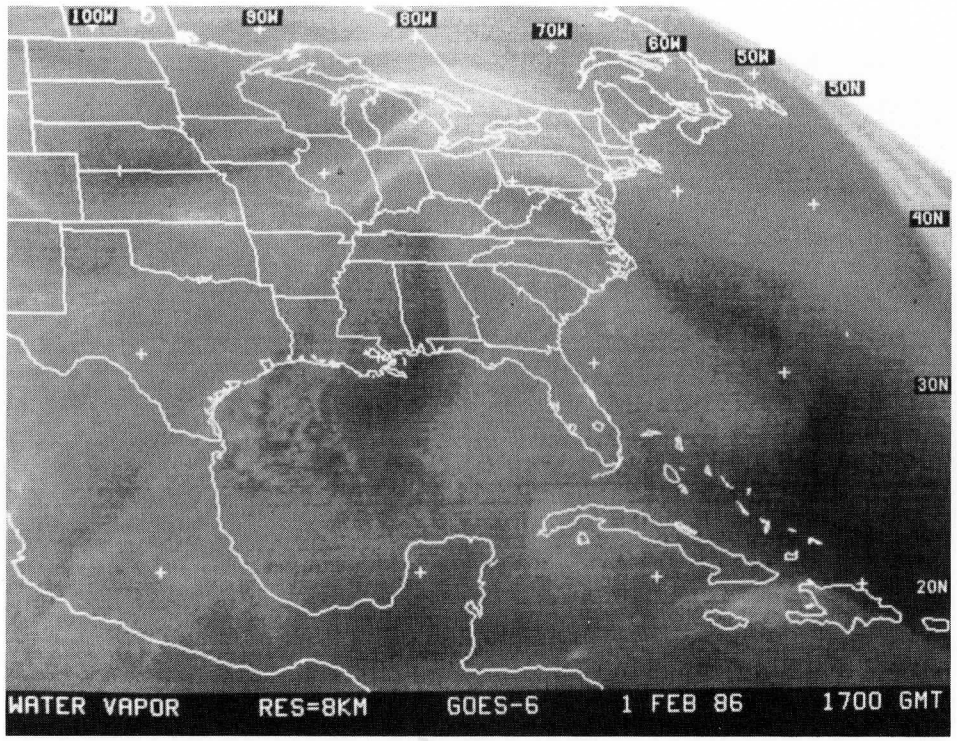
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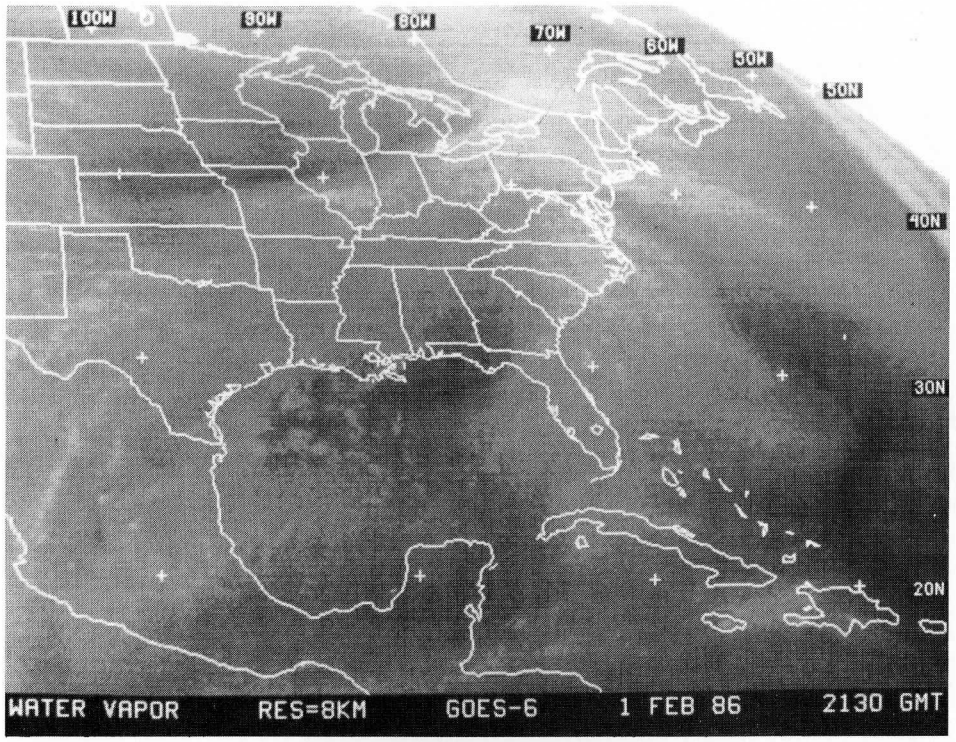
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IOP #3 - Stationary Front / Cyclogenesis Offshore
February 2 - February 4

Satellite Synopsis

Water Vapor

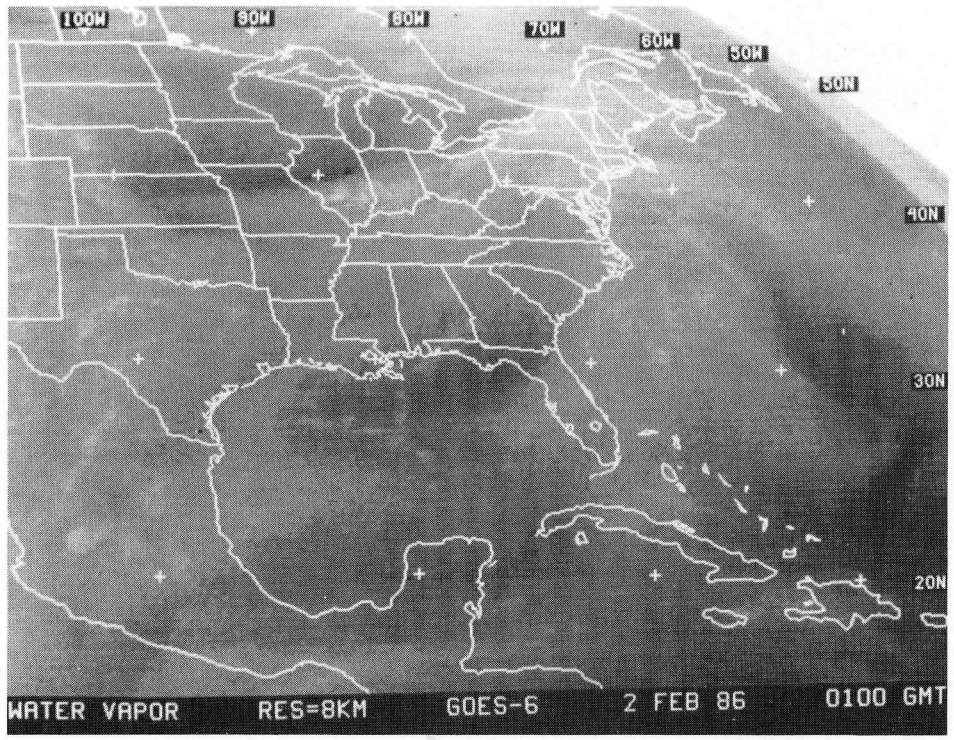
- Very moist environment aloft throughout the period.
- Note the influx of moisture from Central America late on the 3rd into the 4th.
- A strong subsidence/dry area appears over Mexico on the 3rd through the 4th which progresses to the western Gulf by 00 GMT on the 5th.
- A weaker, secondary system is apparent on the 4th which moves northeast into Iowa by 00 GMT on the 5th.
- The ridge over the east is very evident in the moisture pattern.

IR

- A system moves over the New England coast on the 2nd.
- Clouds produced by overrunning exist from the Great Lakes to north of Cape Hatteras on the 3rd through the 4th.
- GALE area in warm sector with some small convection late on the 4th.
- The next system moves in from Mississippi by 00 GMT on the 5th.

Visible

- 2nd, striking wave clouds in West Virginia, Virginia and Pennsylvania.
- 2nd, Gulf Stream convergence line develops (with oscillations late).
- 4th, some Gulf Stream convection.
- 4th, east to west convergence band along 33N from 77-73W.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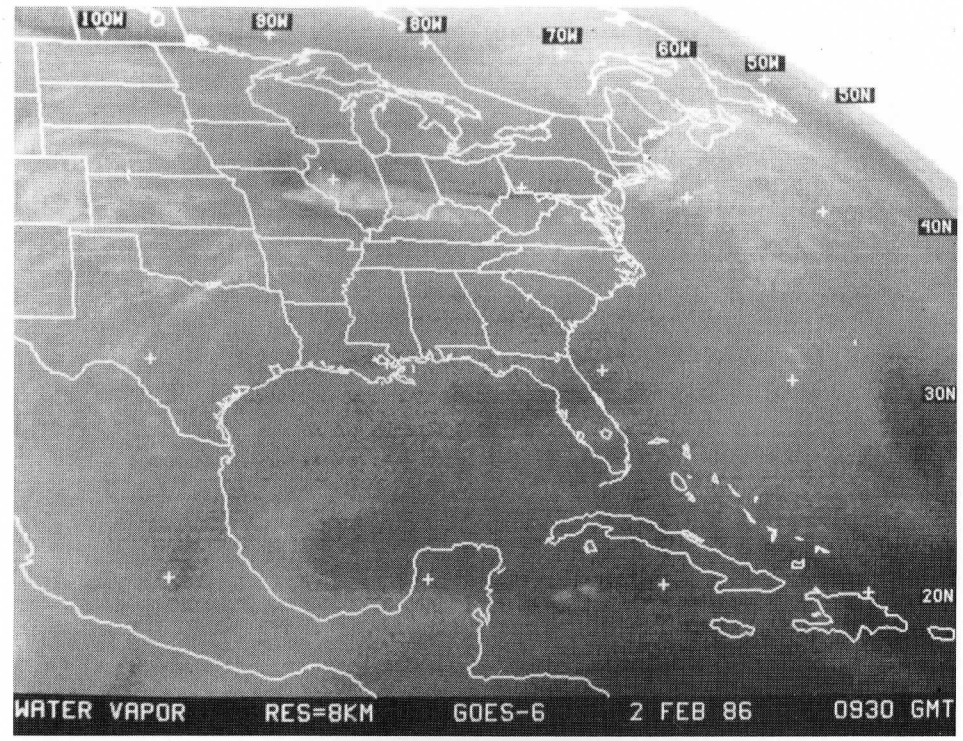
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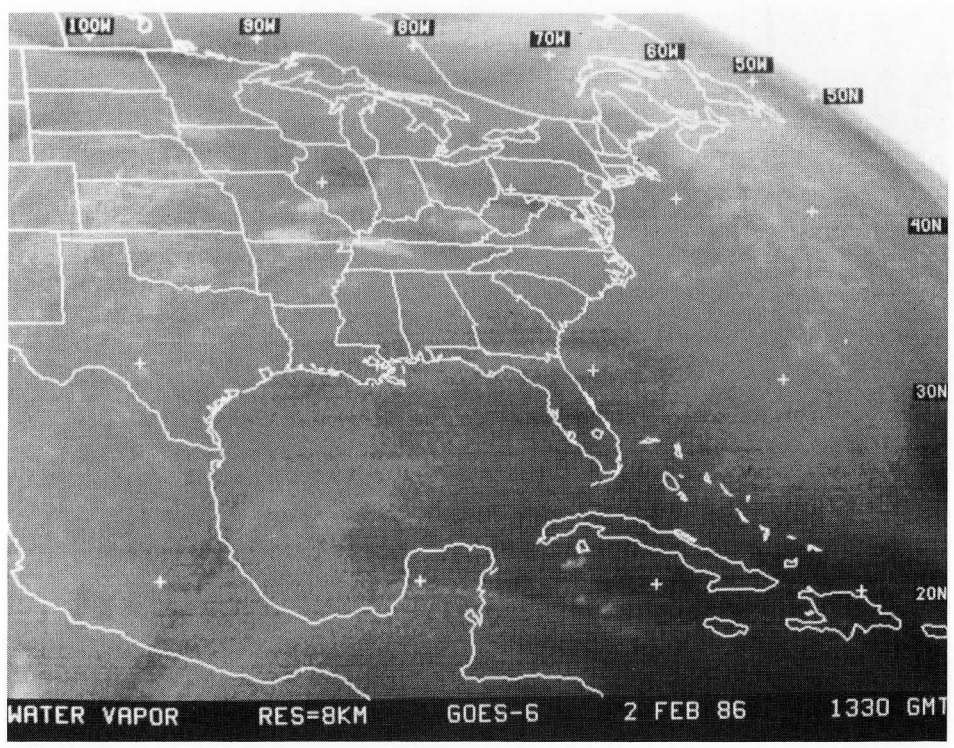
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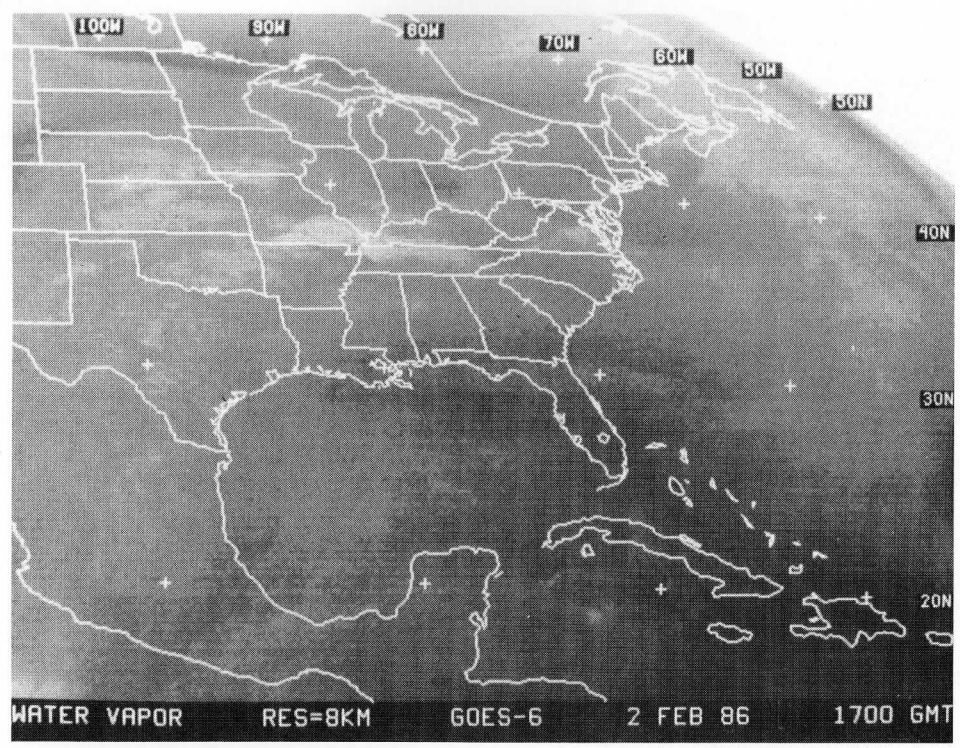
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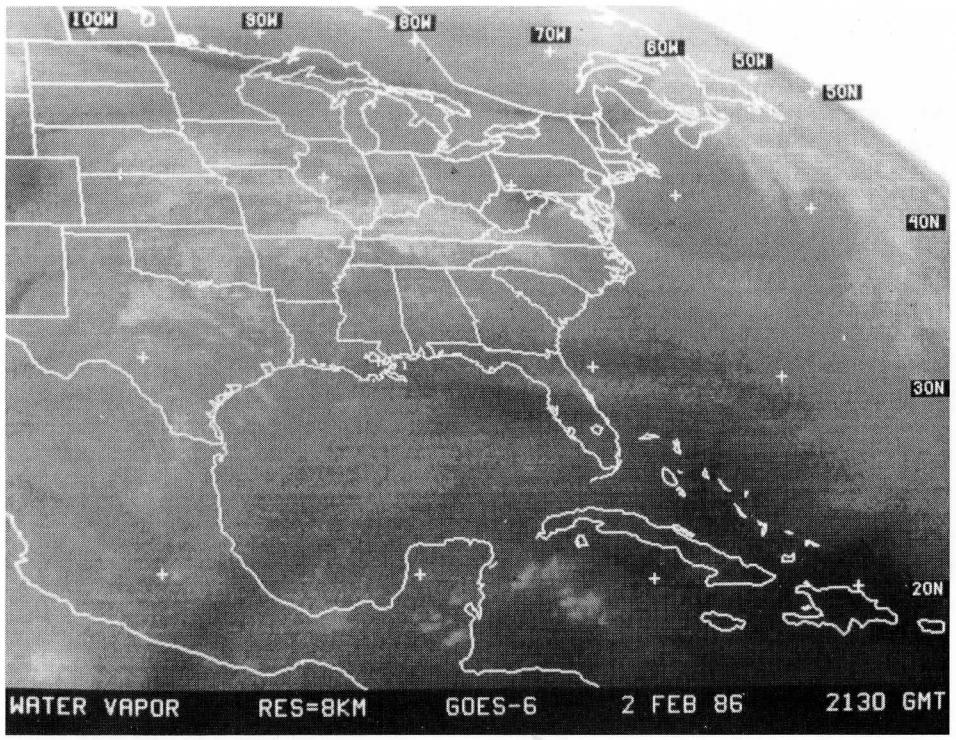
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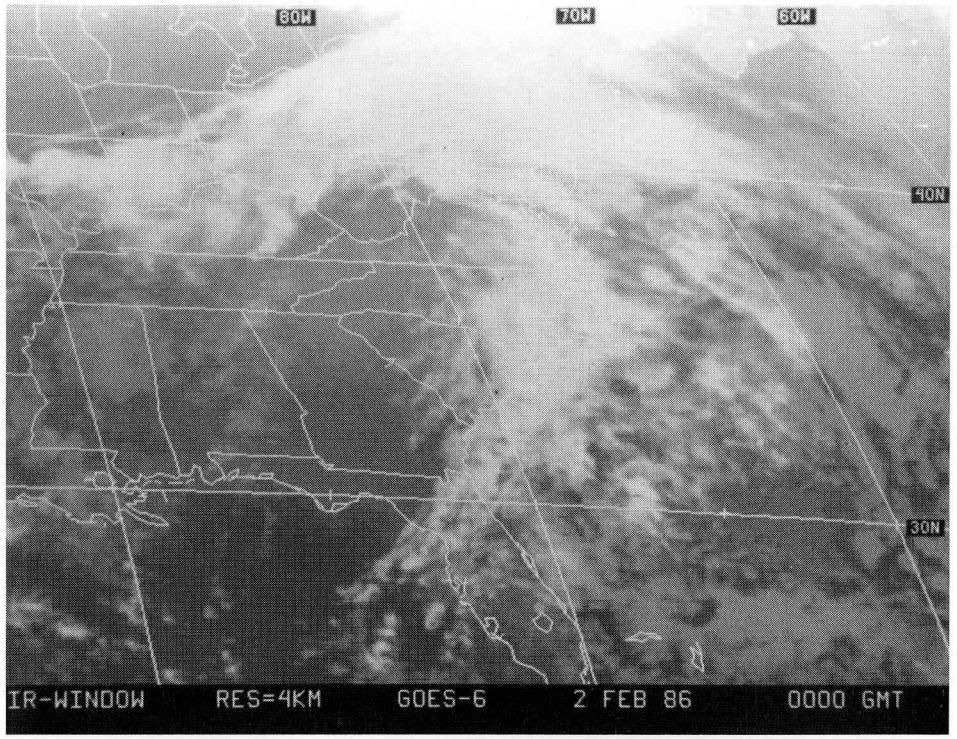
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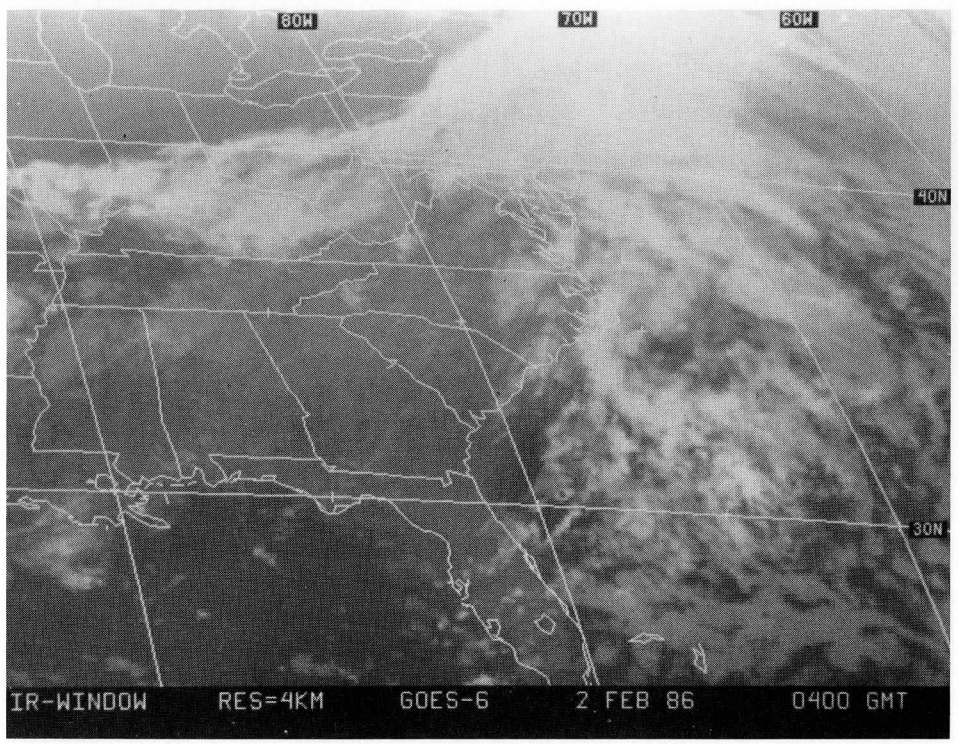
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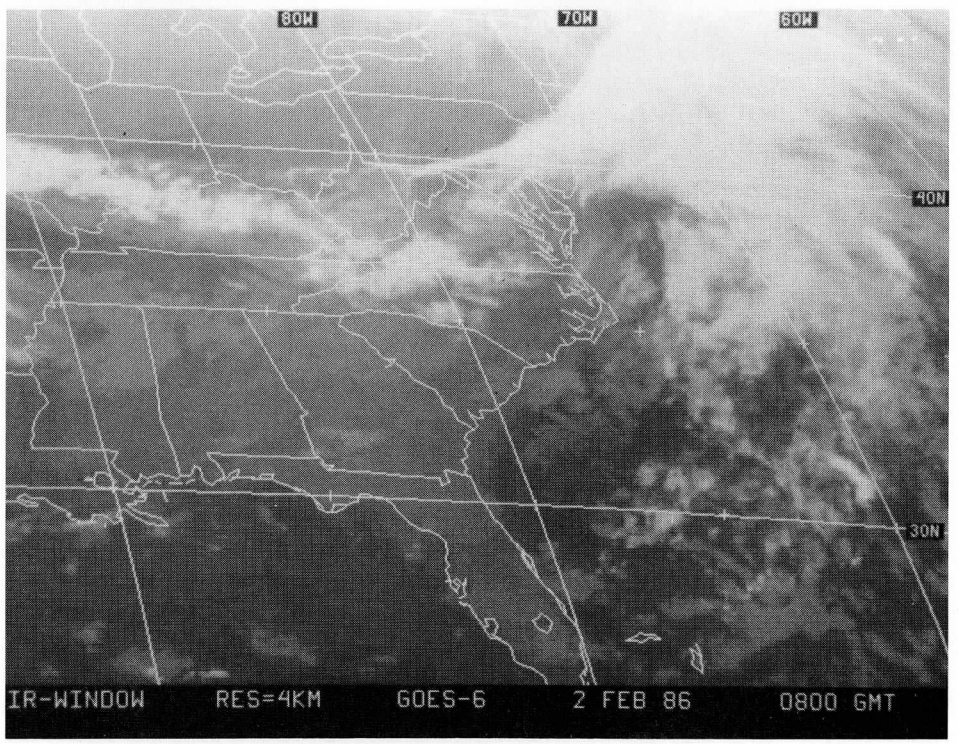
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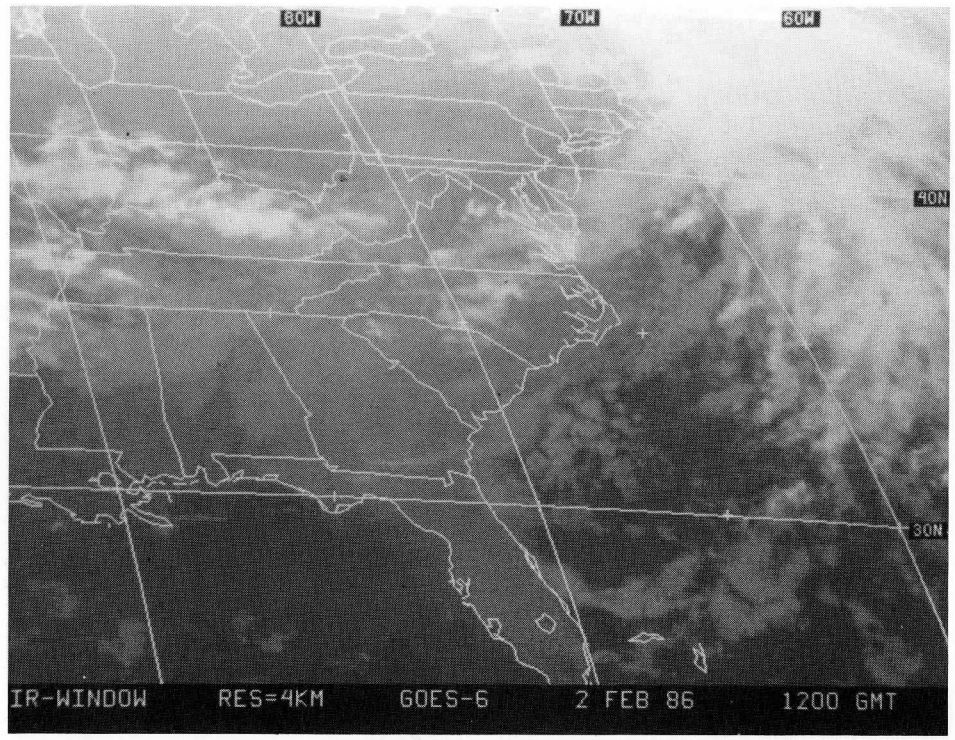
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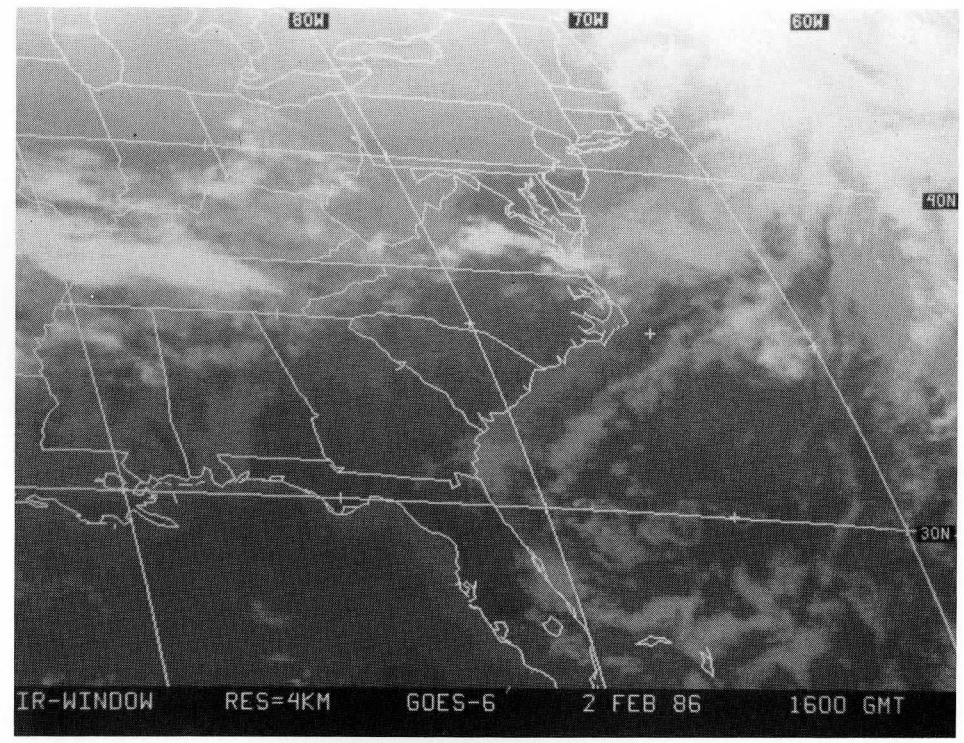
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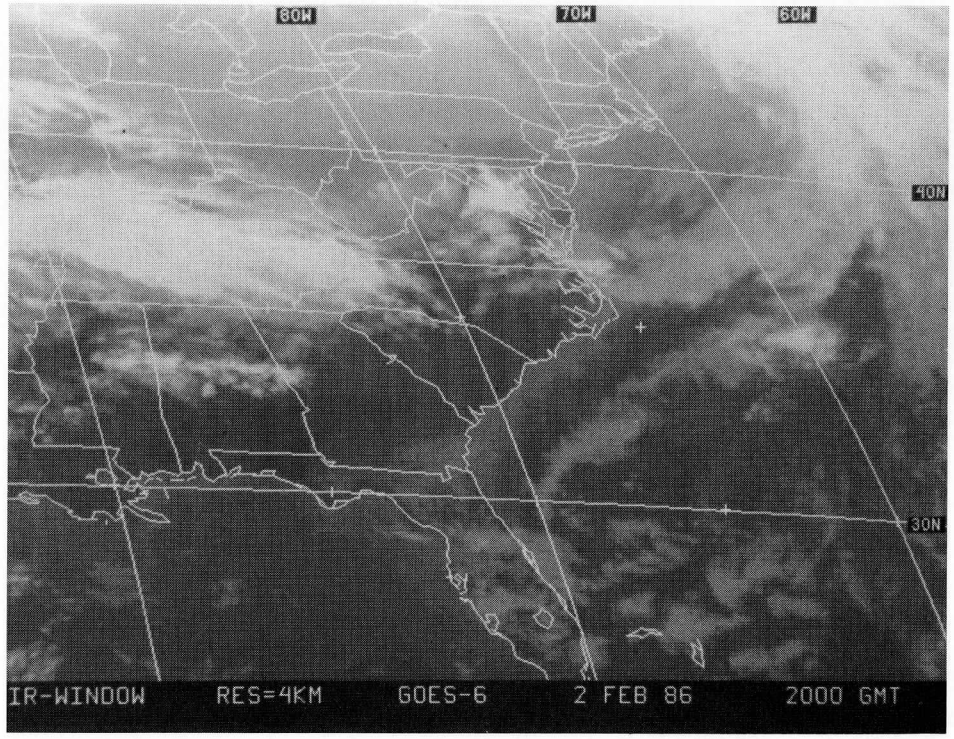
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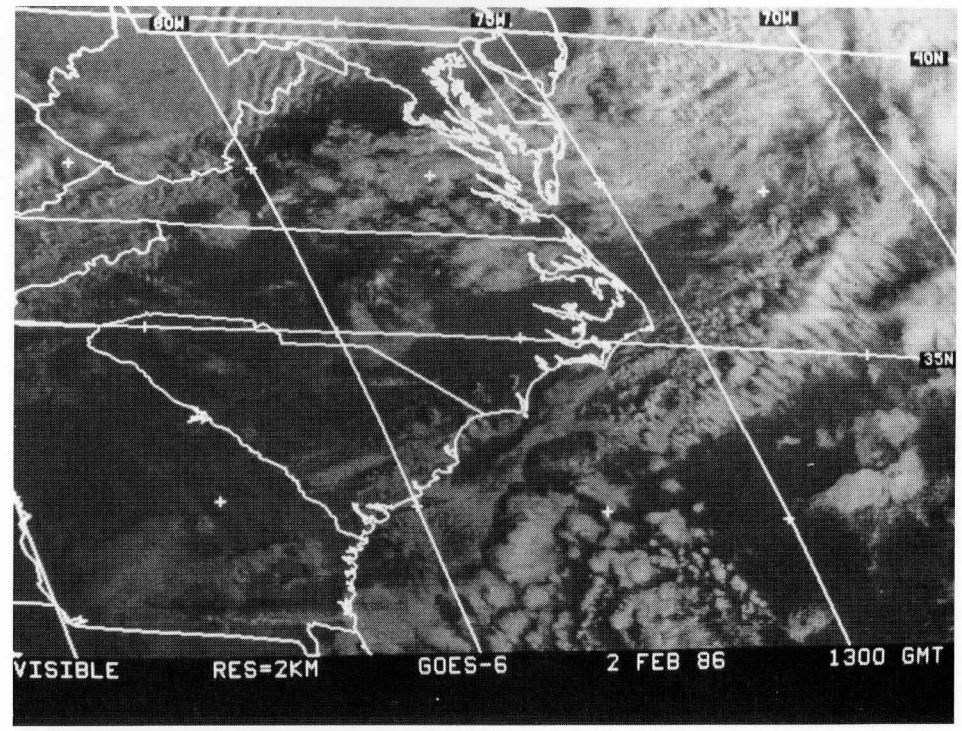
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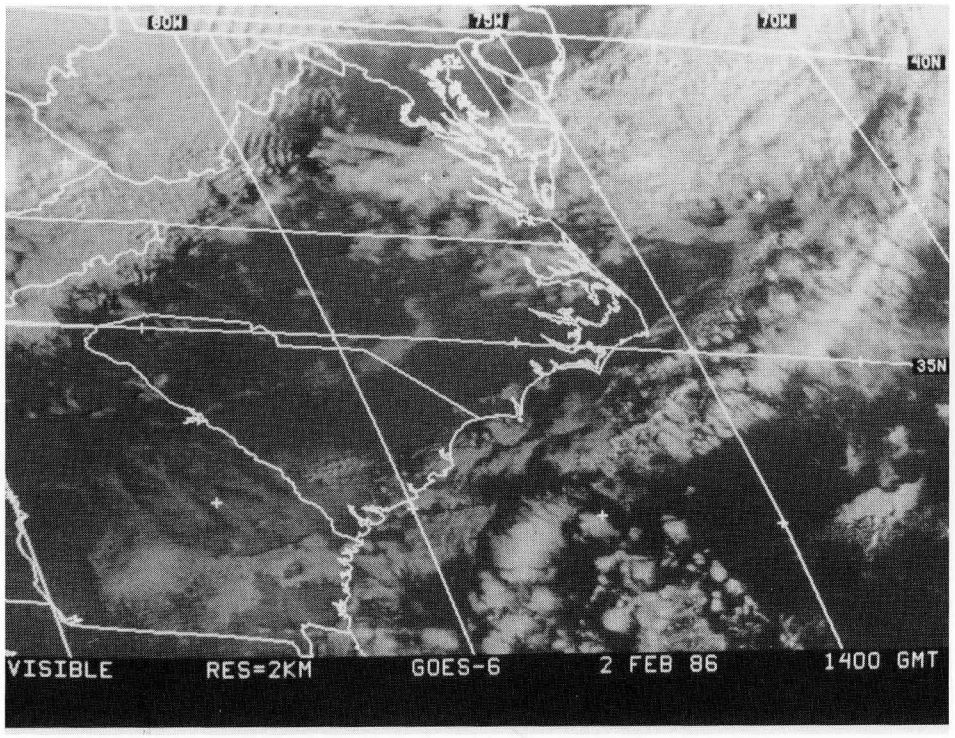
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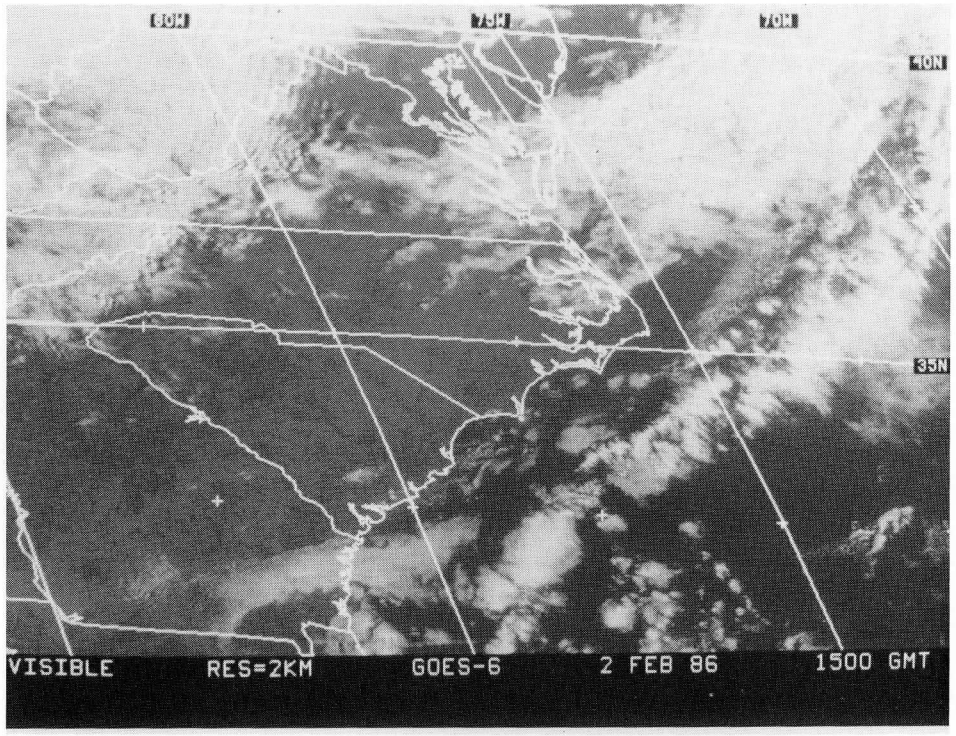
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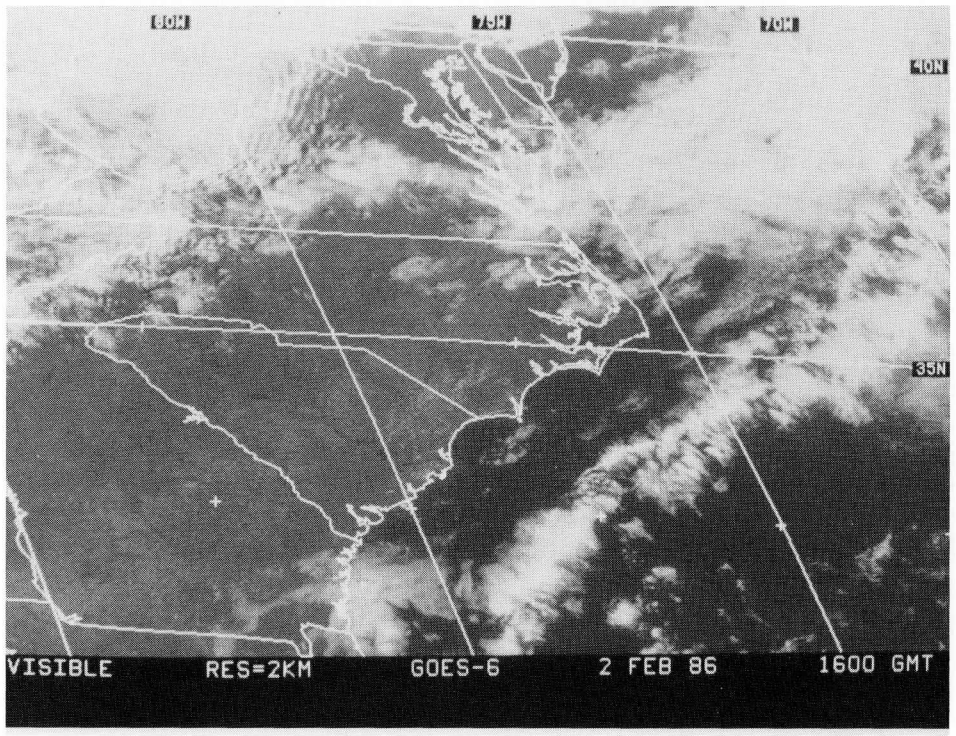
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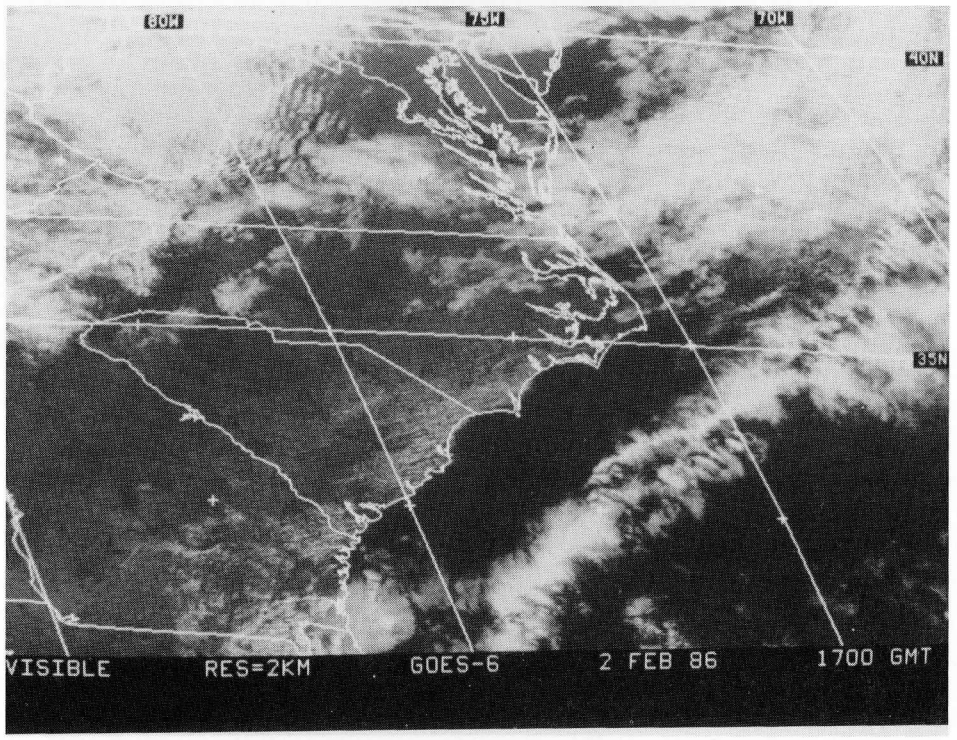
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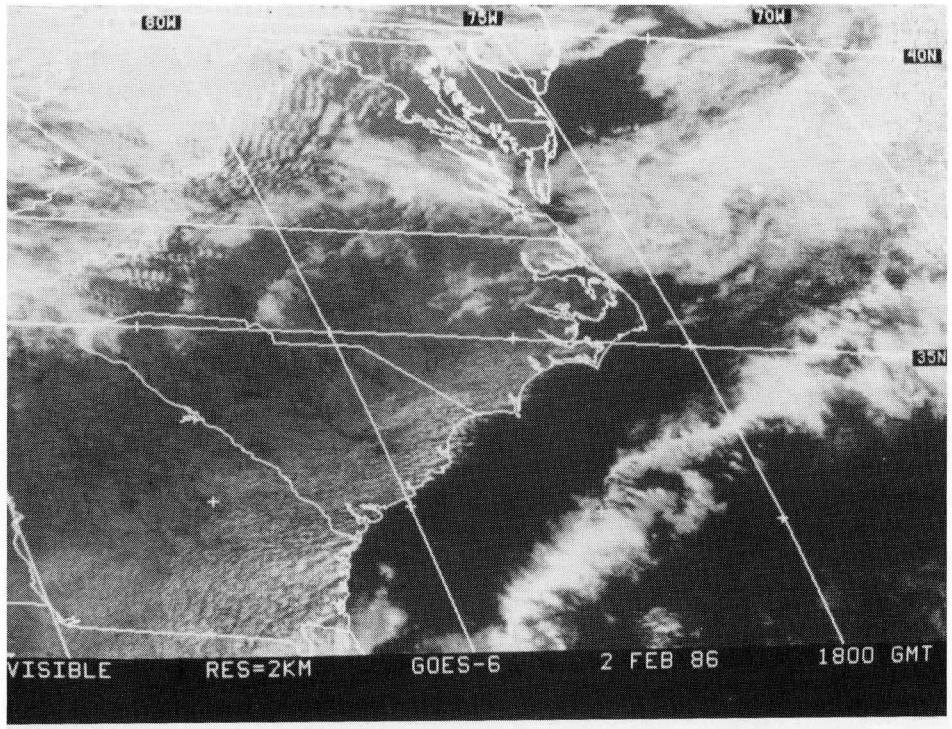
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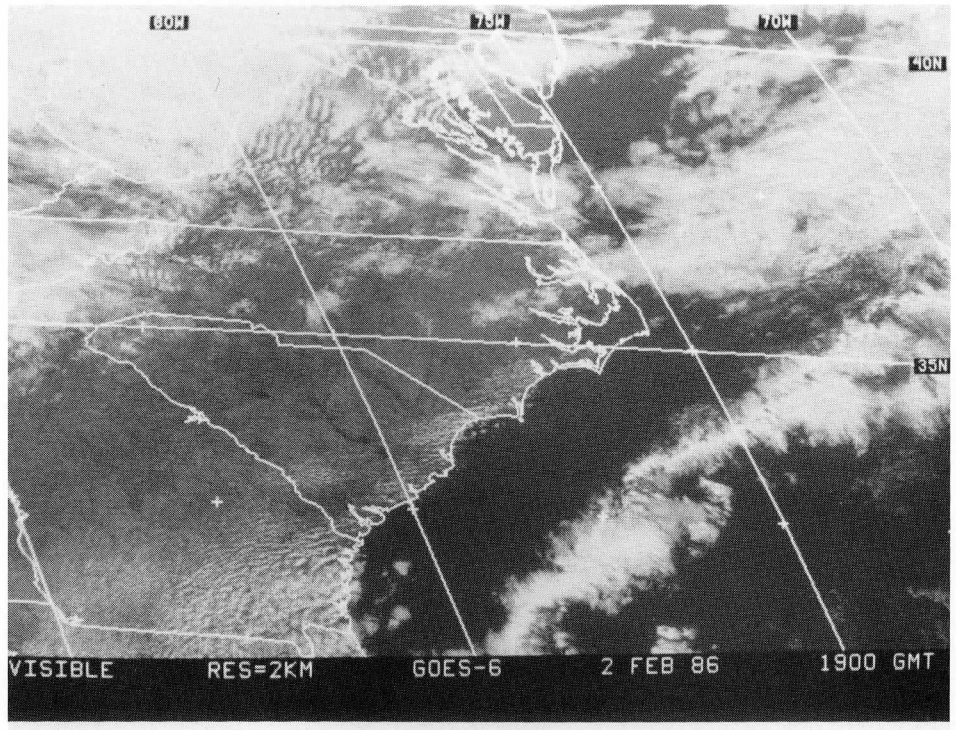
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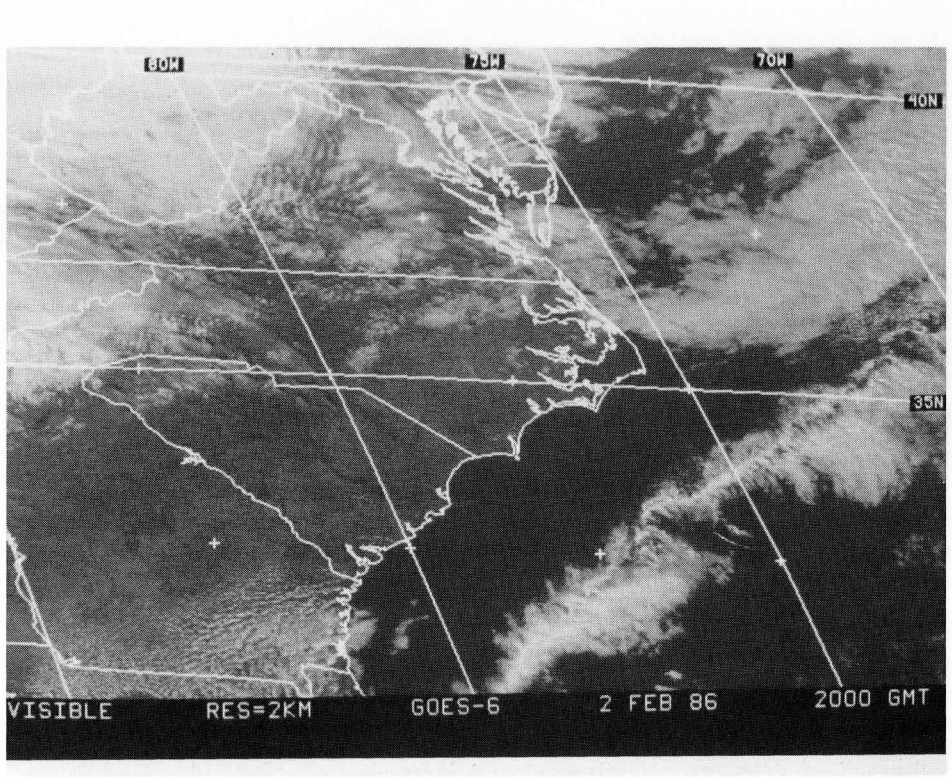
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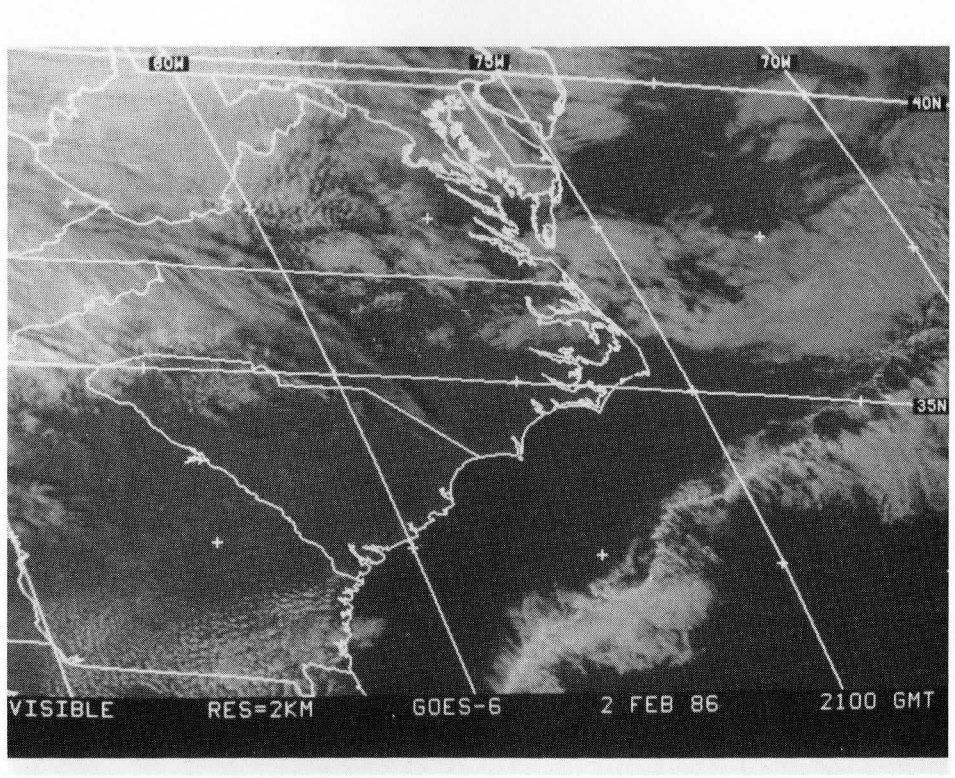
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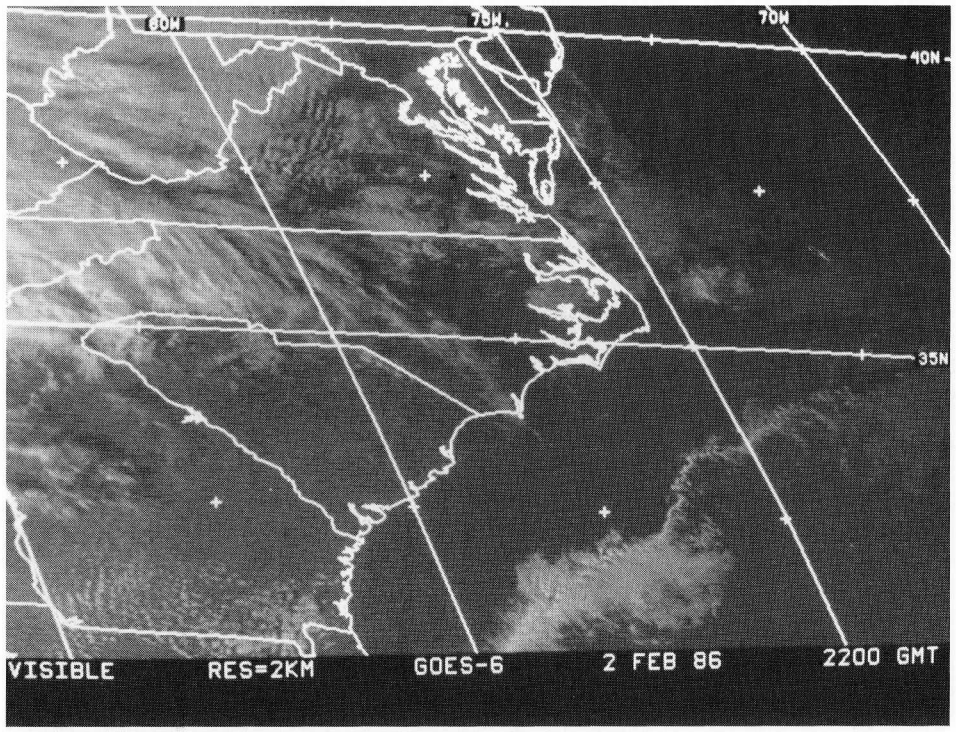
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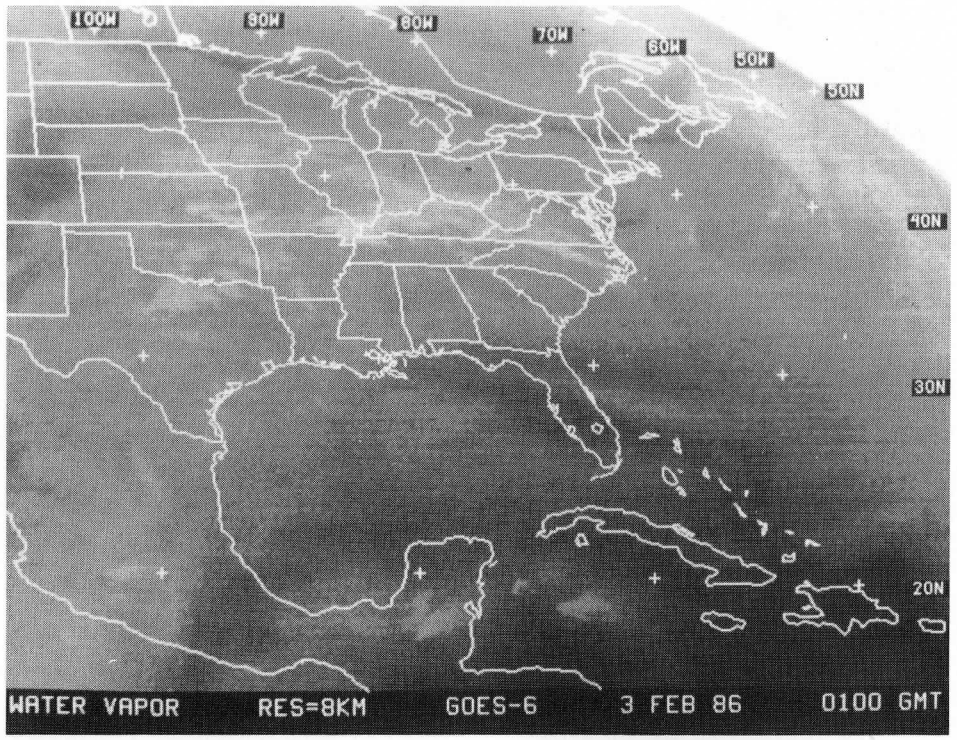
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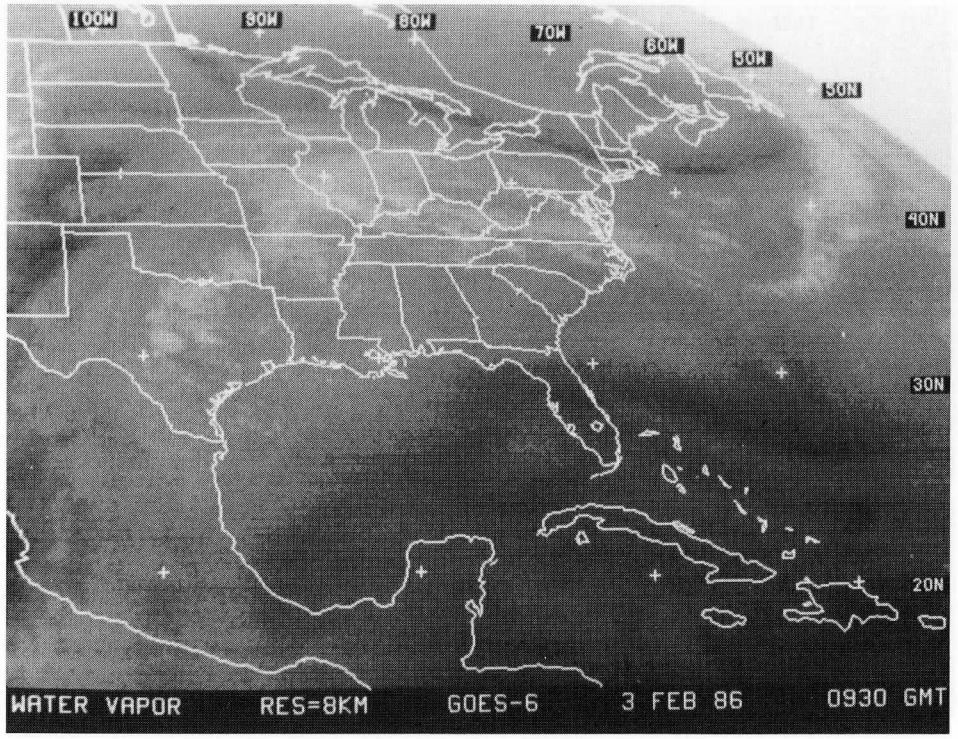
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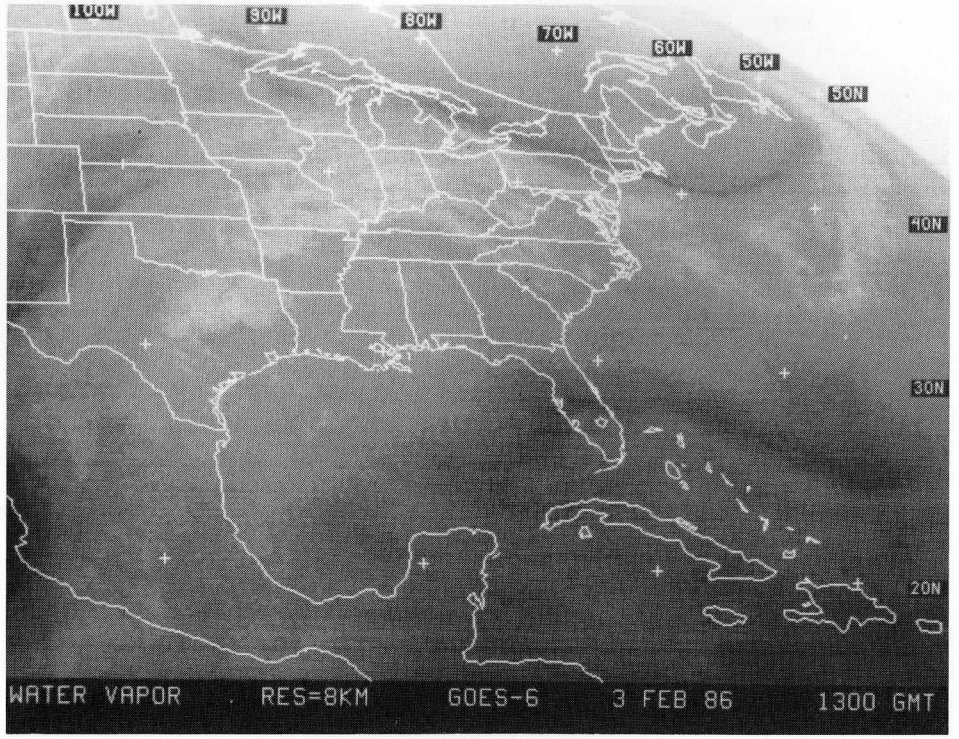
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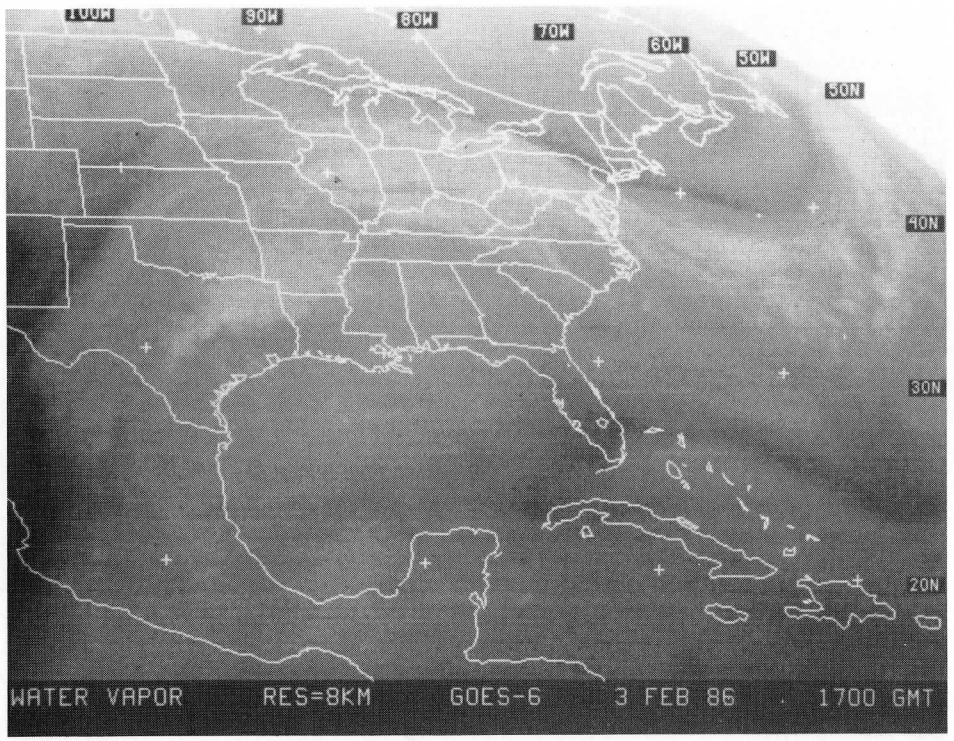
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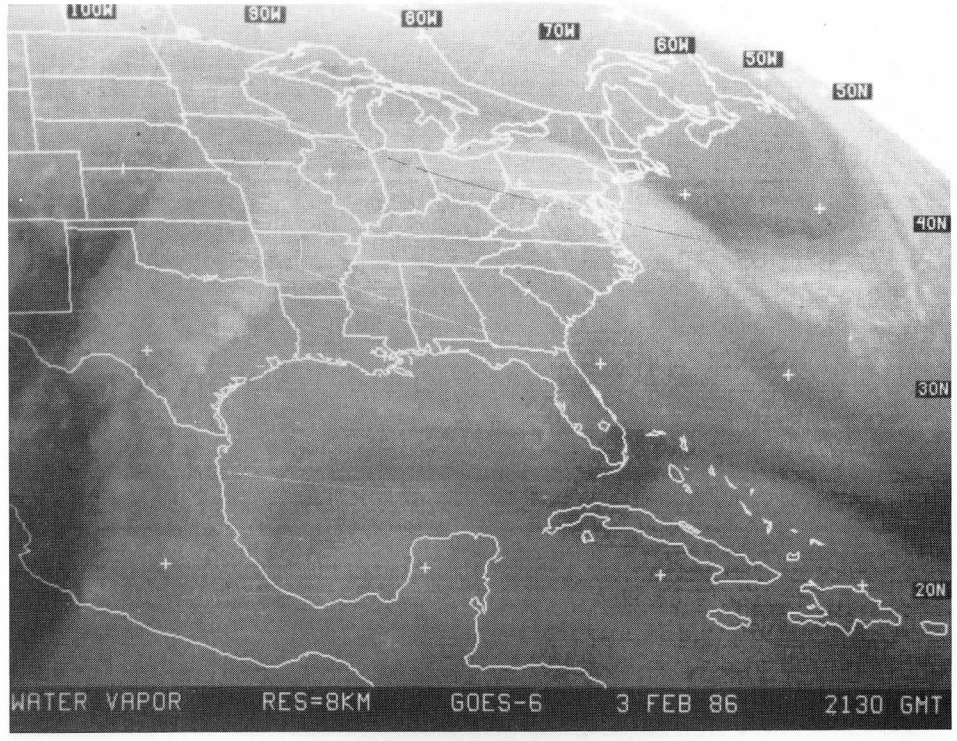
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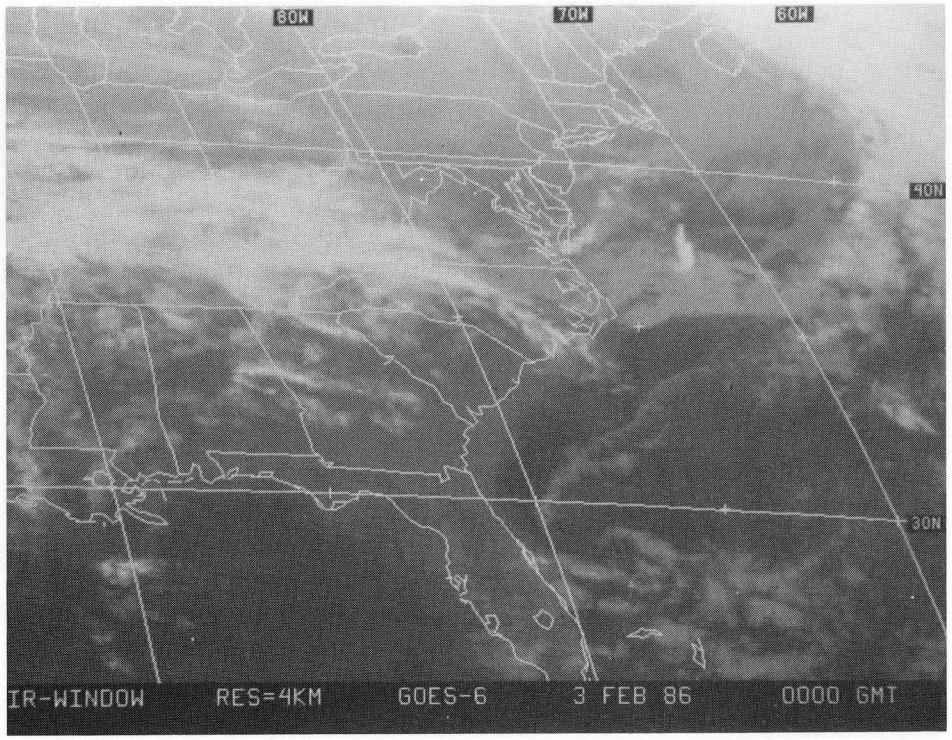
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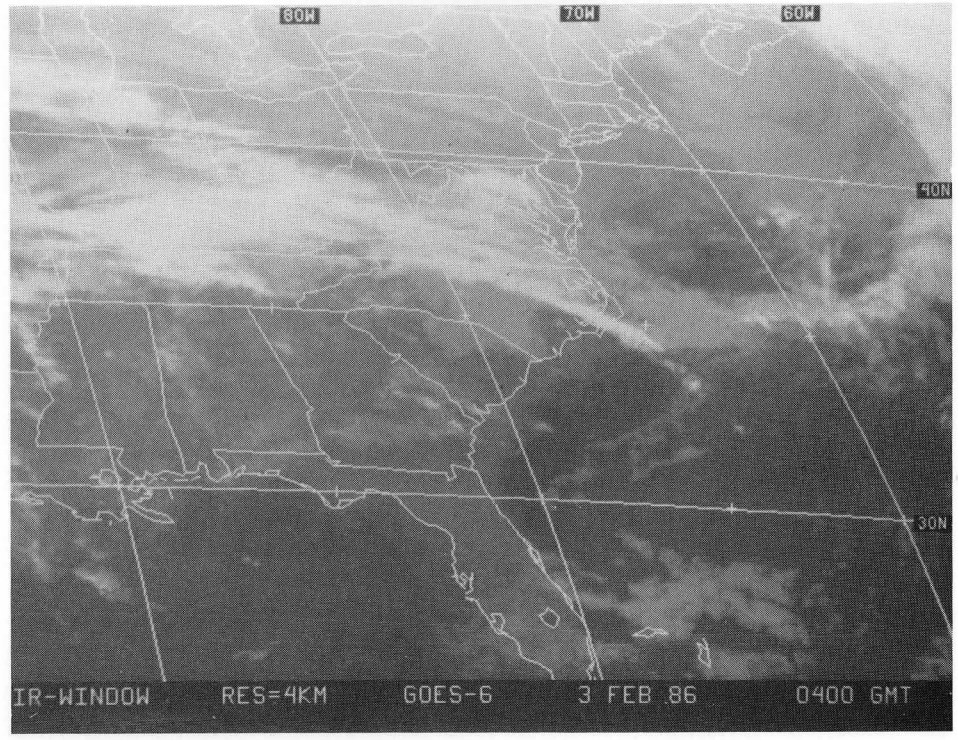
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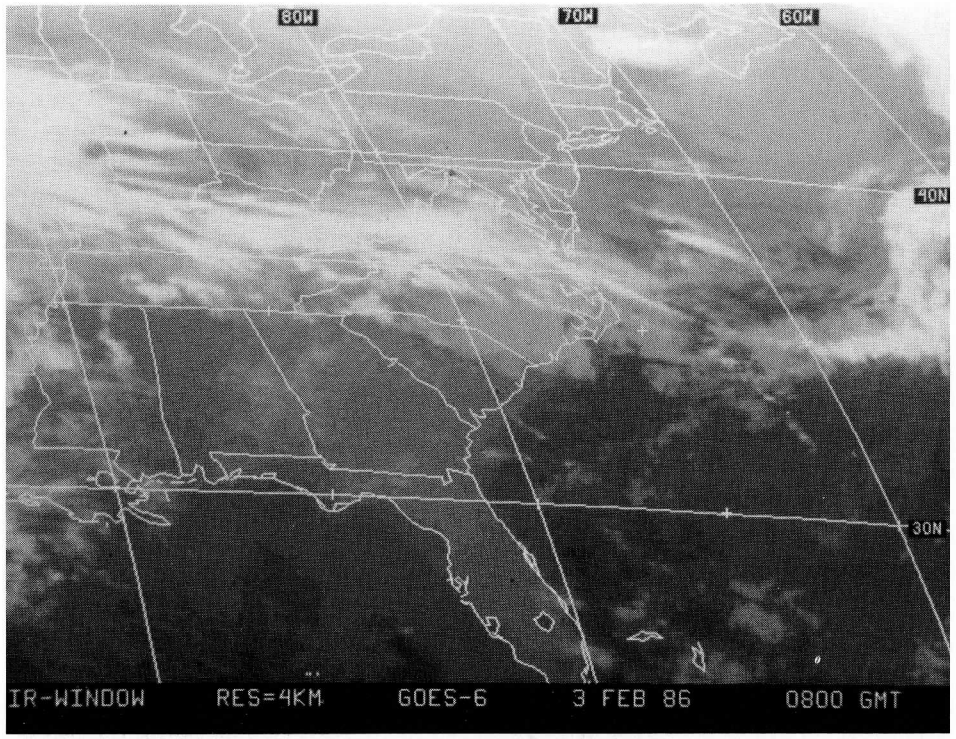
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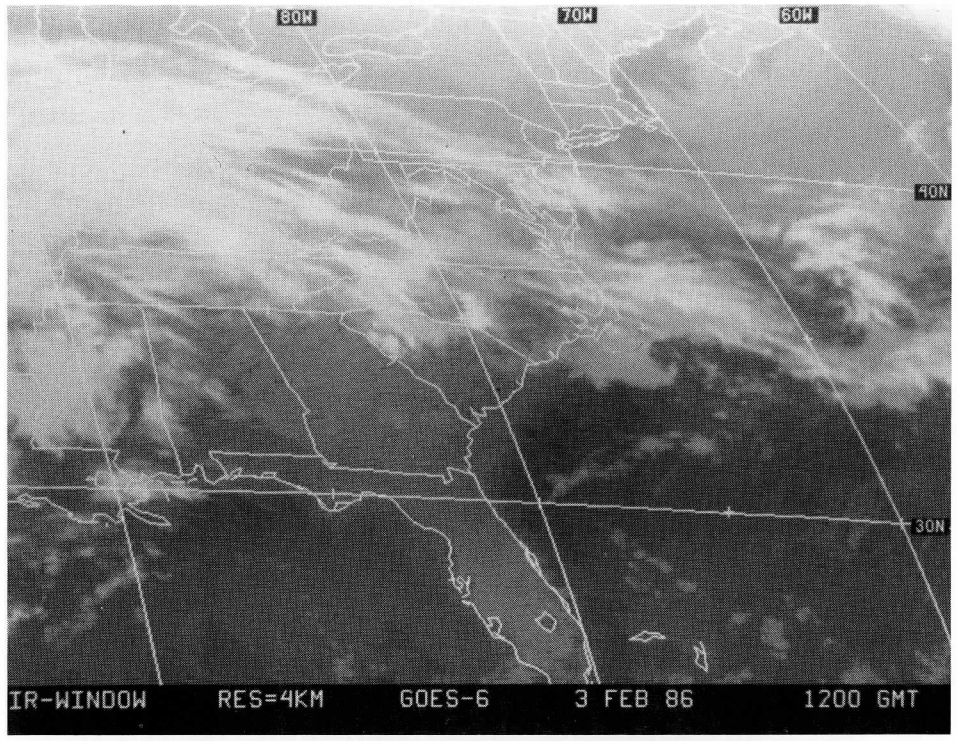
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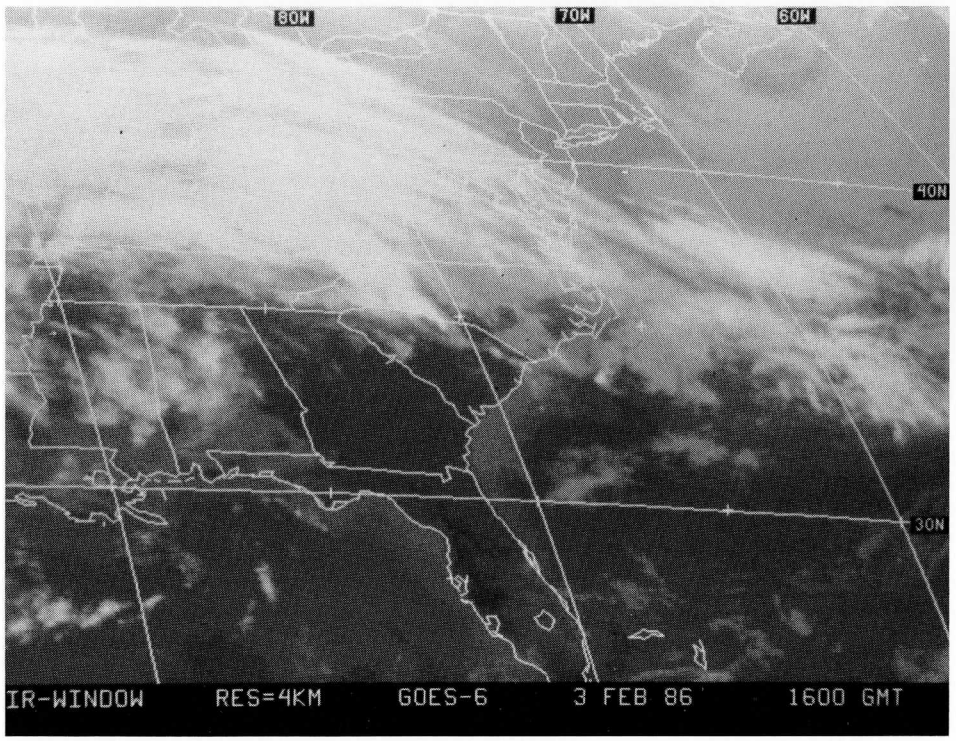
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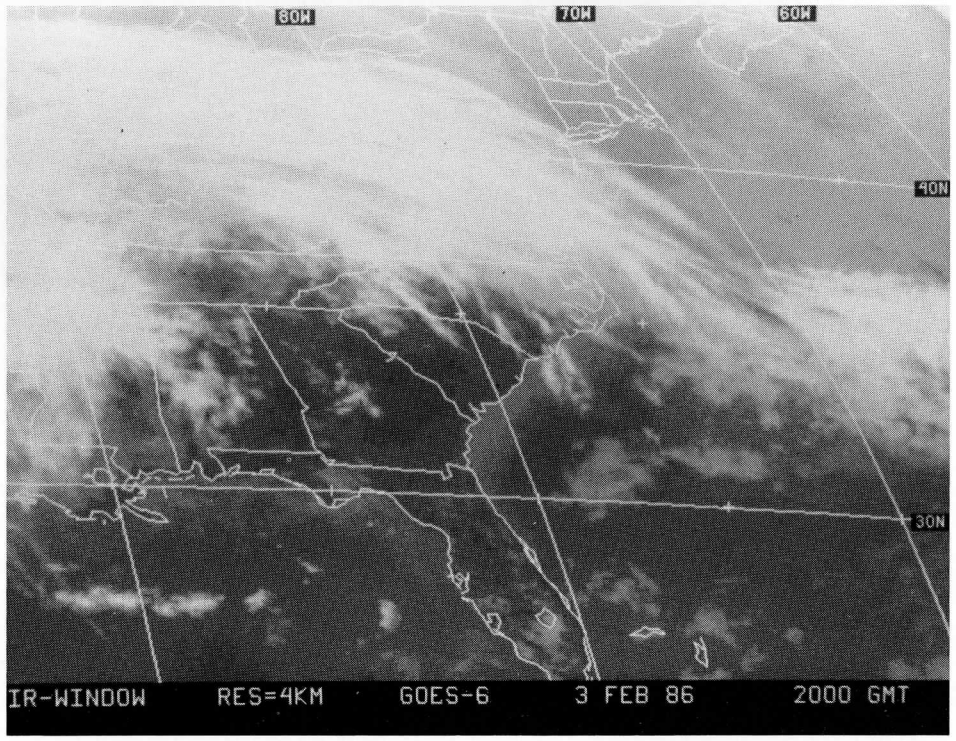
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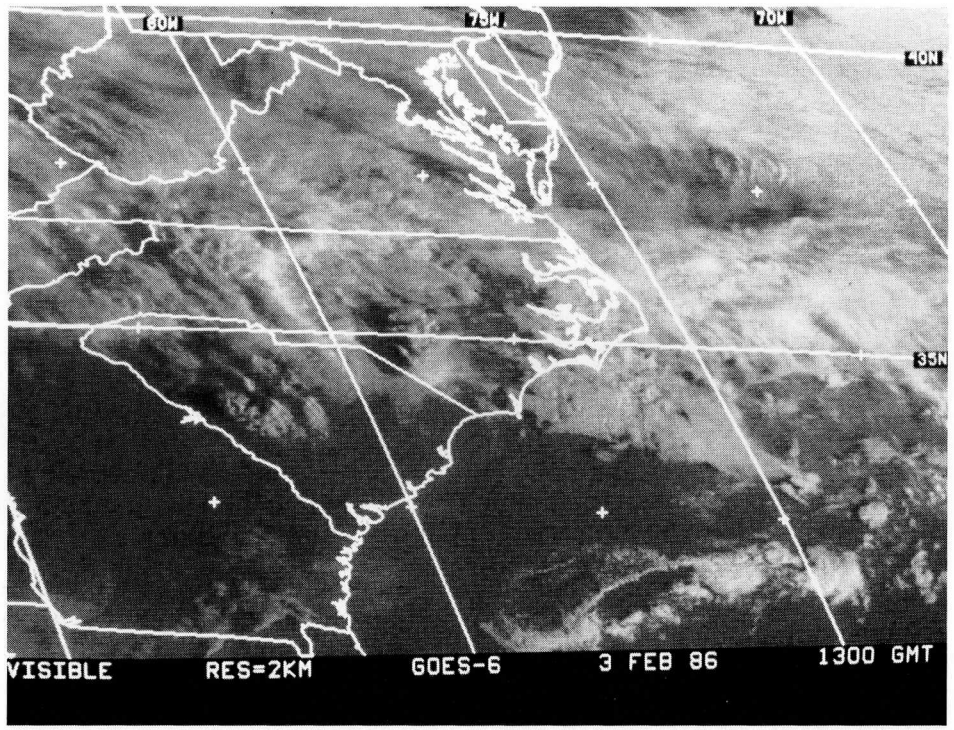
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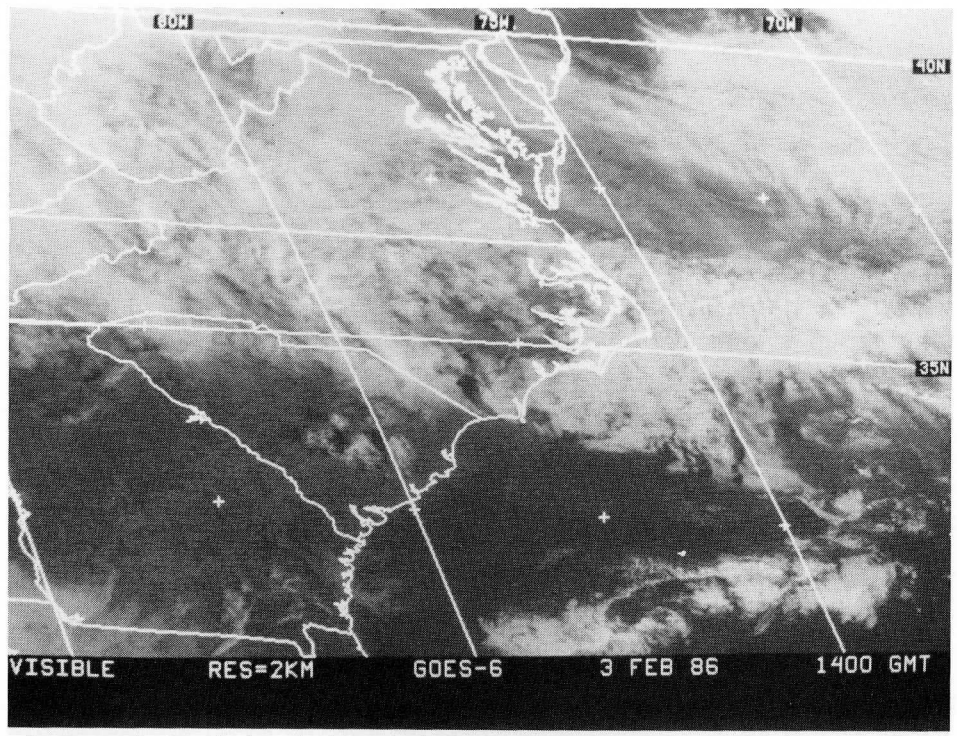
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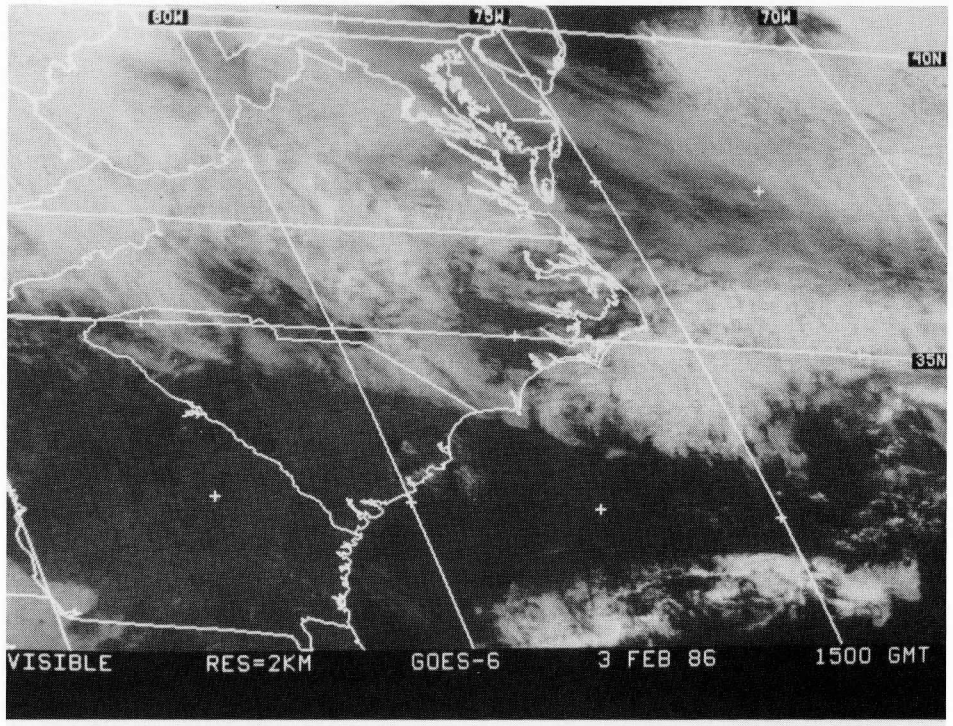
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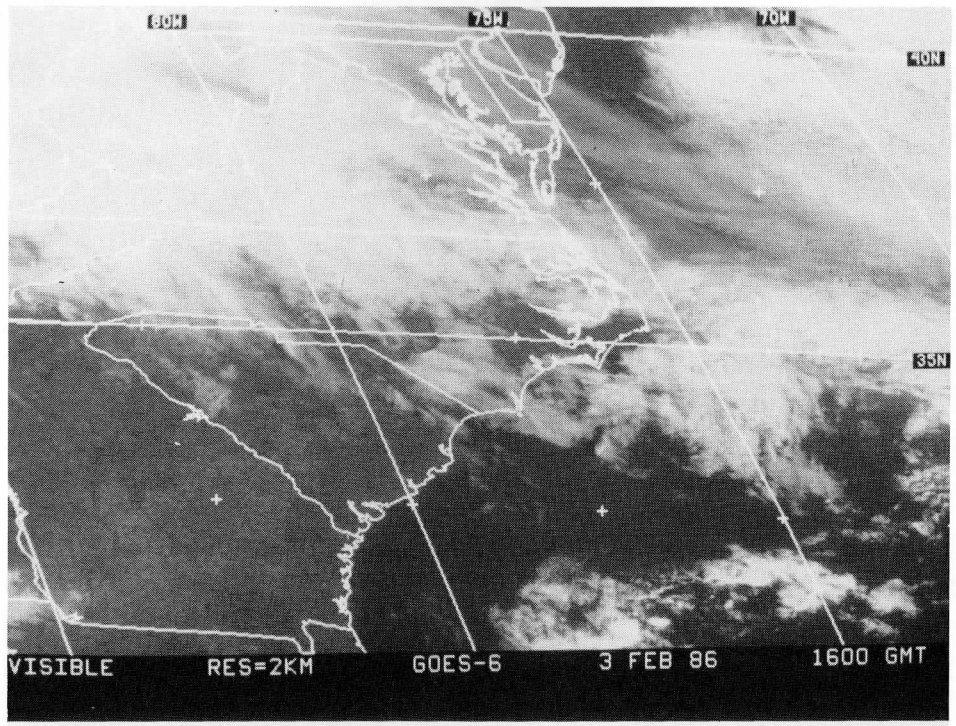
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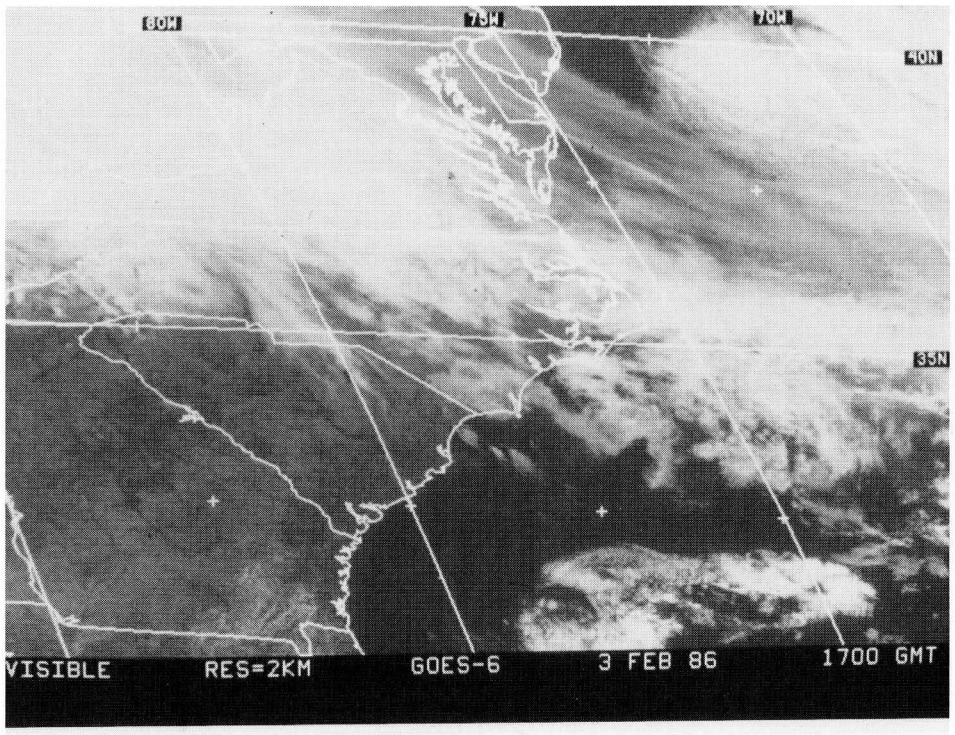
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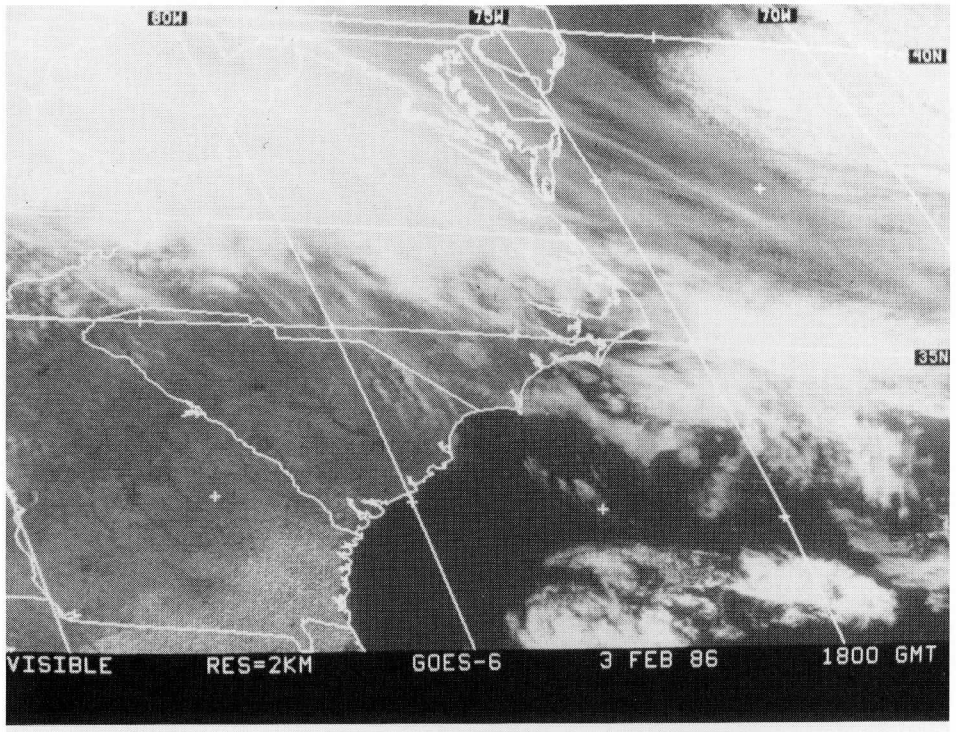
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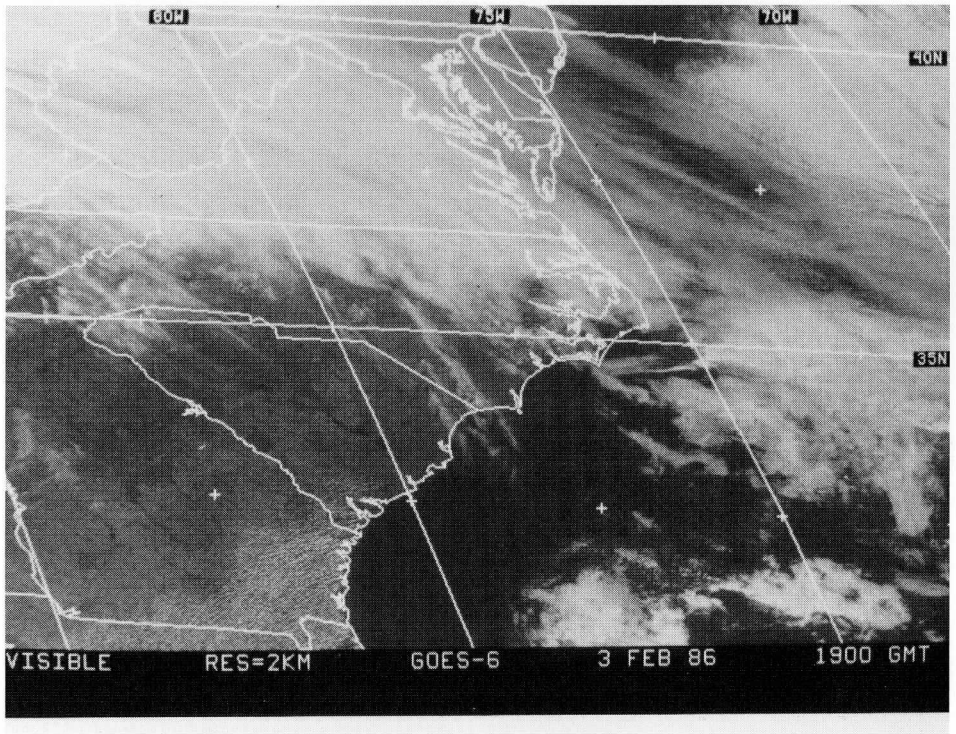
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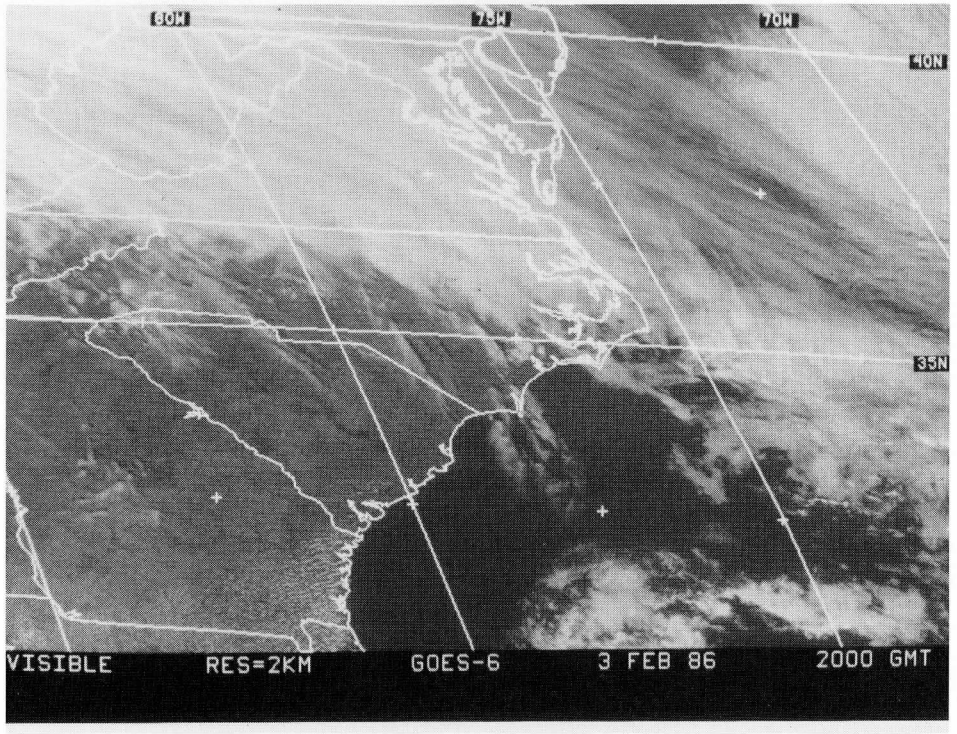
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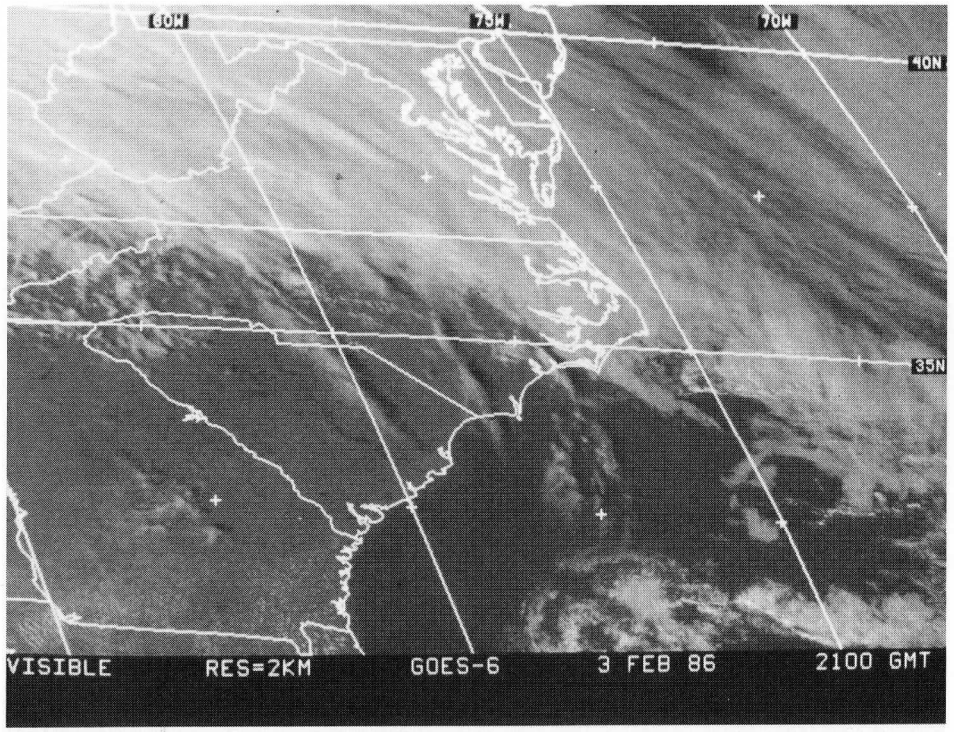
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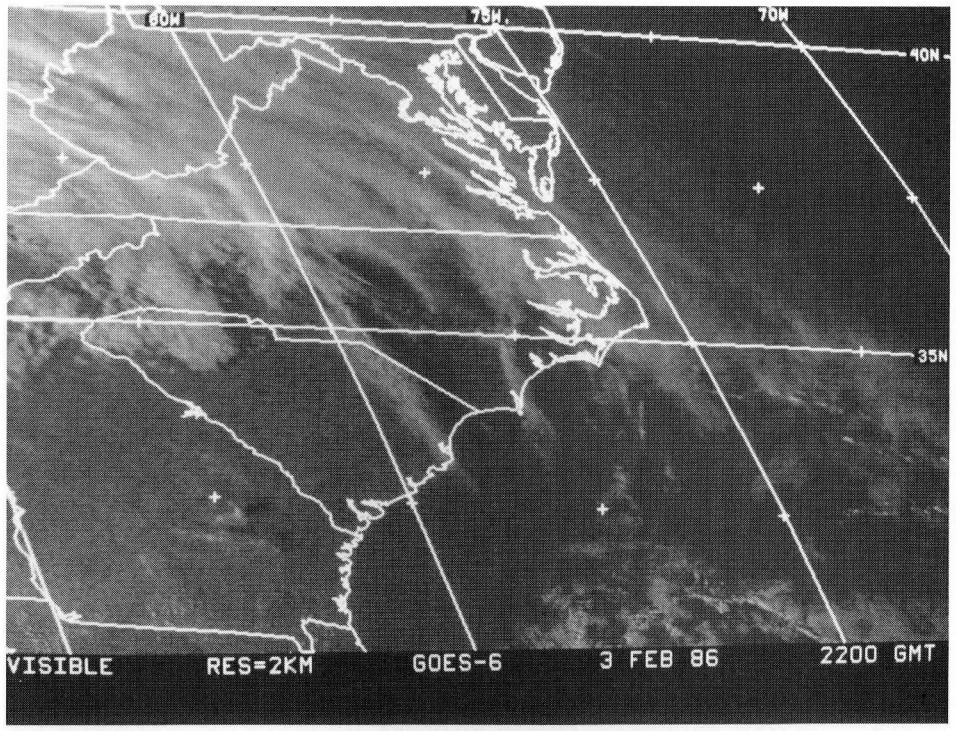
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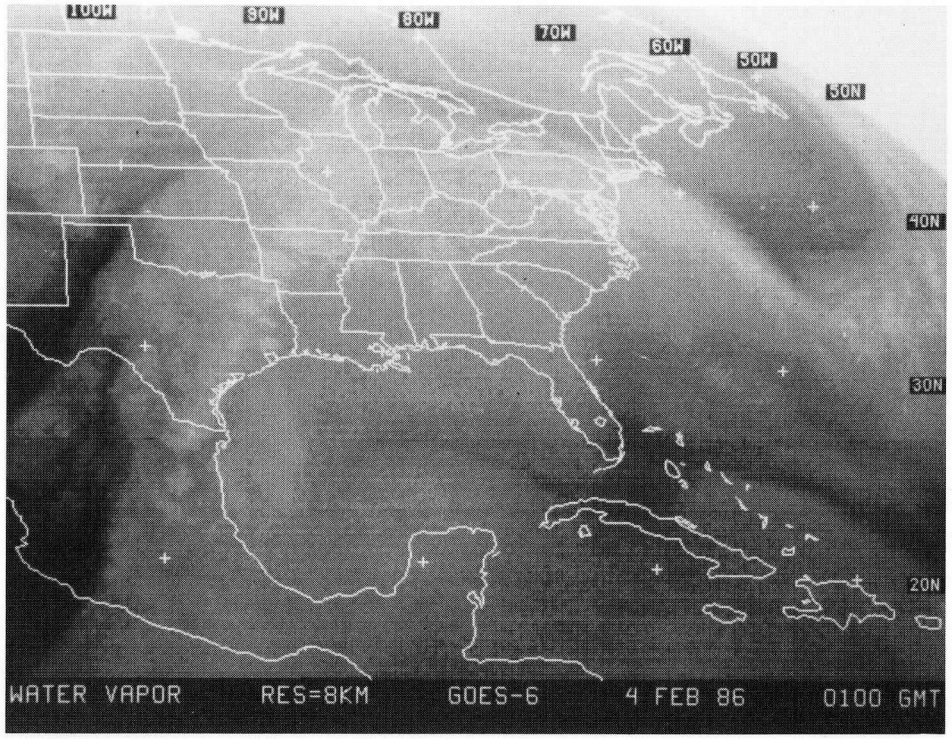
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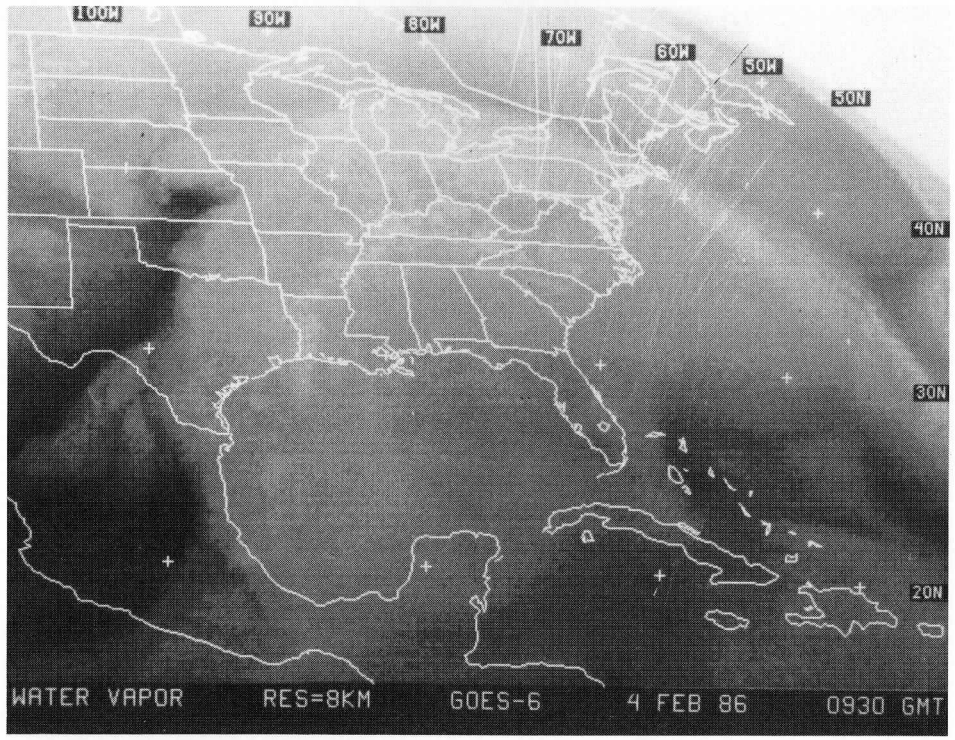
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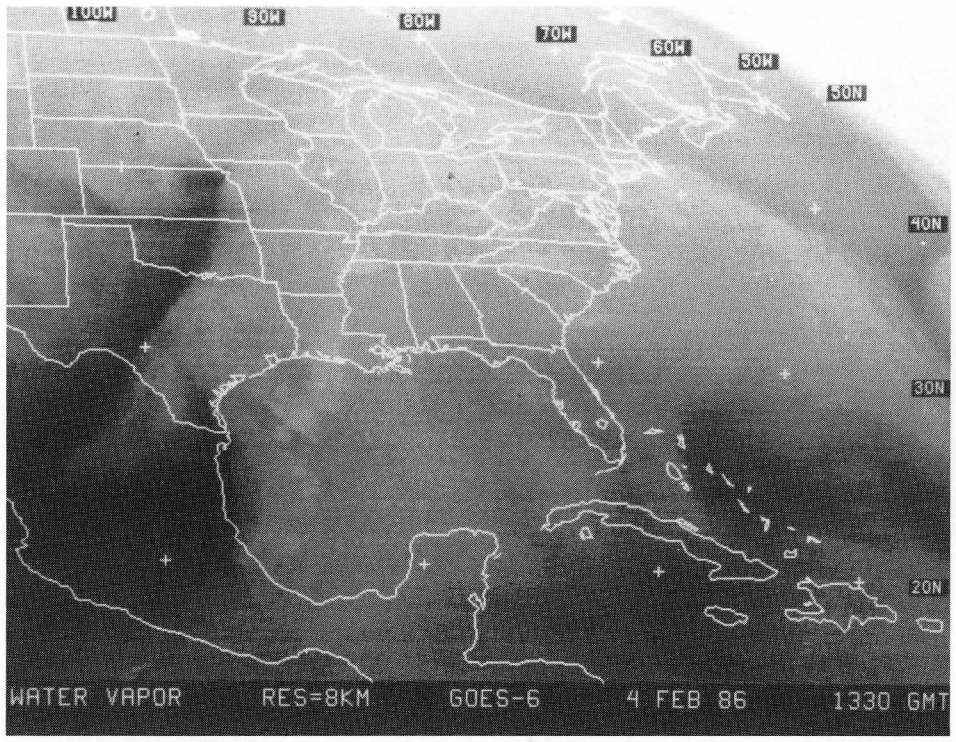
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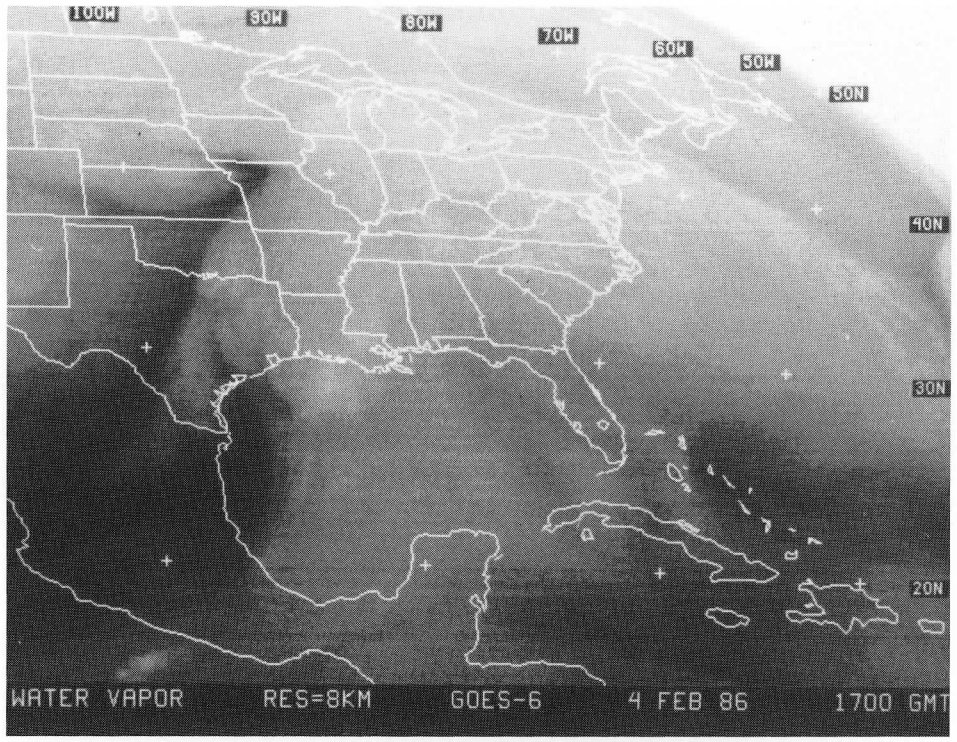
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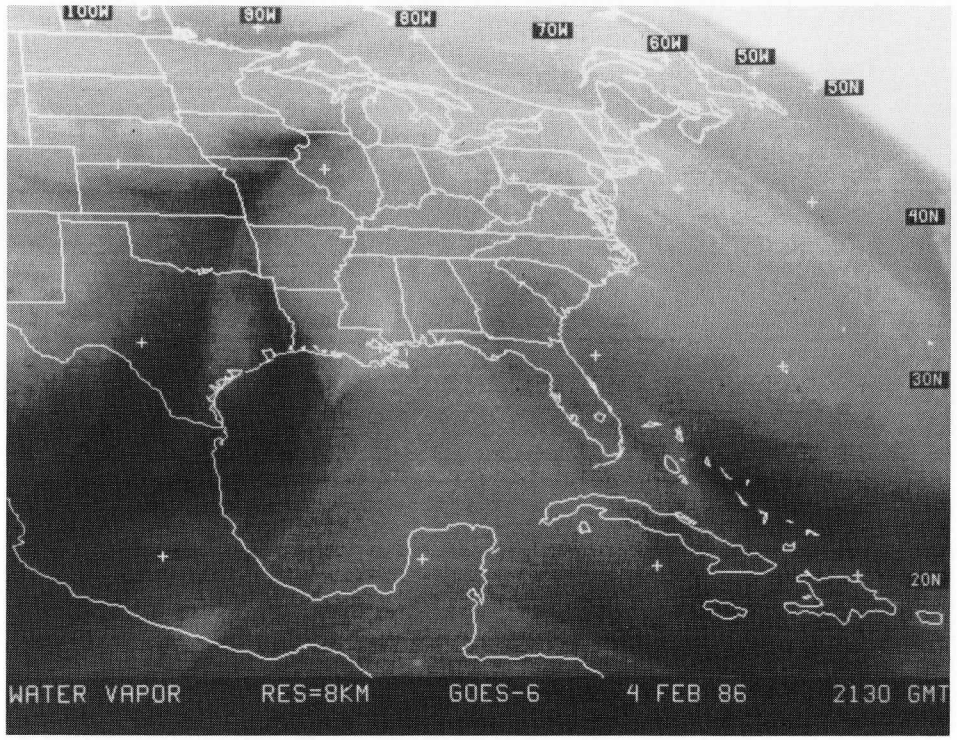
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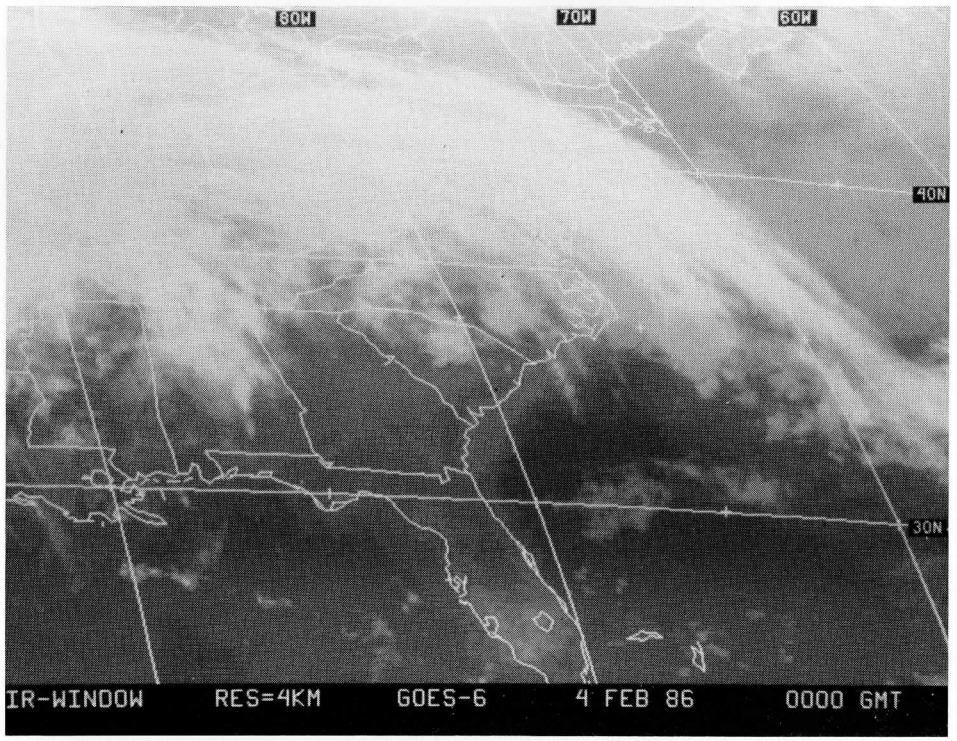
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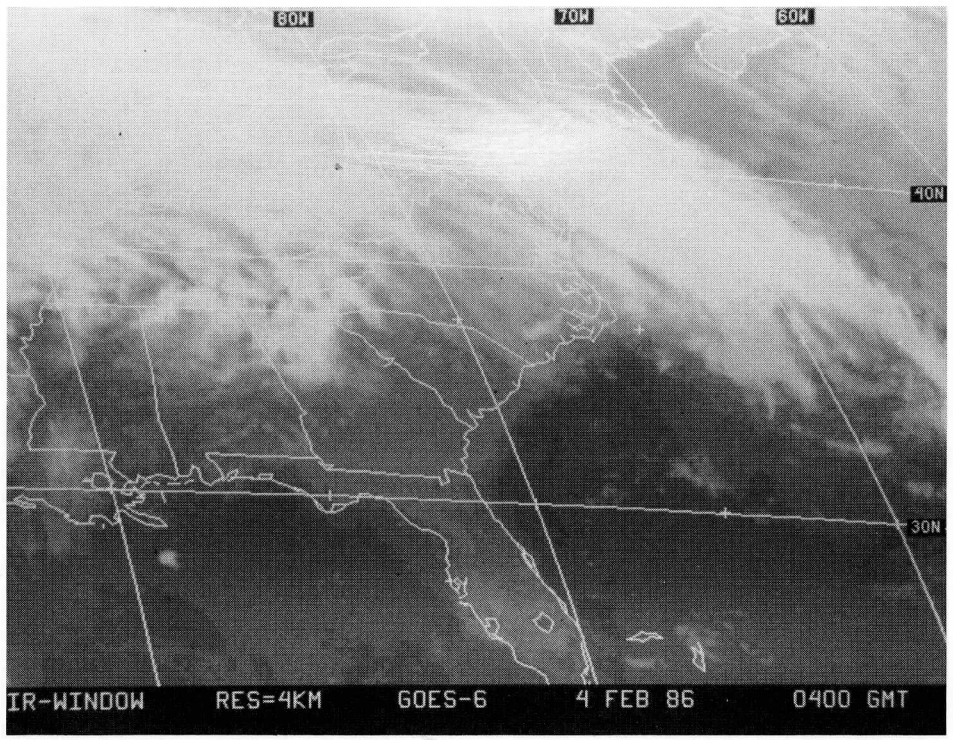
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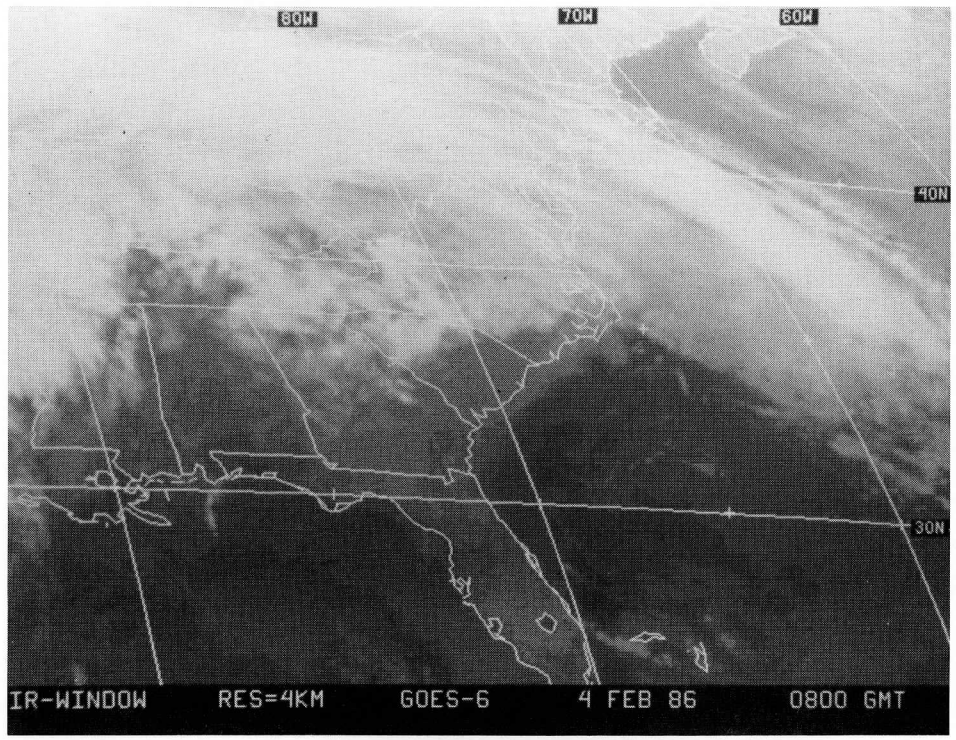
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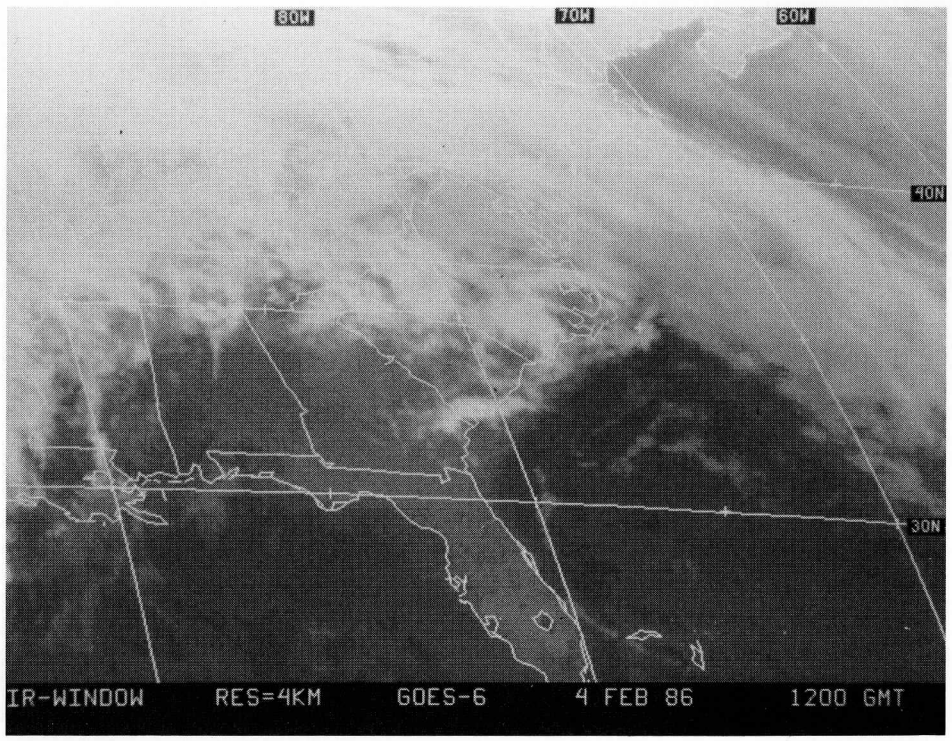
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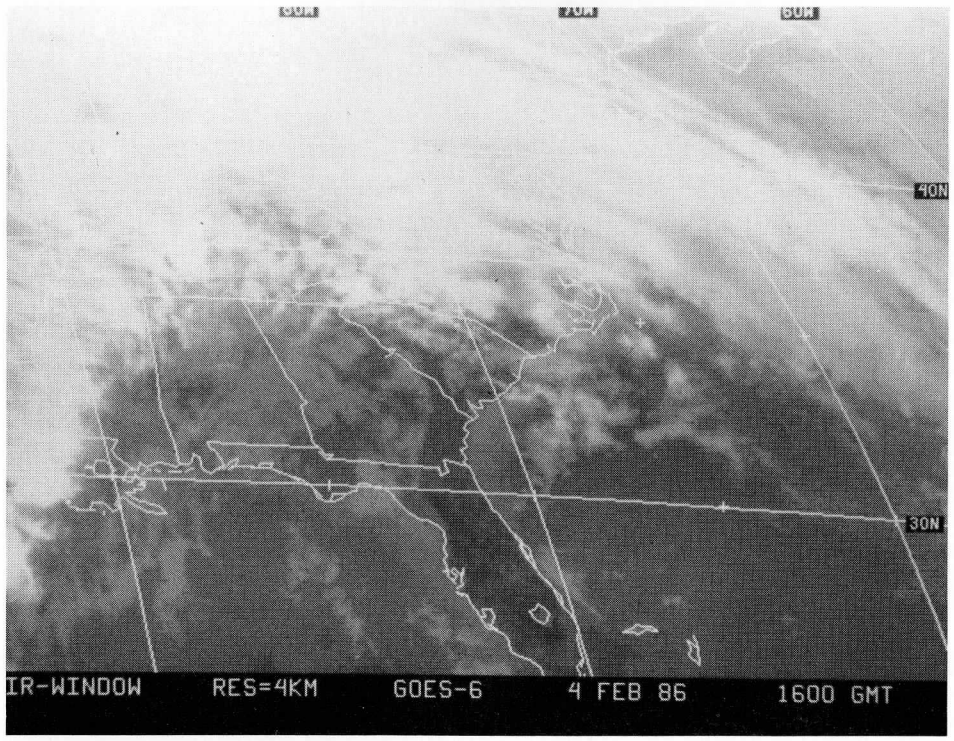
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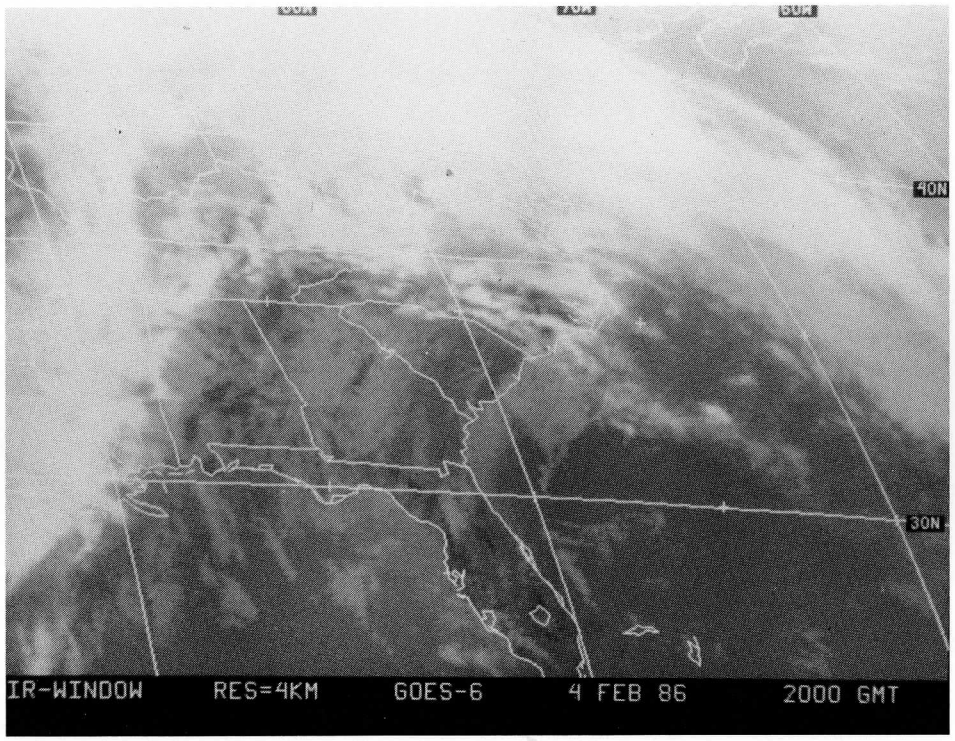
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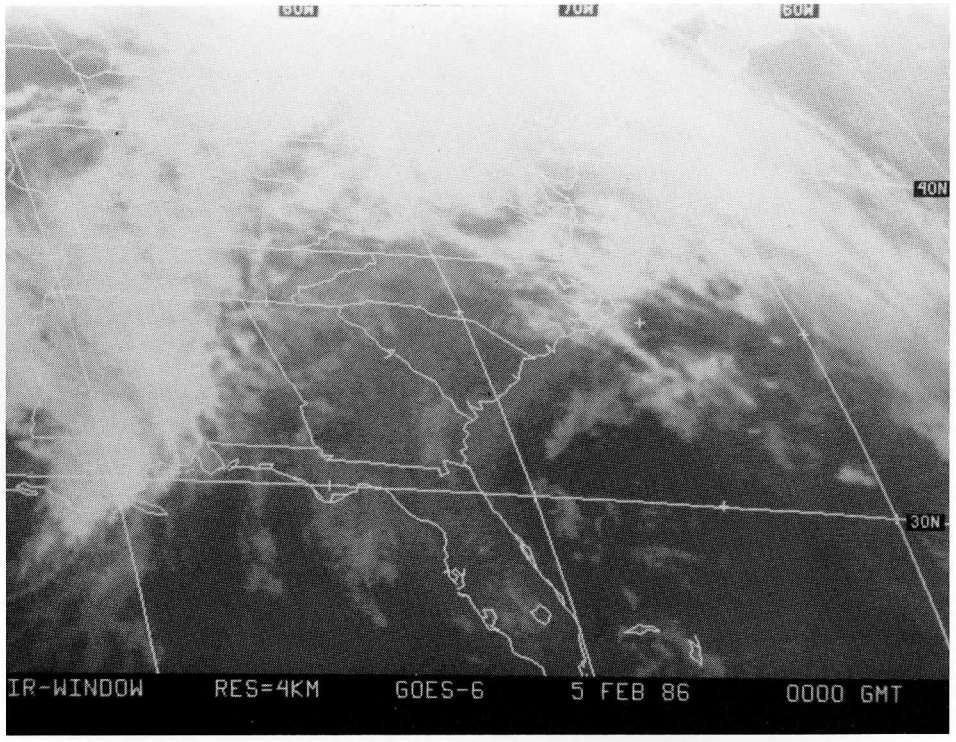
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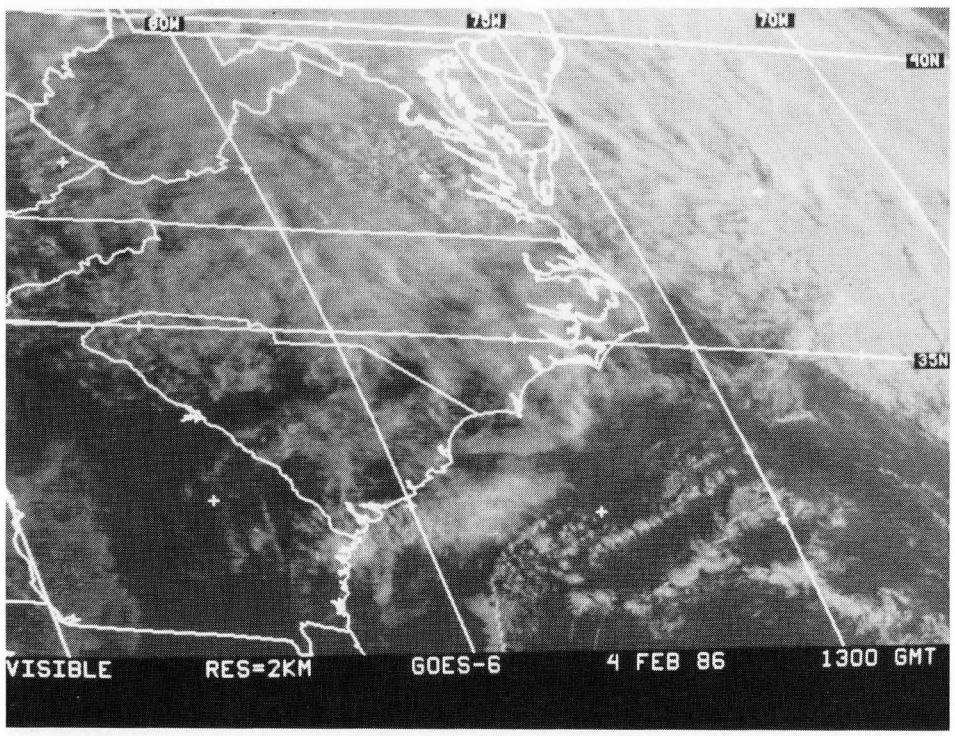
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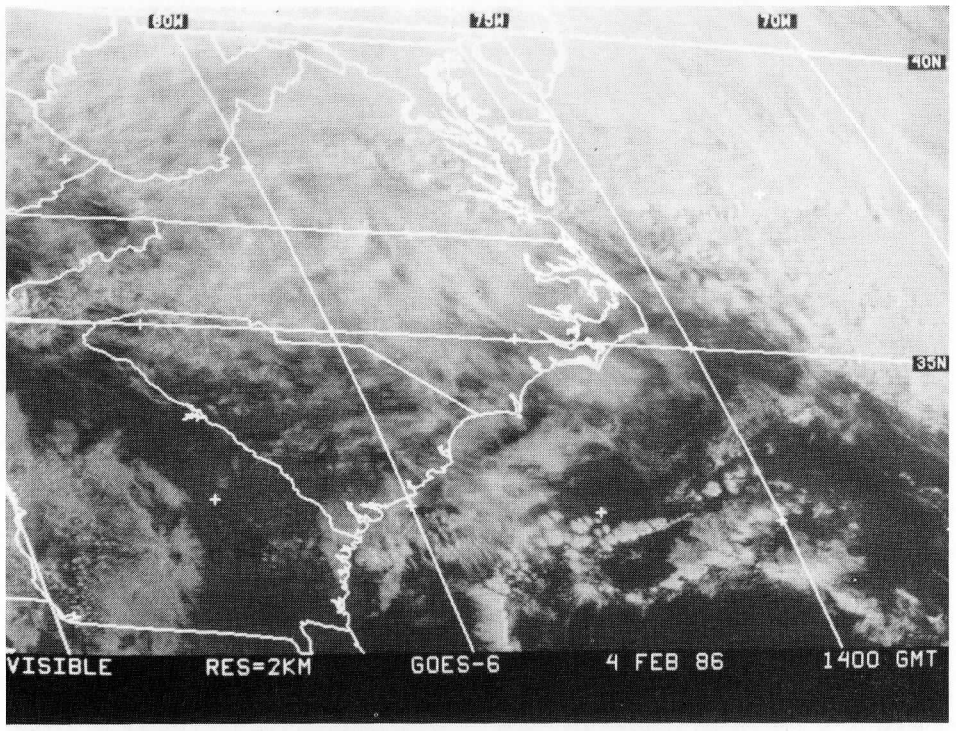
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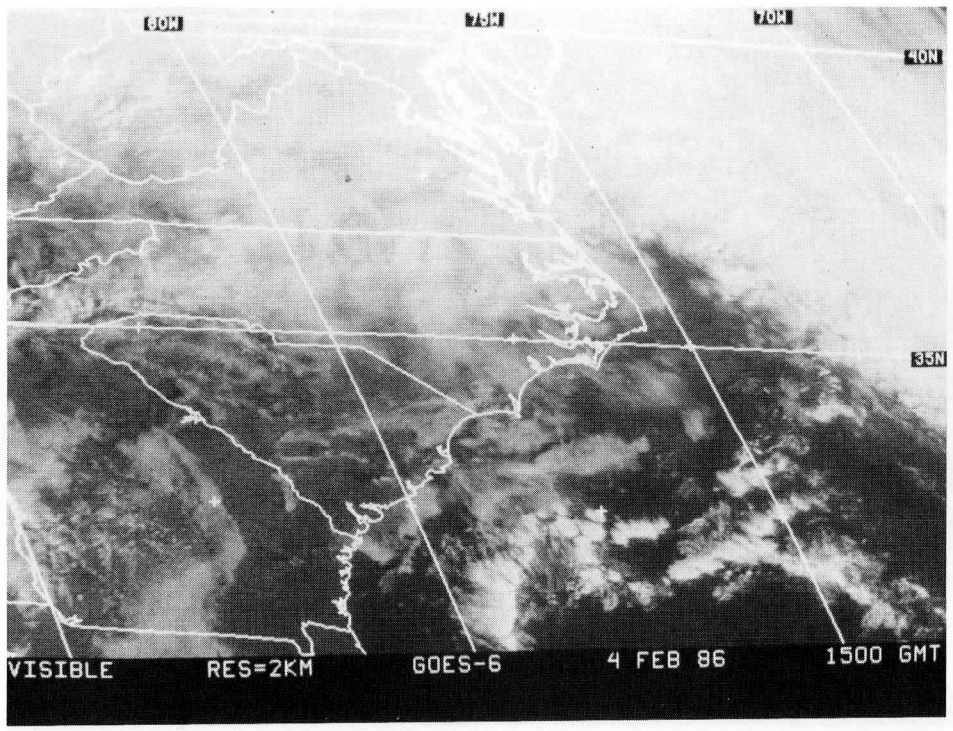
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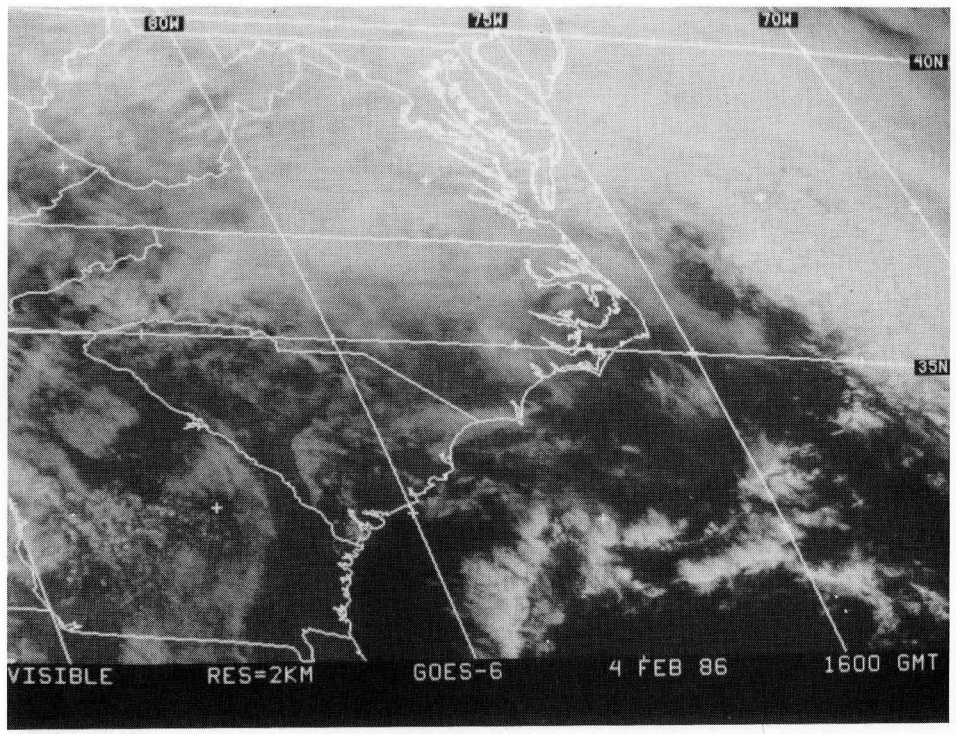
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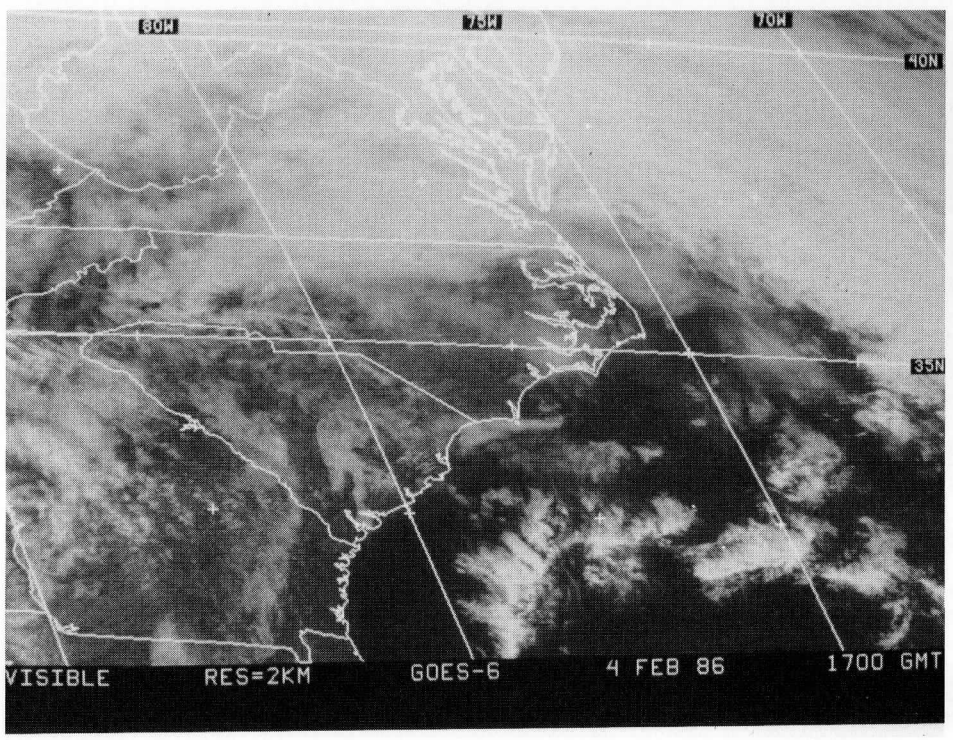
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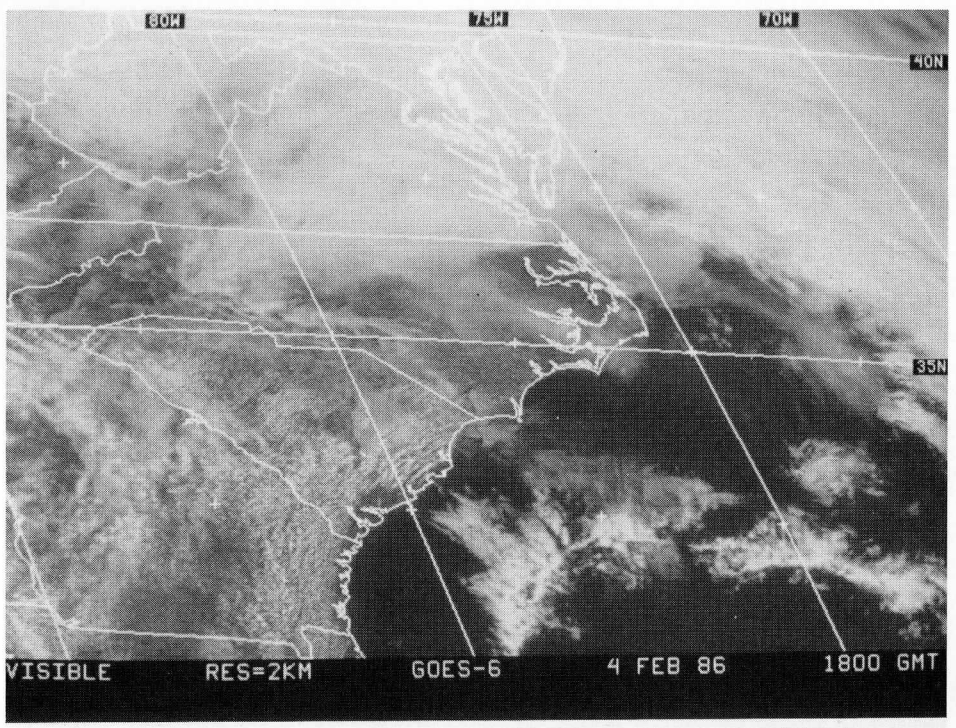
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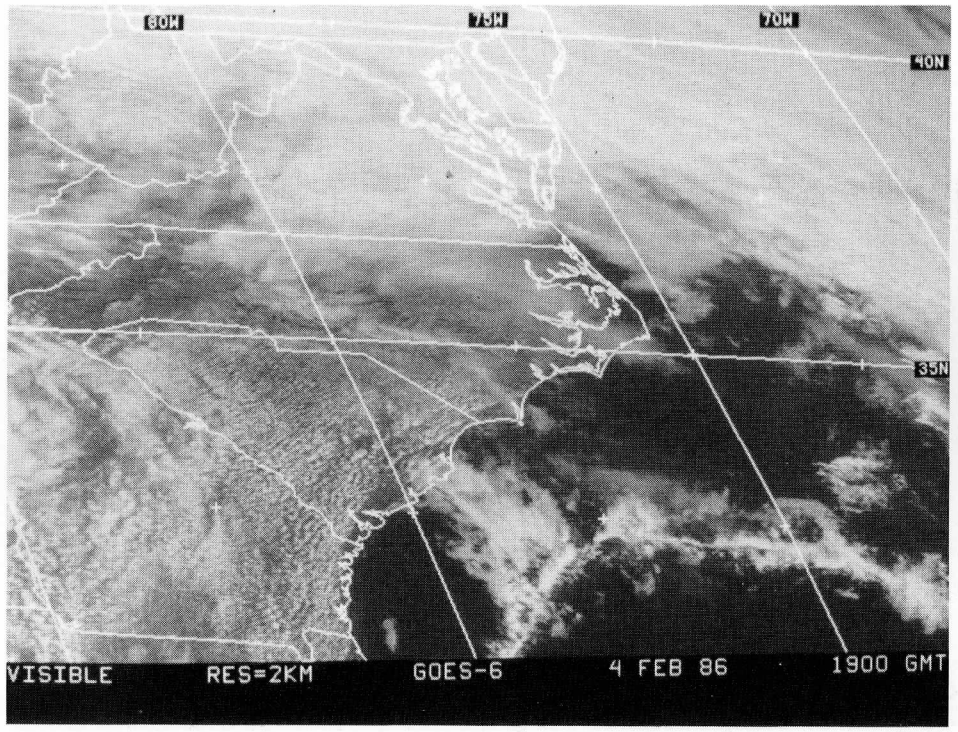
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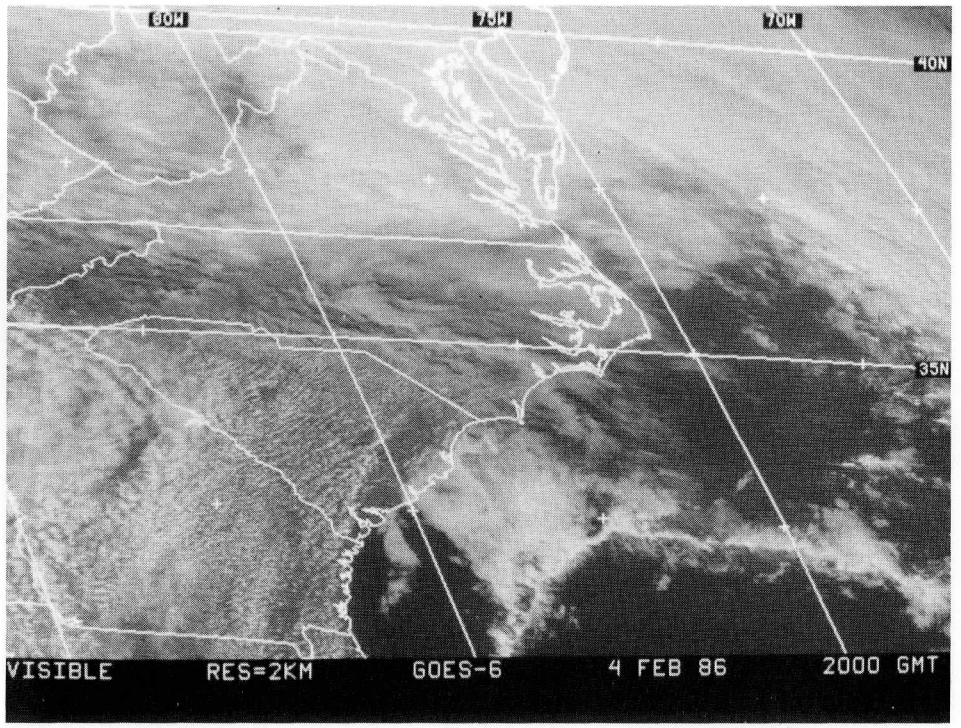
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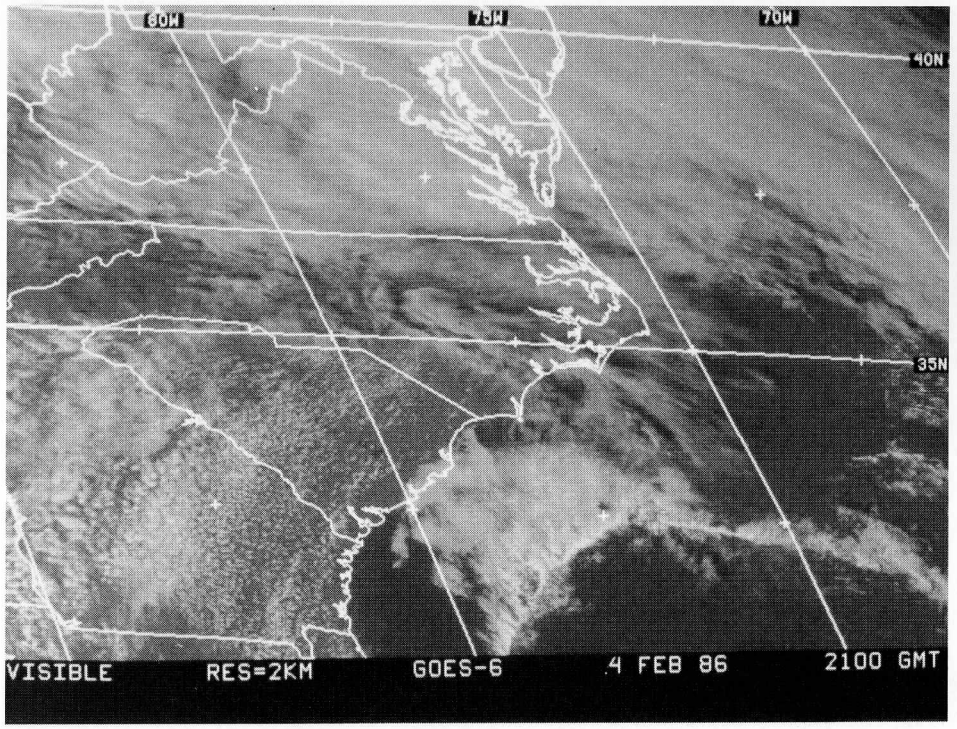
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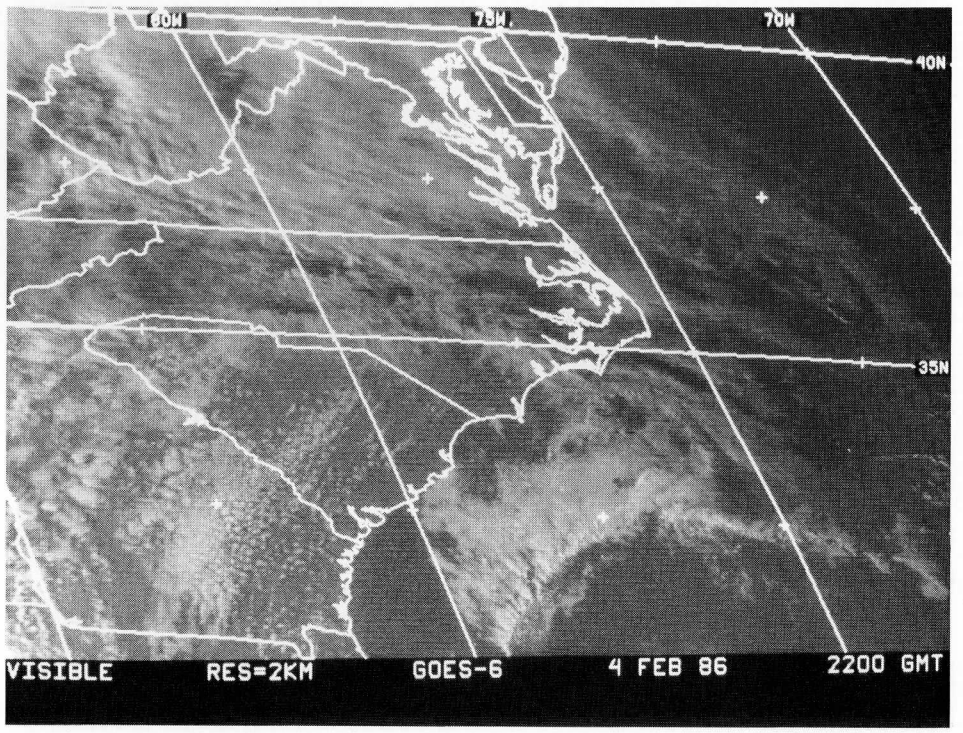
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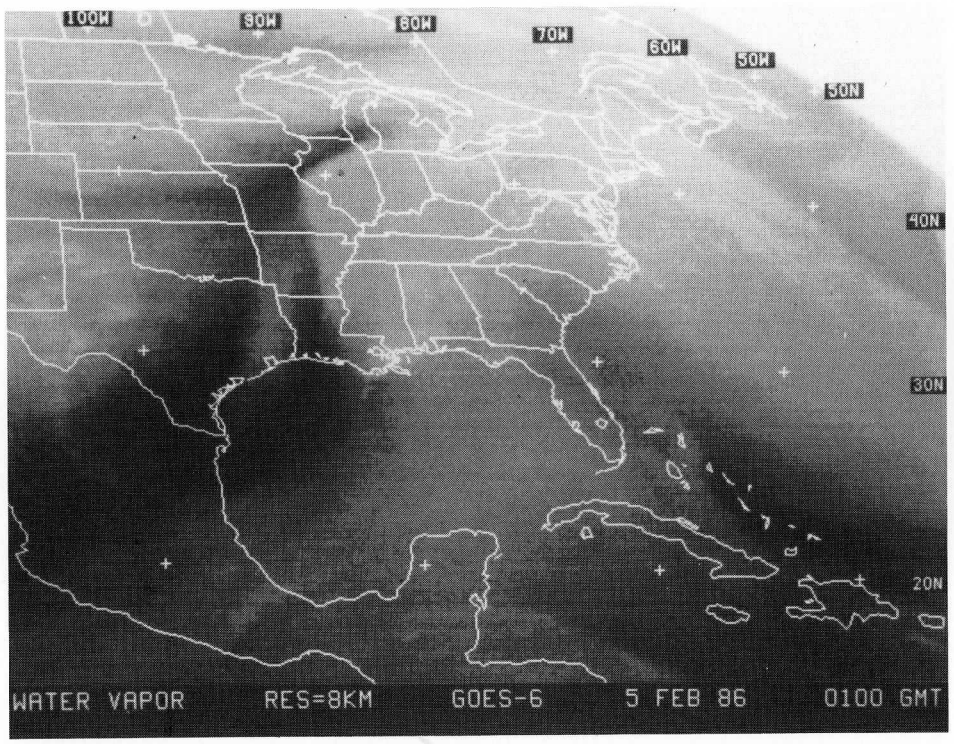
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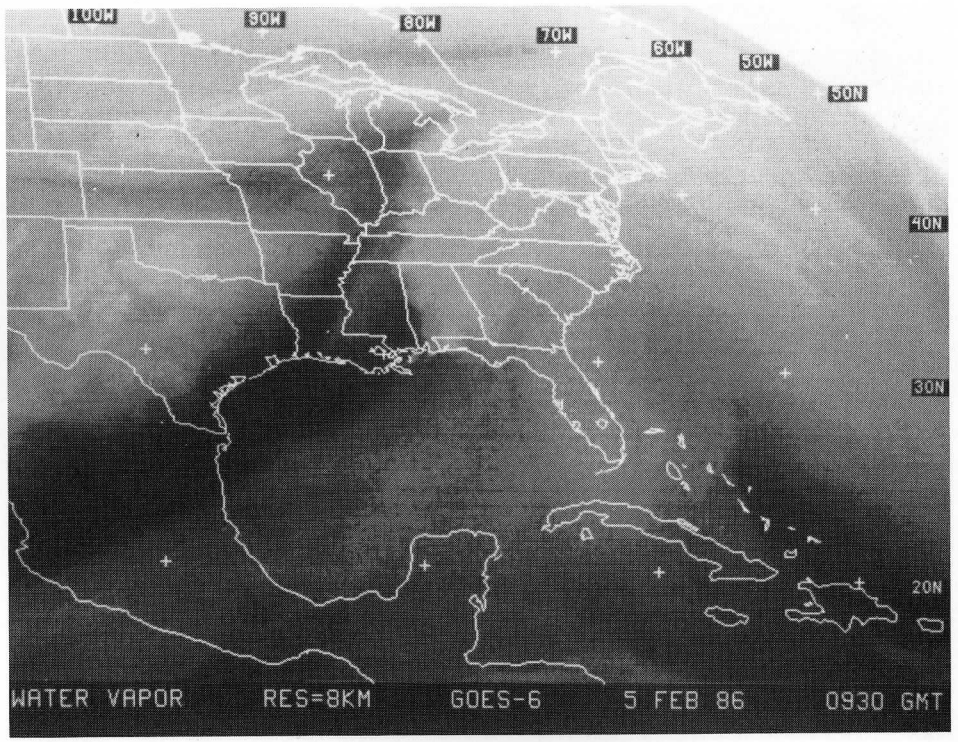
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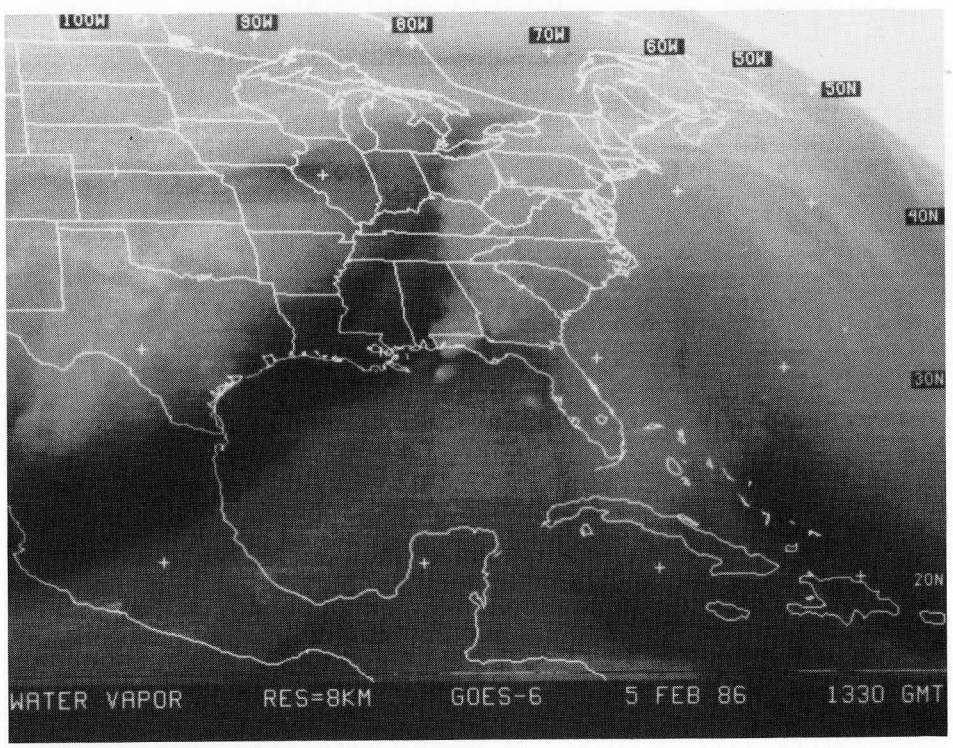
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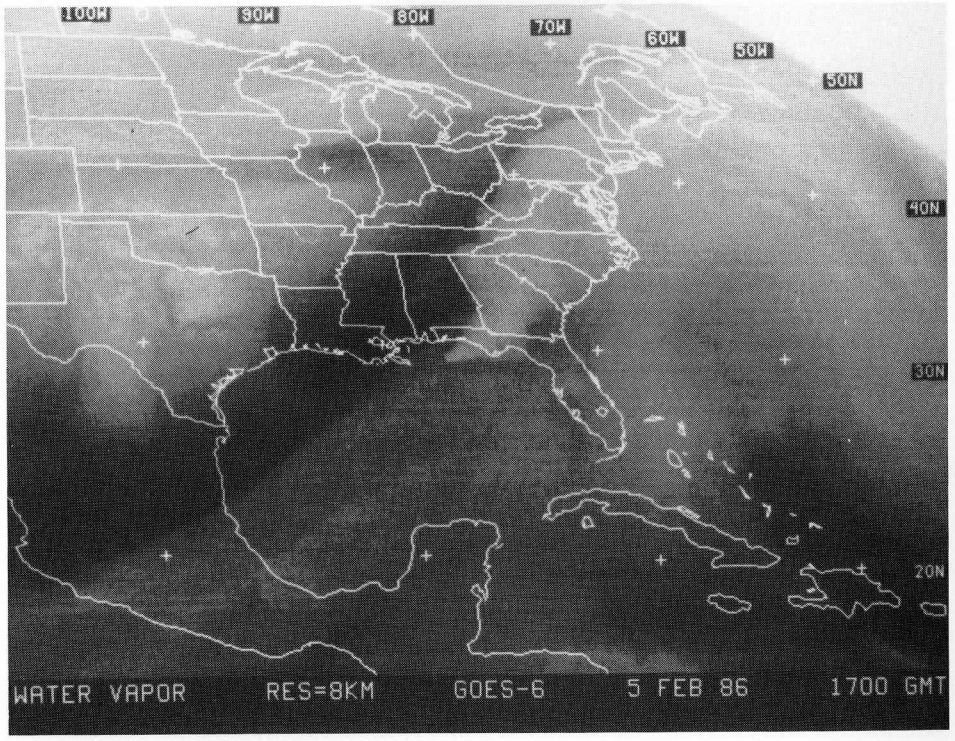
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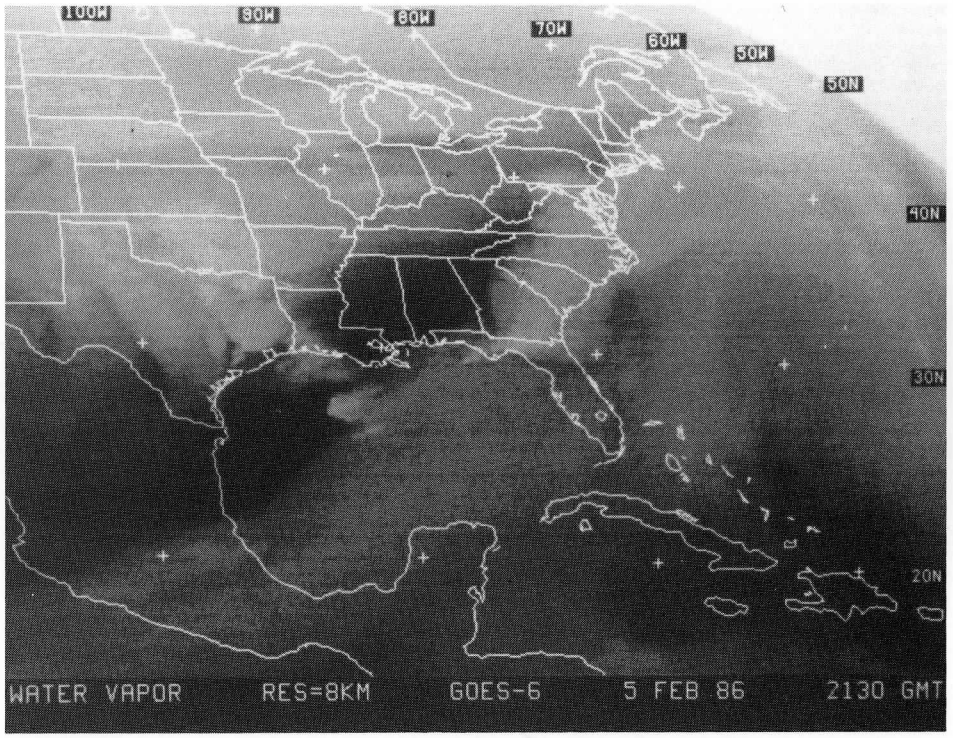
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IOP #4 - Backdoor Cold Front / Offshore Cyclogenesis
February 6 - February 8

Satellite Synopsis

Water Vapor

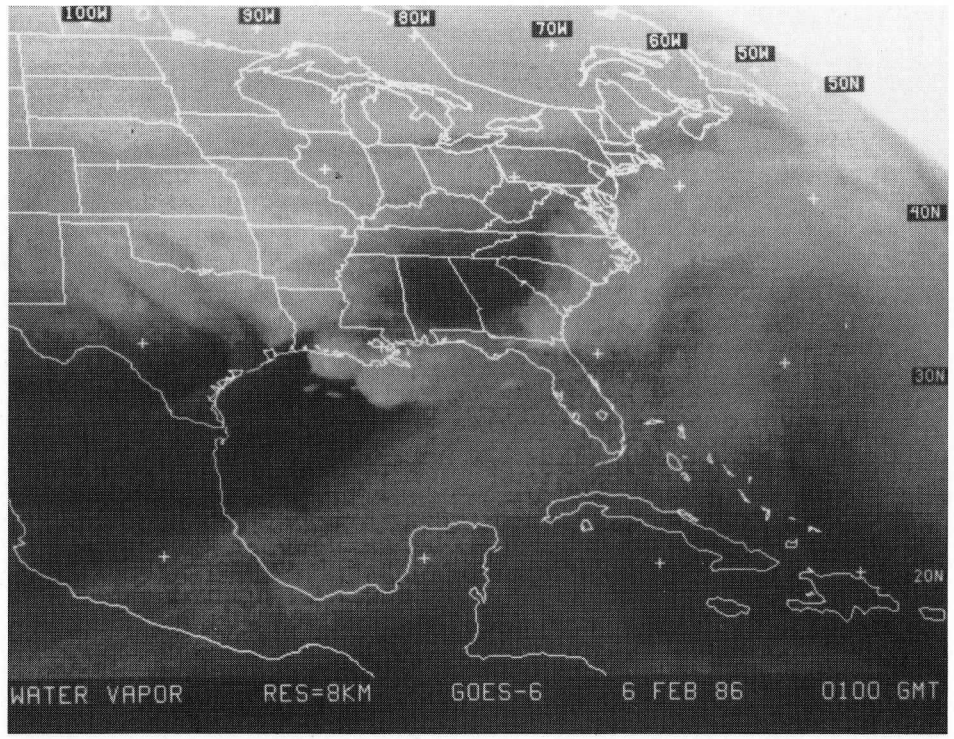
- A circulation center is shown in Nebraska/Oklahoma area with a dry wedge from the Gulf to southern Illinois on the 6th.
- 6th, big thunderstorms in the Gulf of Mexico.
- A dry wedge exists over the Carolinas by 00 GMT on the 7th with a circulation evident in the West Virginia area.
- 7th, a dry zone extends from Mexico to North Carolina, with a weak short wave apparent moving from Iowa to West Virginia on the 7th.
- 8th, strong thunderstorms in Gulf erupt in the dry mid-tropospheric air.

IR

- 6th, squall line in the Gulf of Mexico.

Visible

- 6th, convection off South Carolina.
- 7th, wave clouds over Appalachians.
- 7th, low level circulation northeast of Cape Hatteras.
- 7th, rope clouds evident near low, with stratus deck wrapping around behind the low in Virginia and North Carolina.
- 7th, strong line of thunderstorms on the east side of Gulf Stream early with overshooting tops.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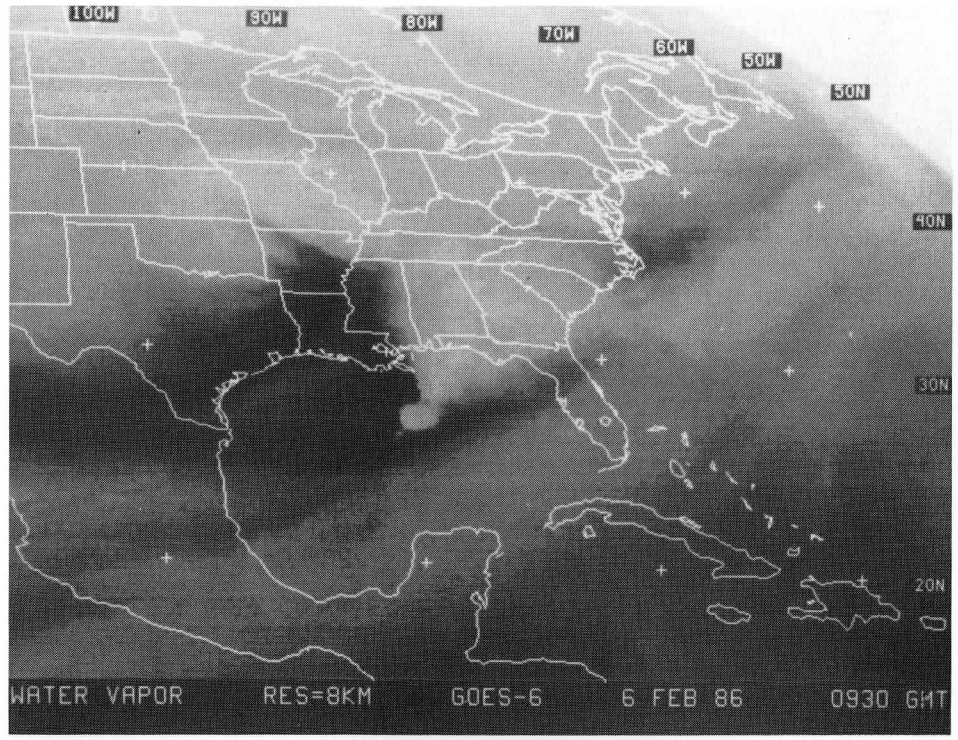
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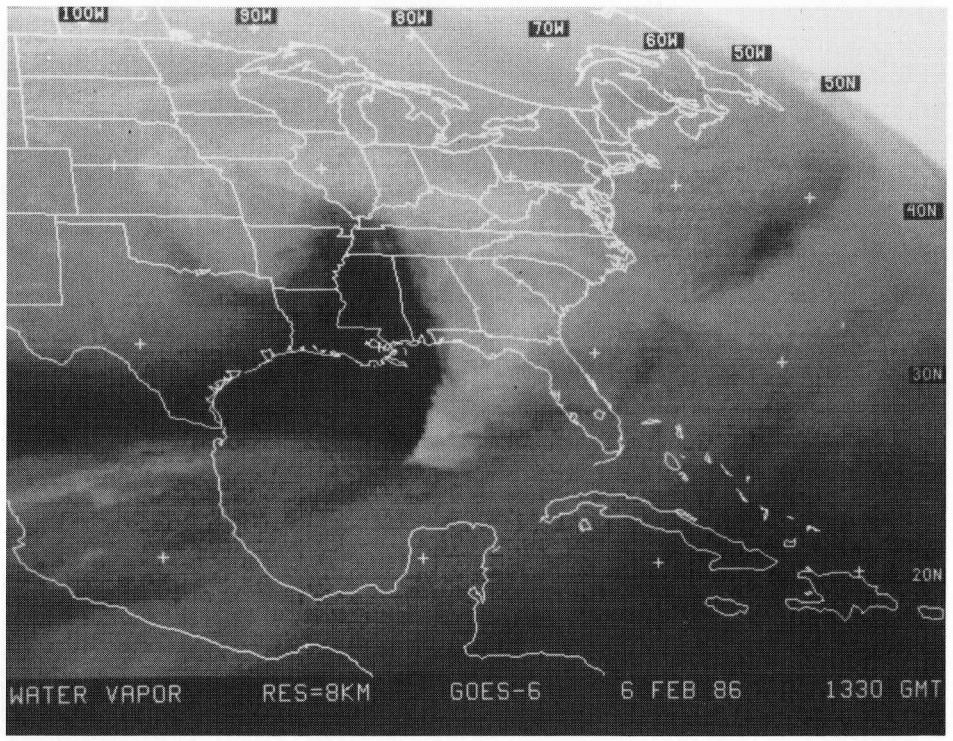
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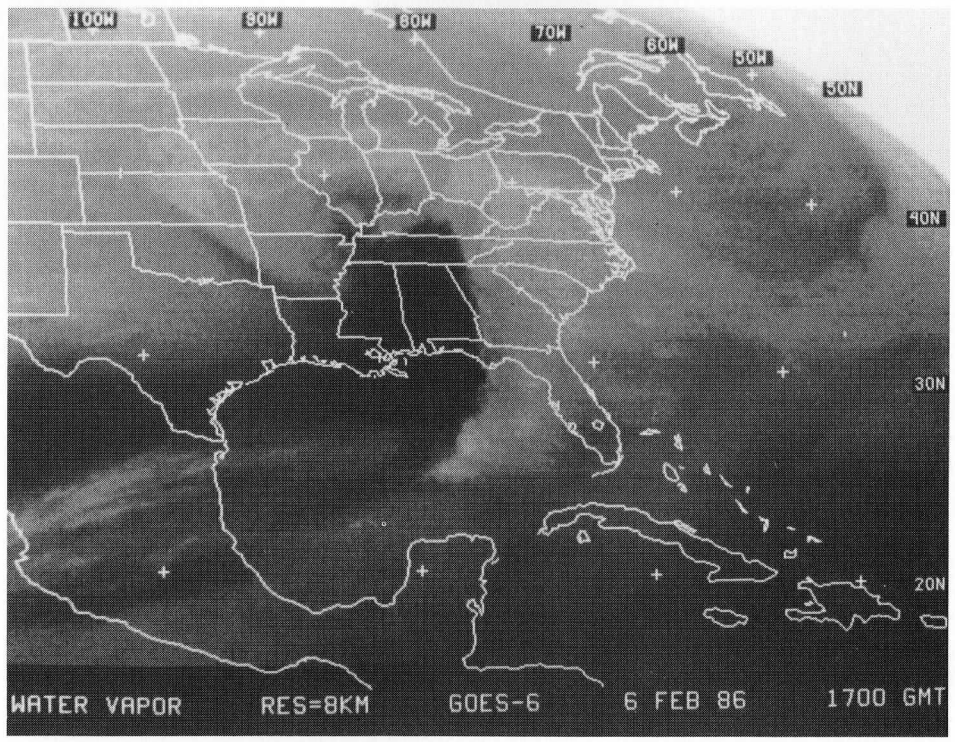
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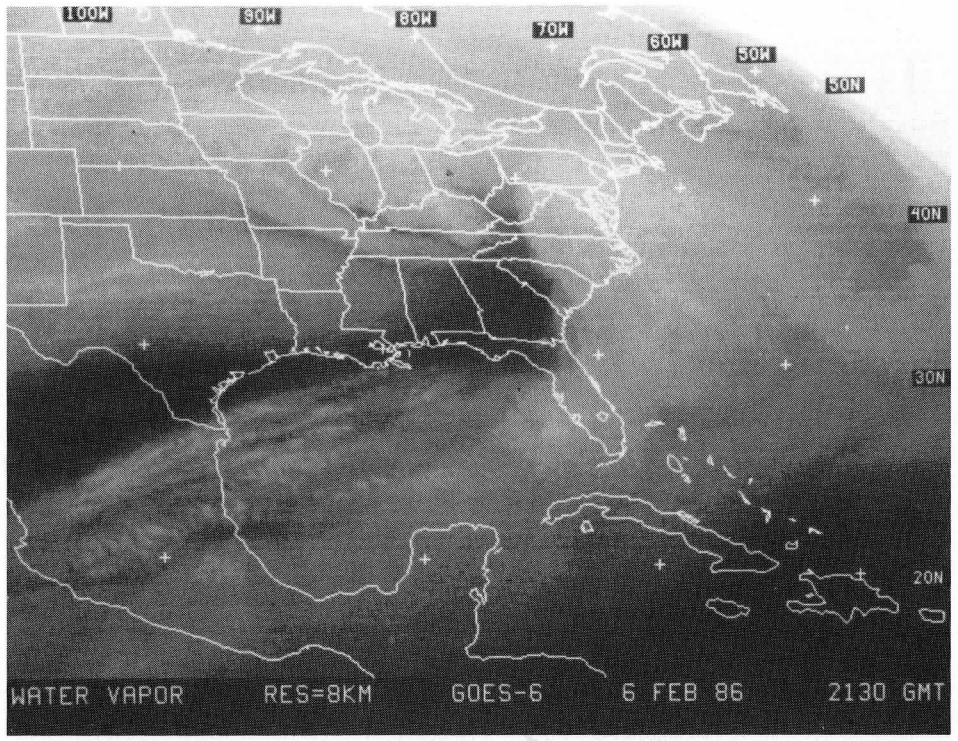
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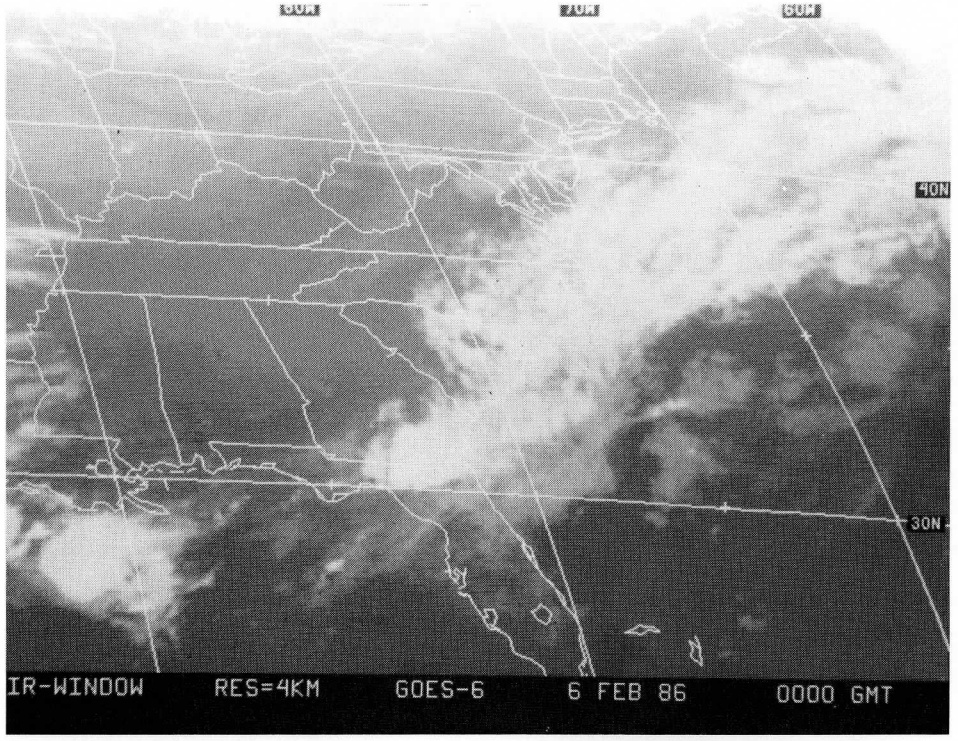
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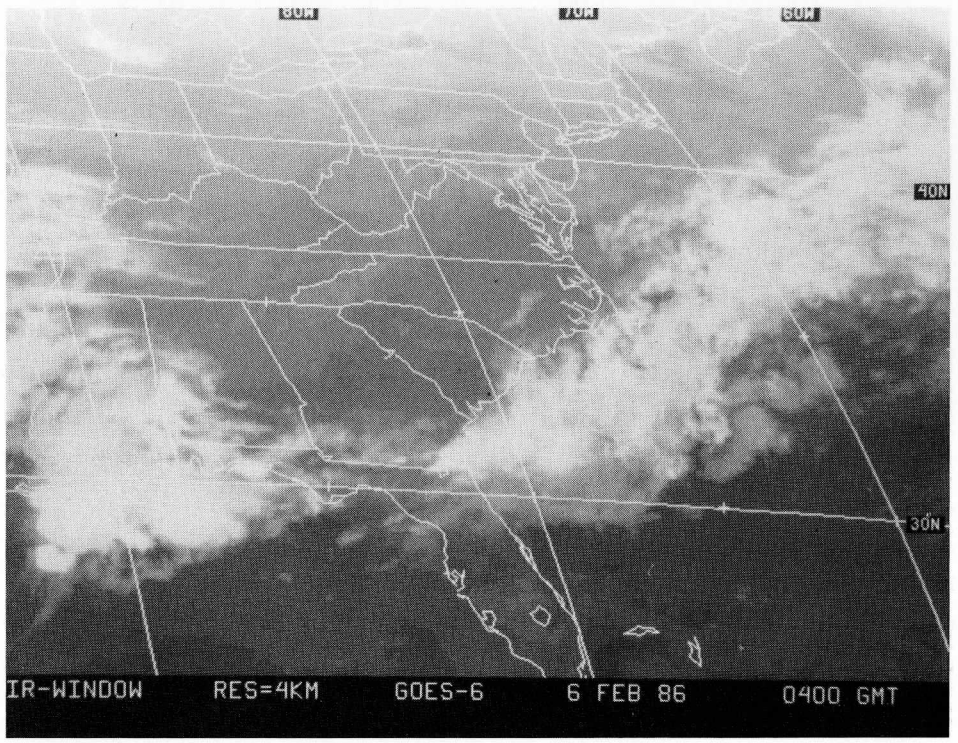
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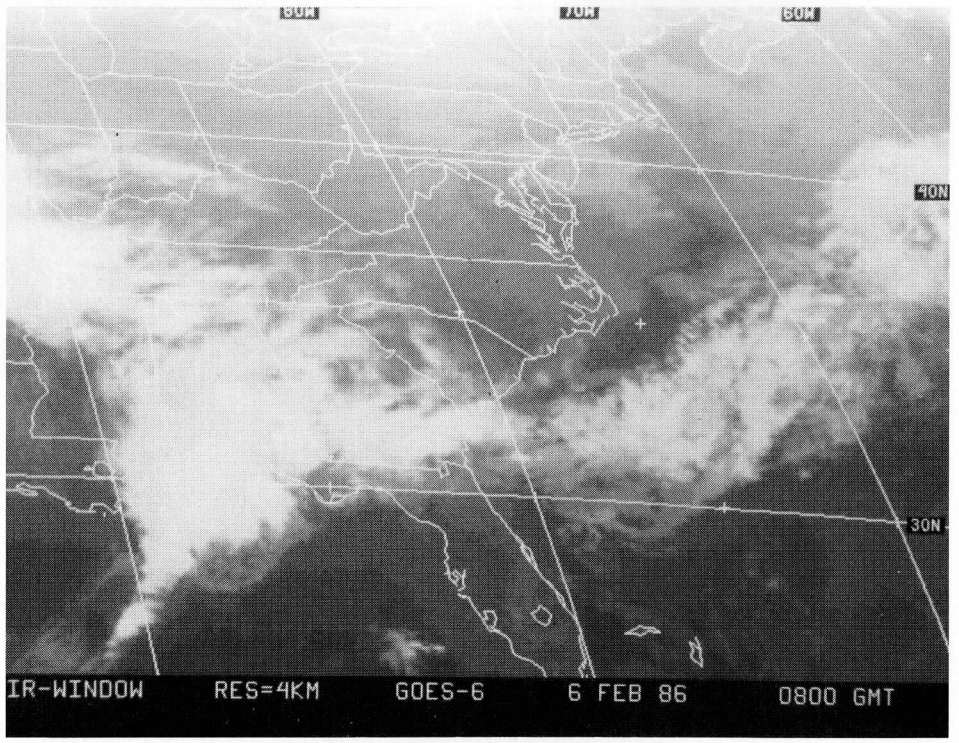
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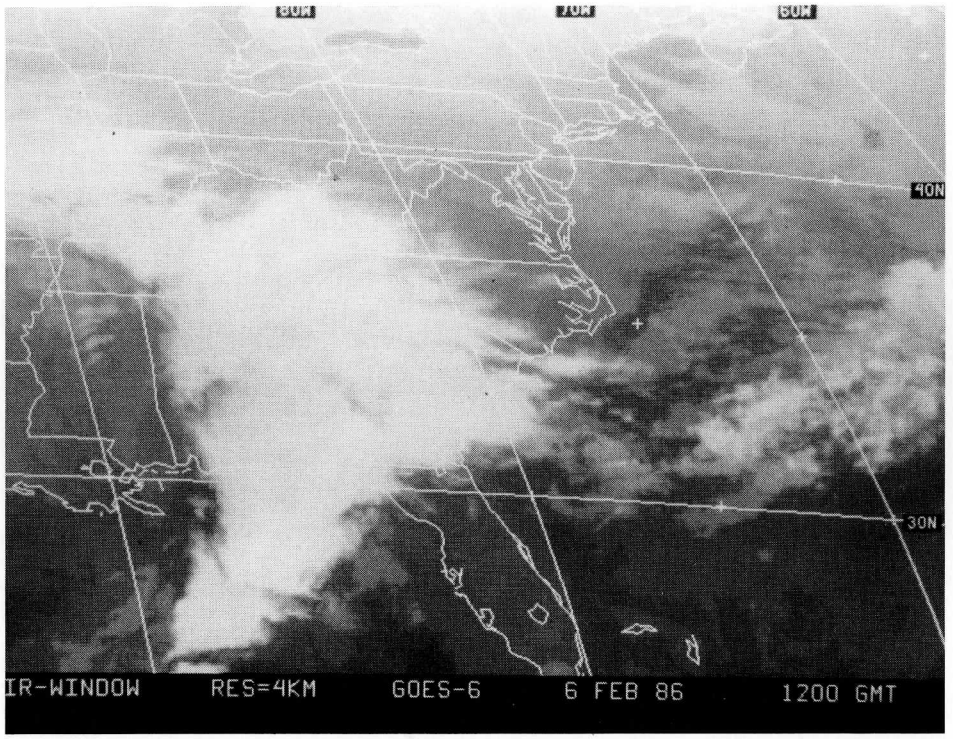
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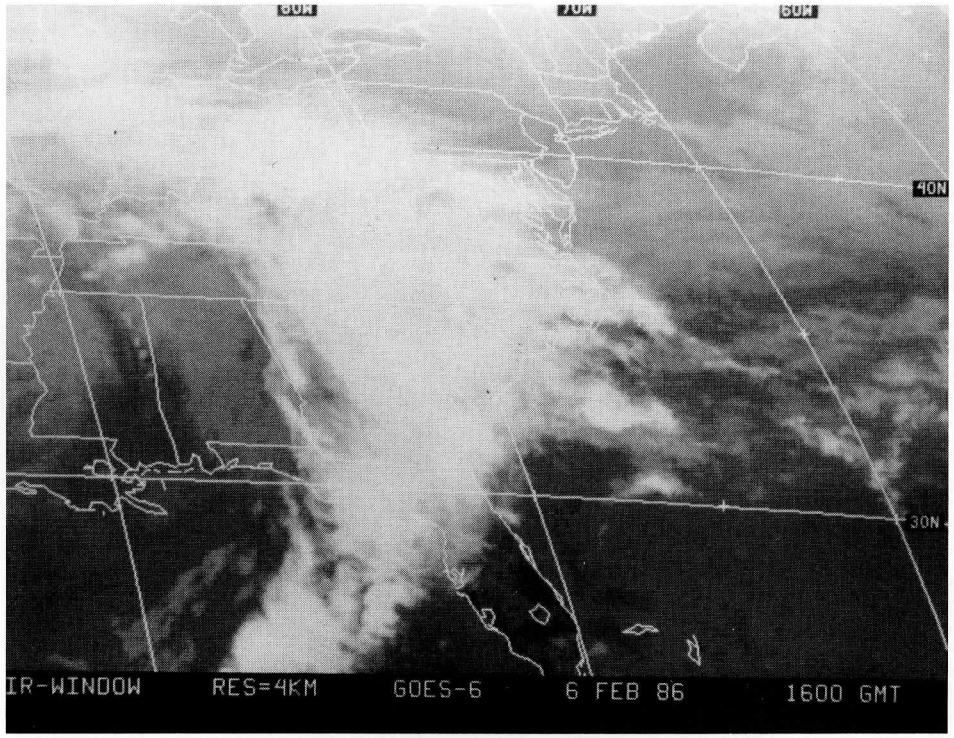
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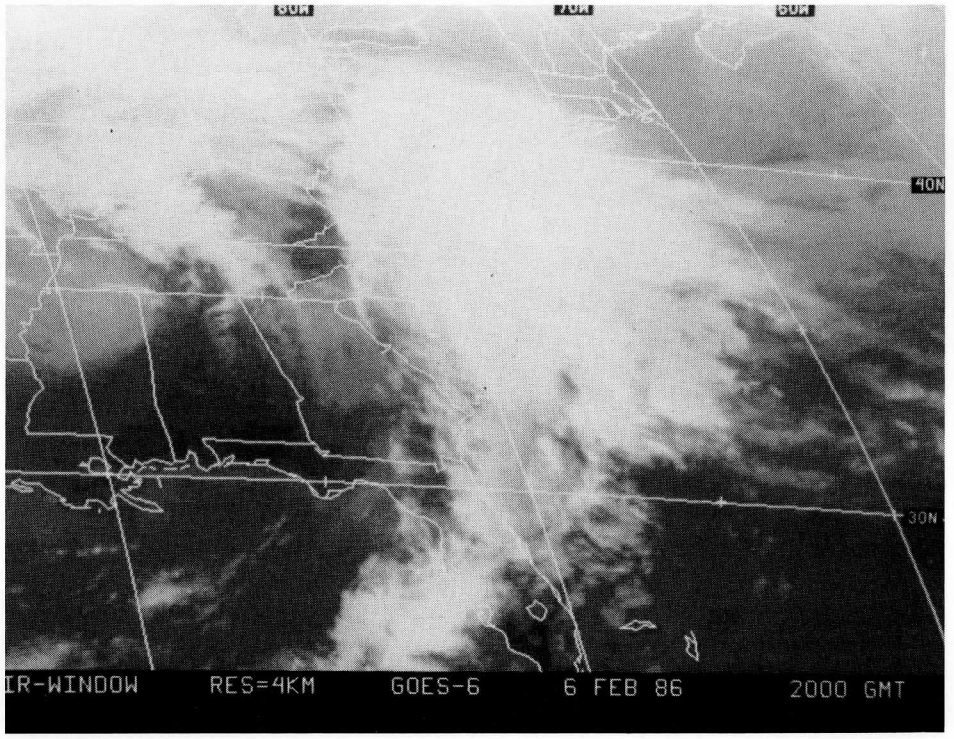
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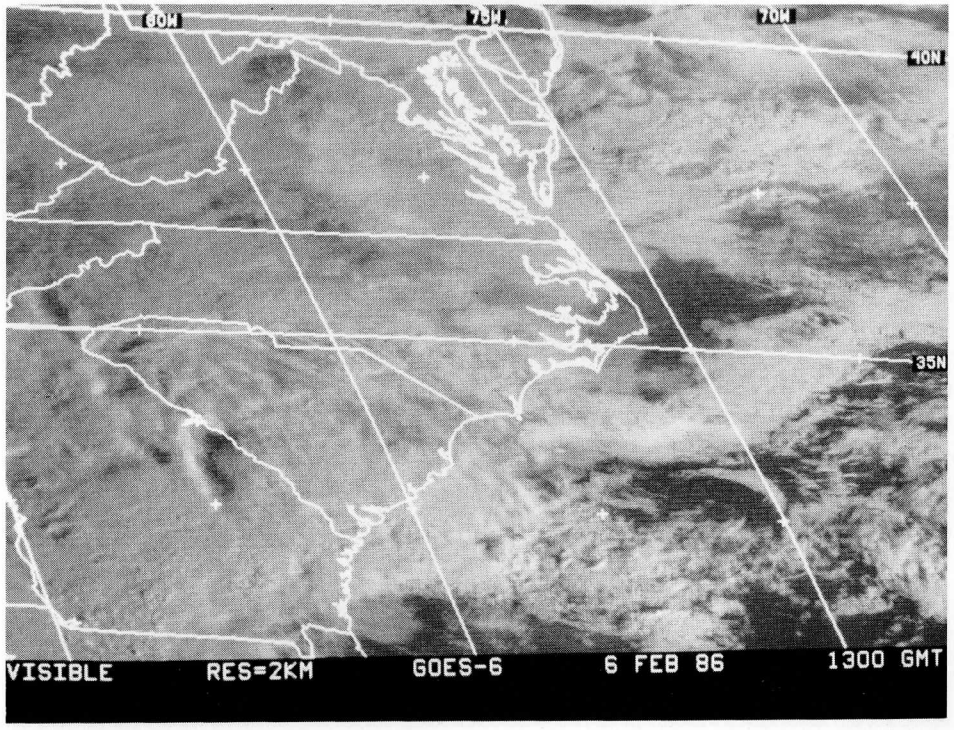
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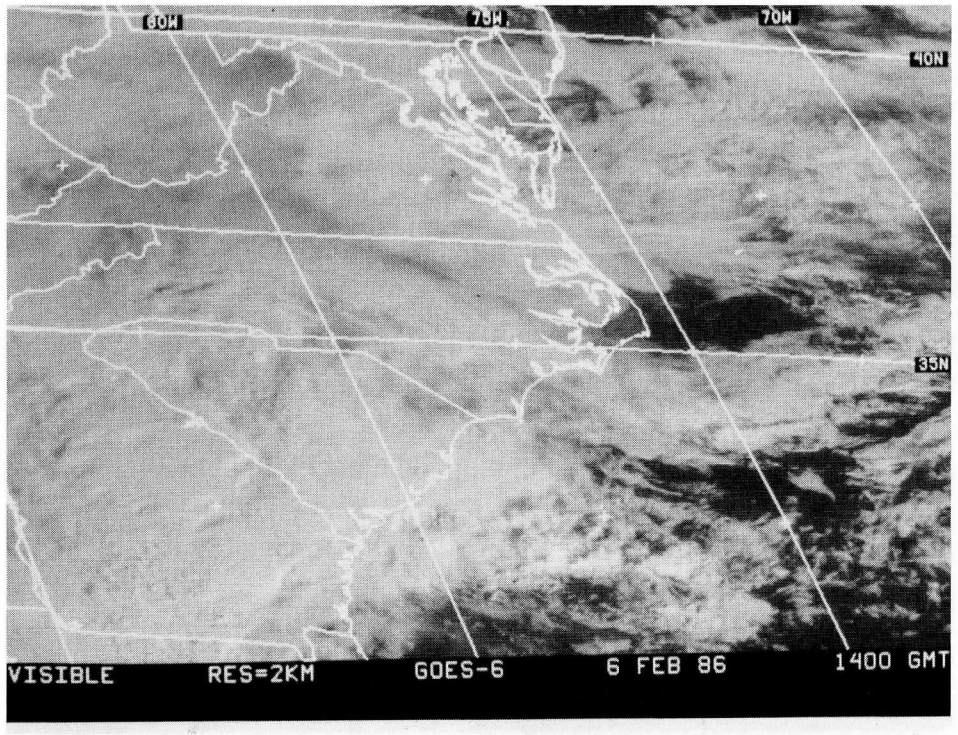
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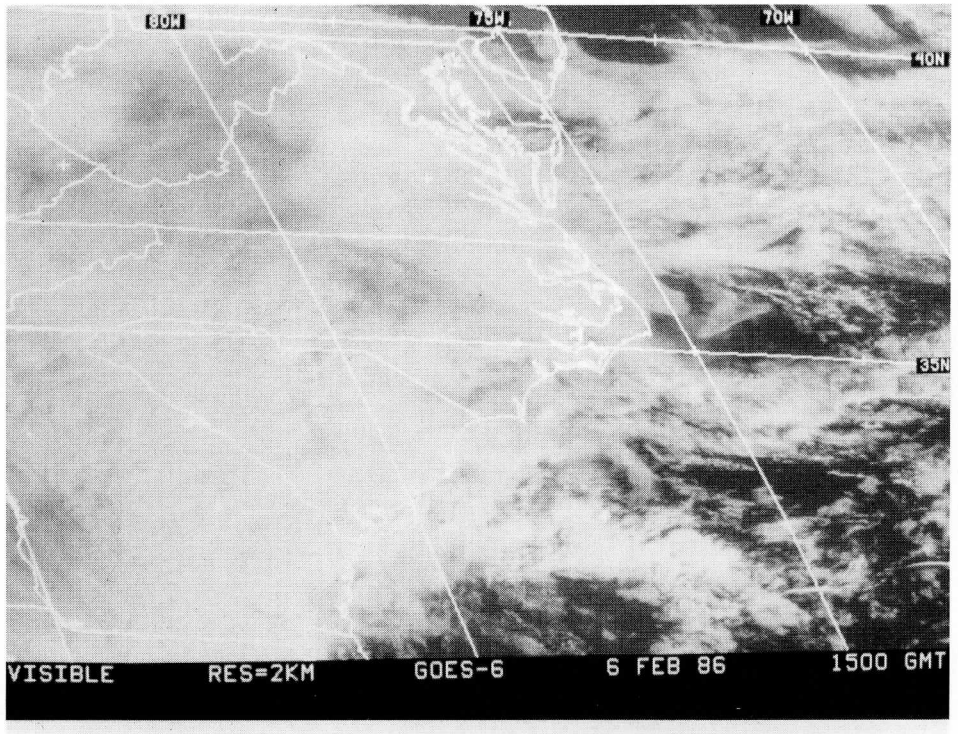
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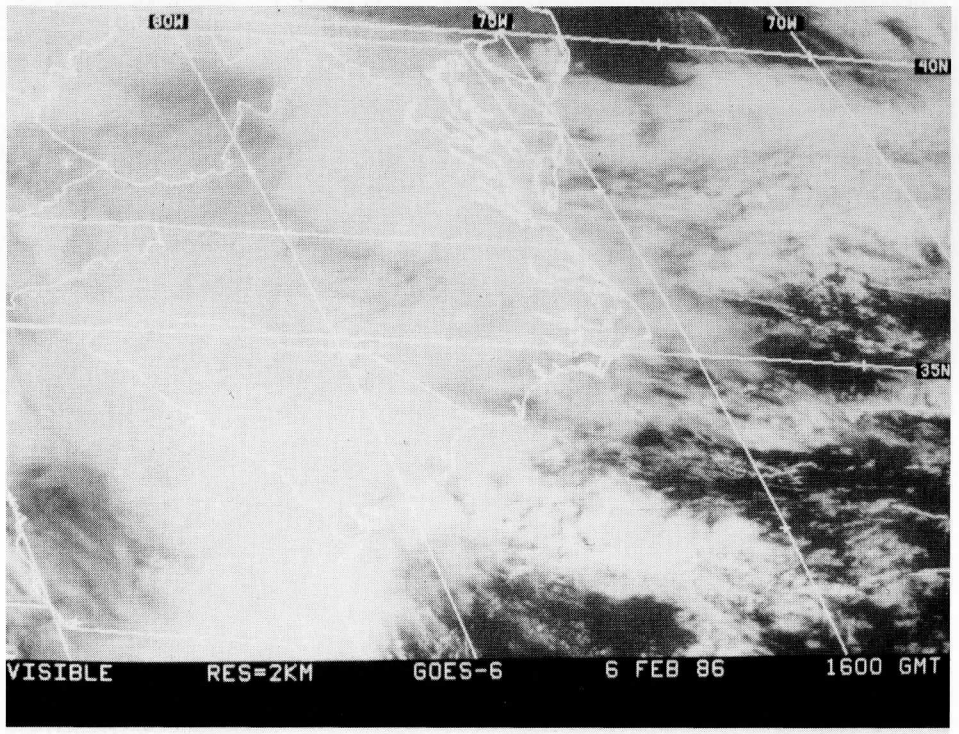
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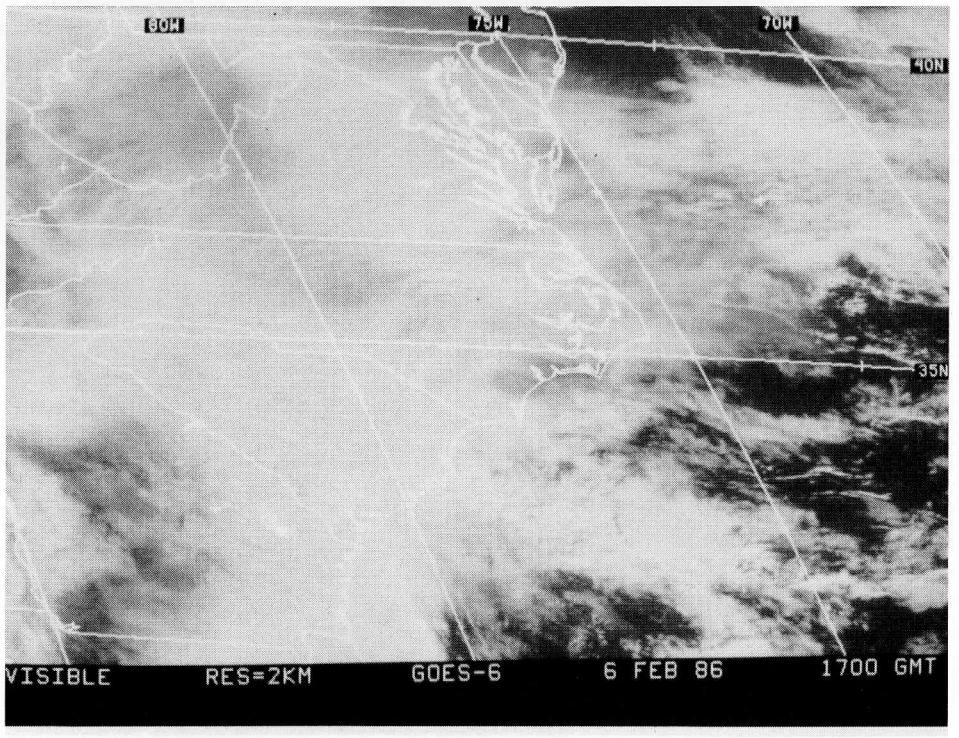
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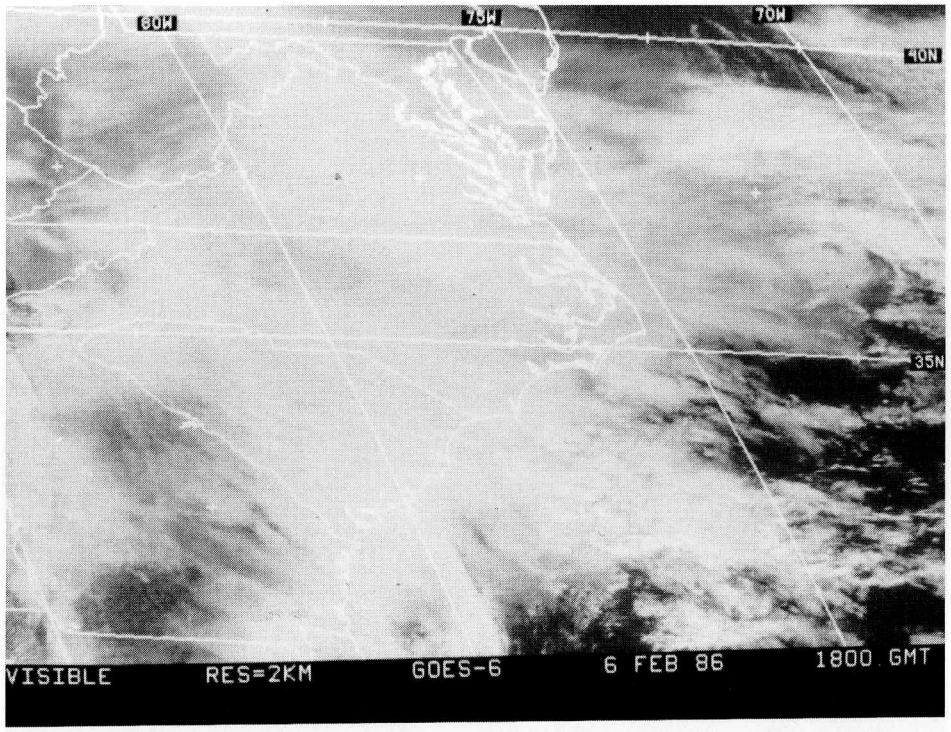
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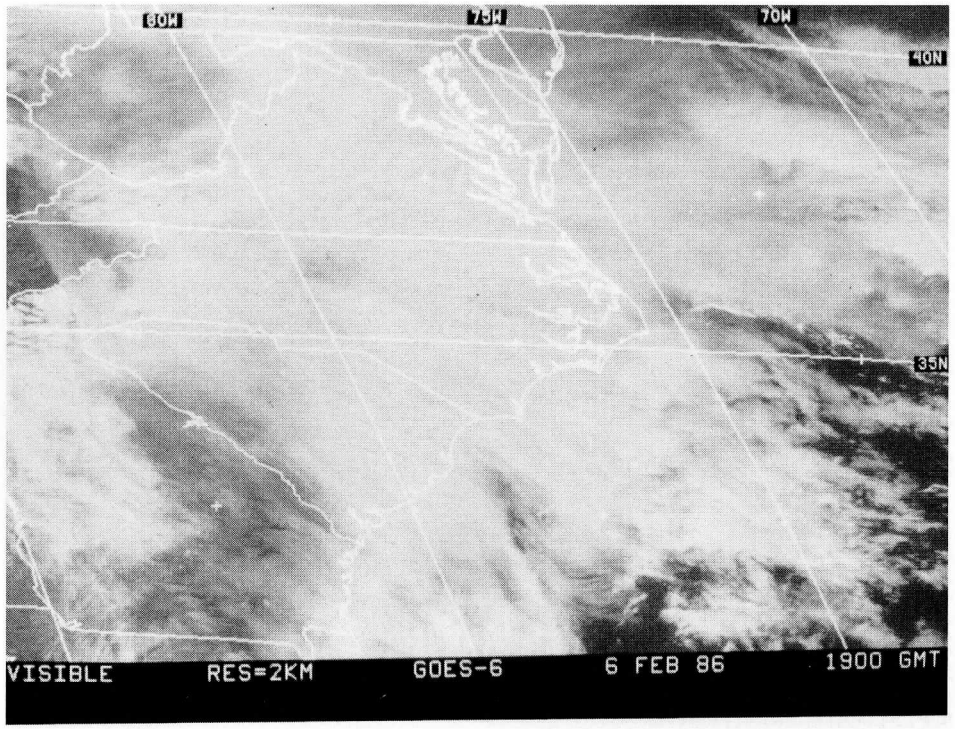
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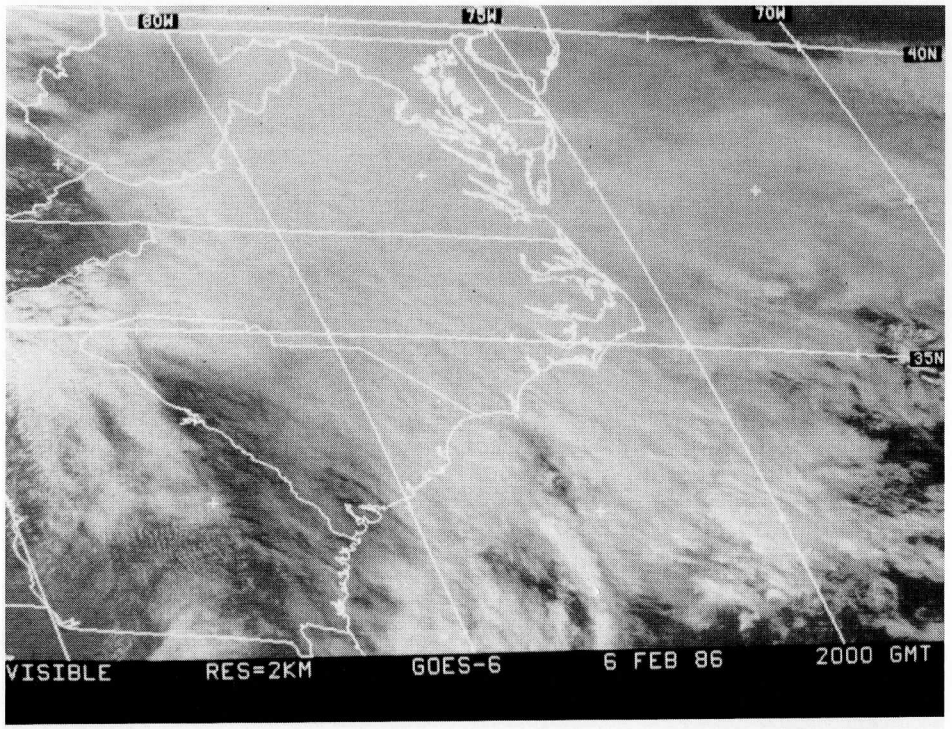
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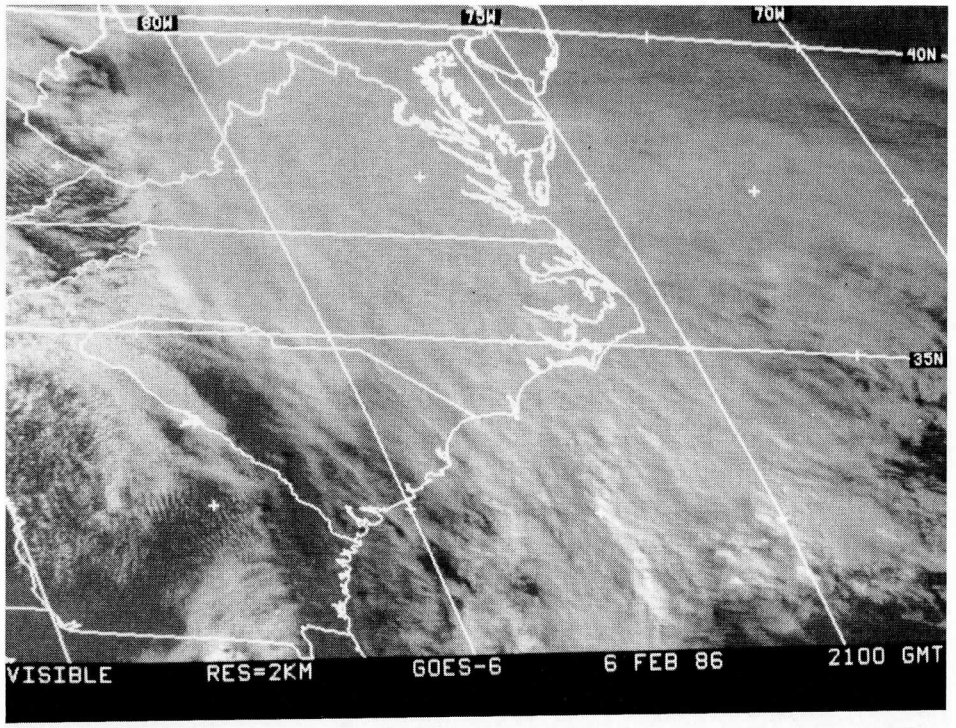
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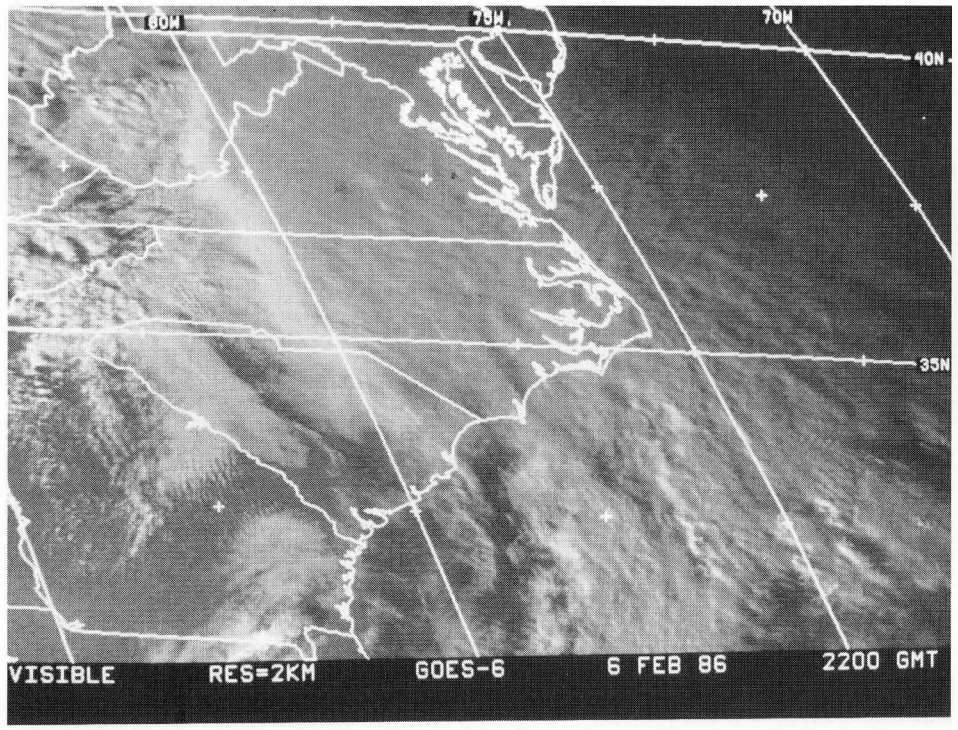
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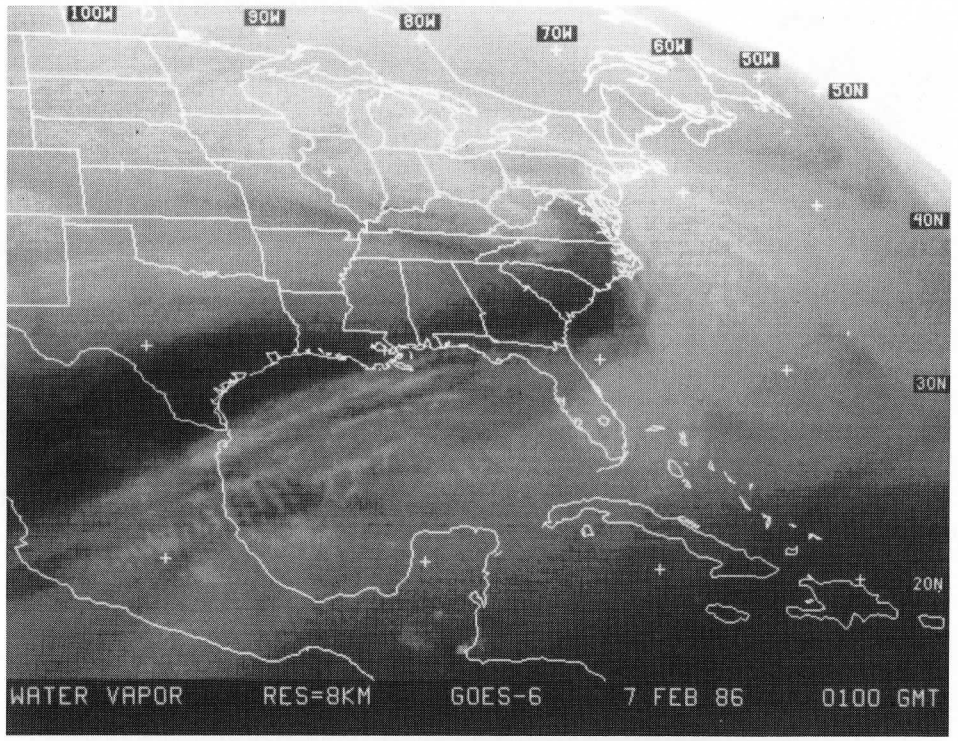
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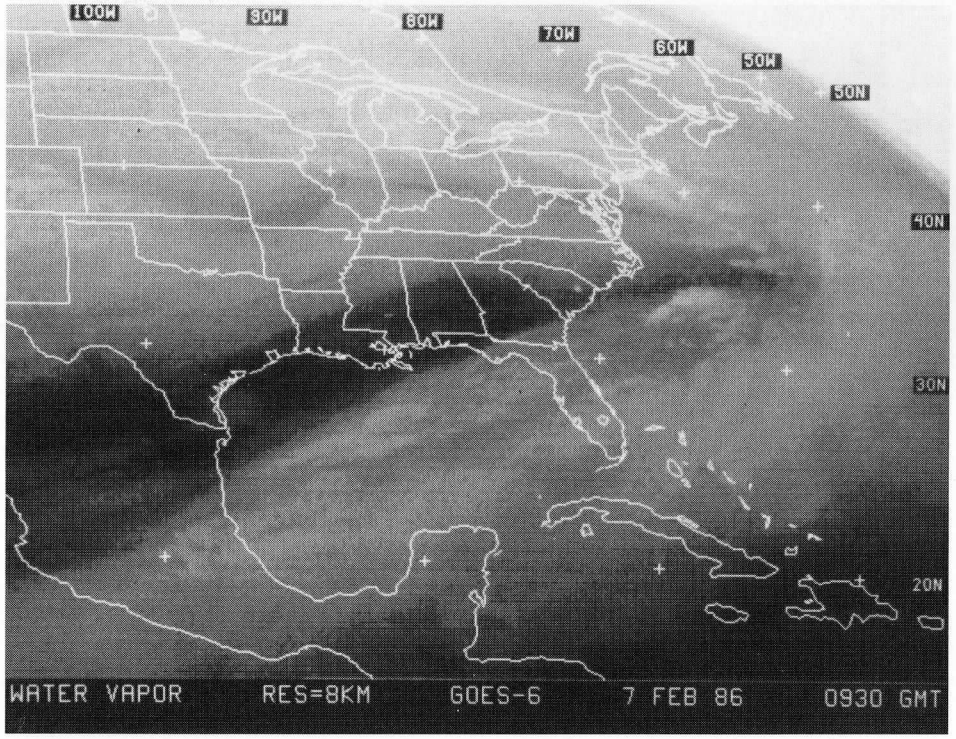
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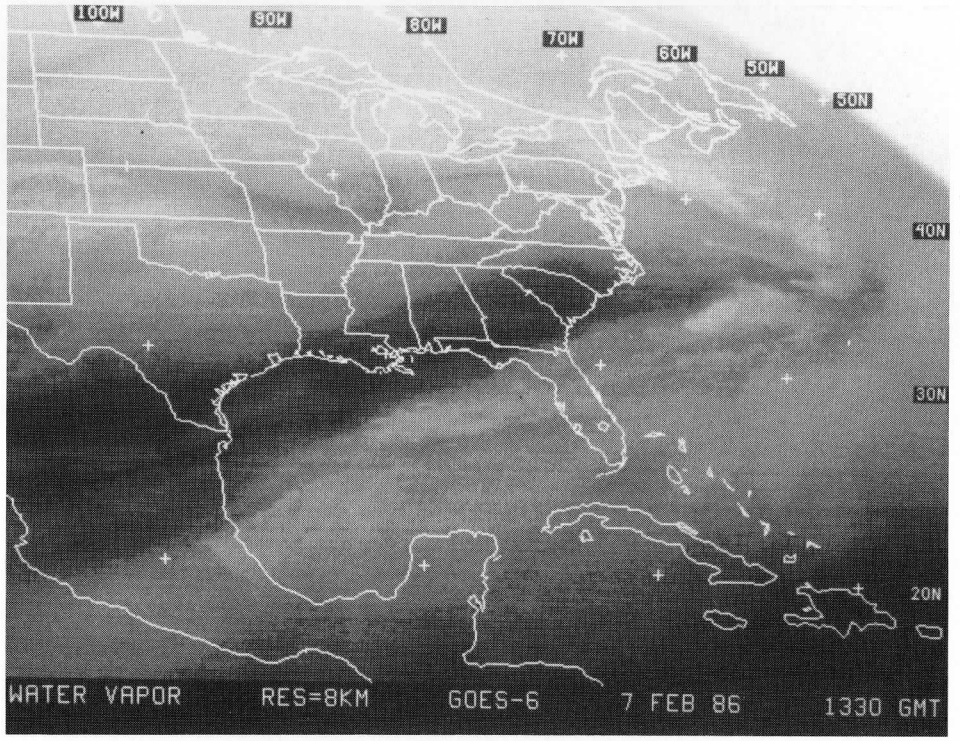
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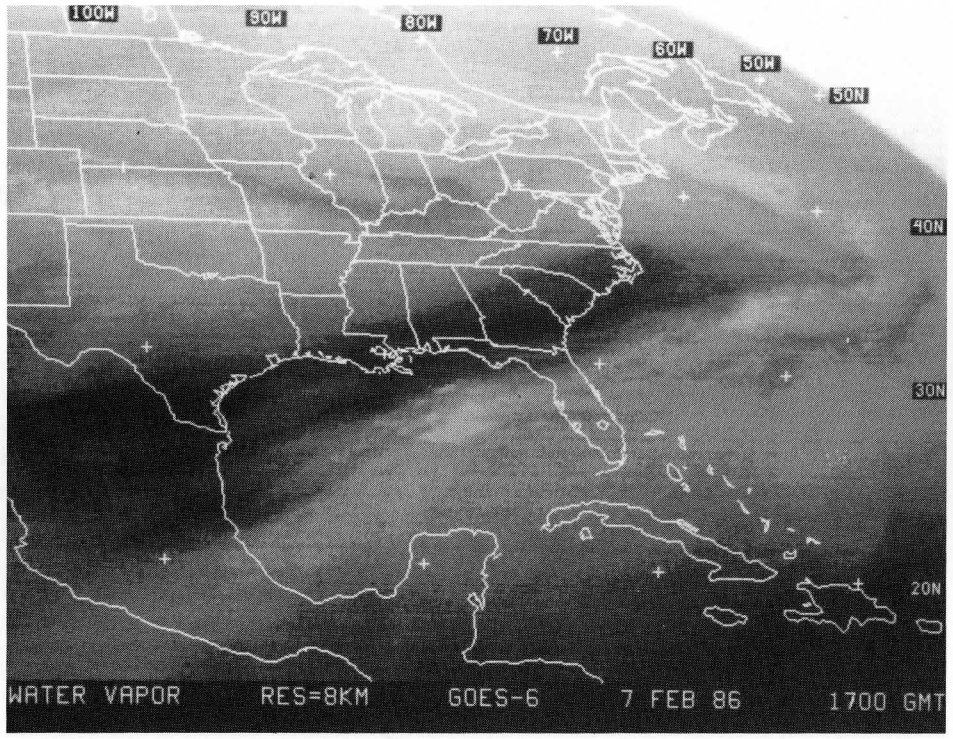
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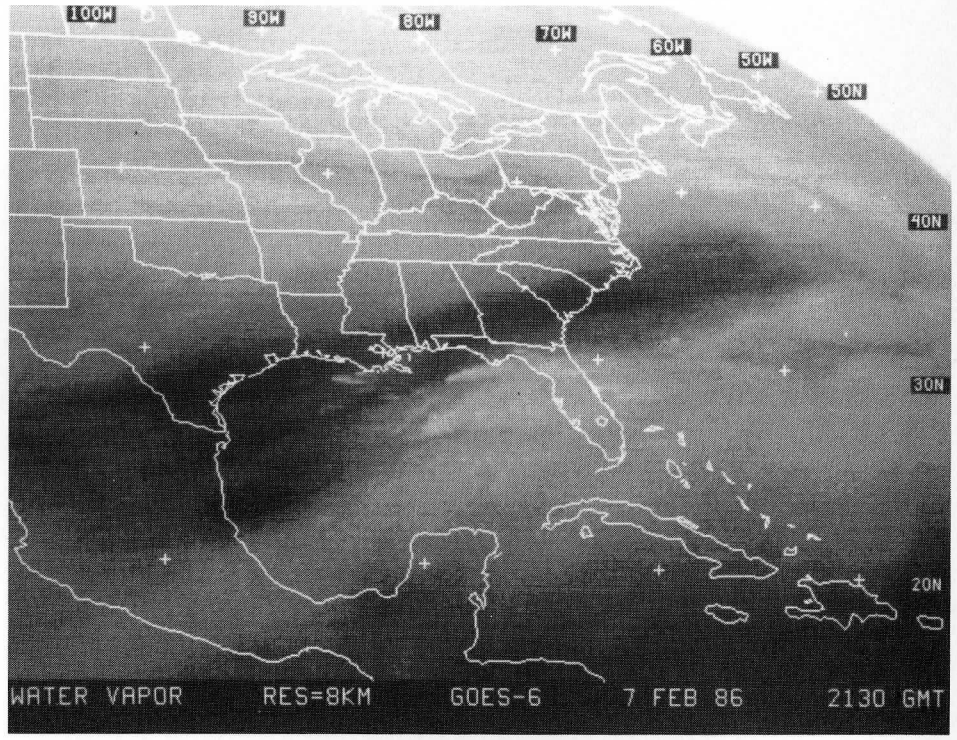
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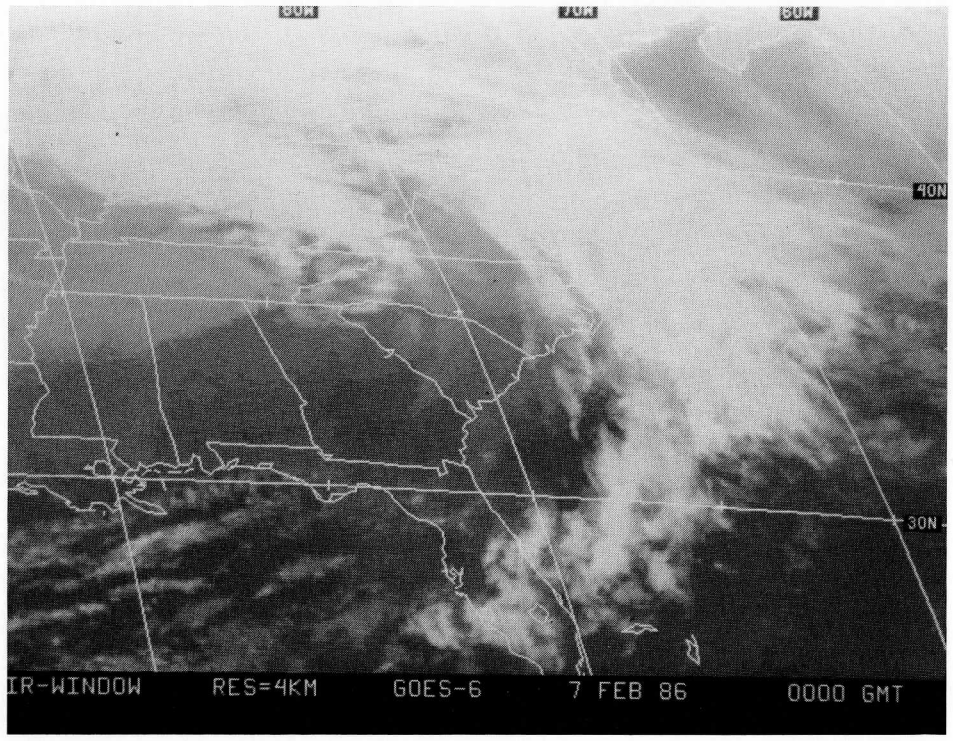
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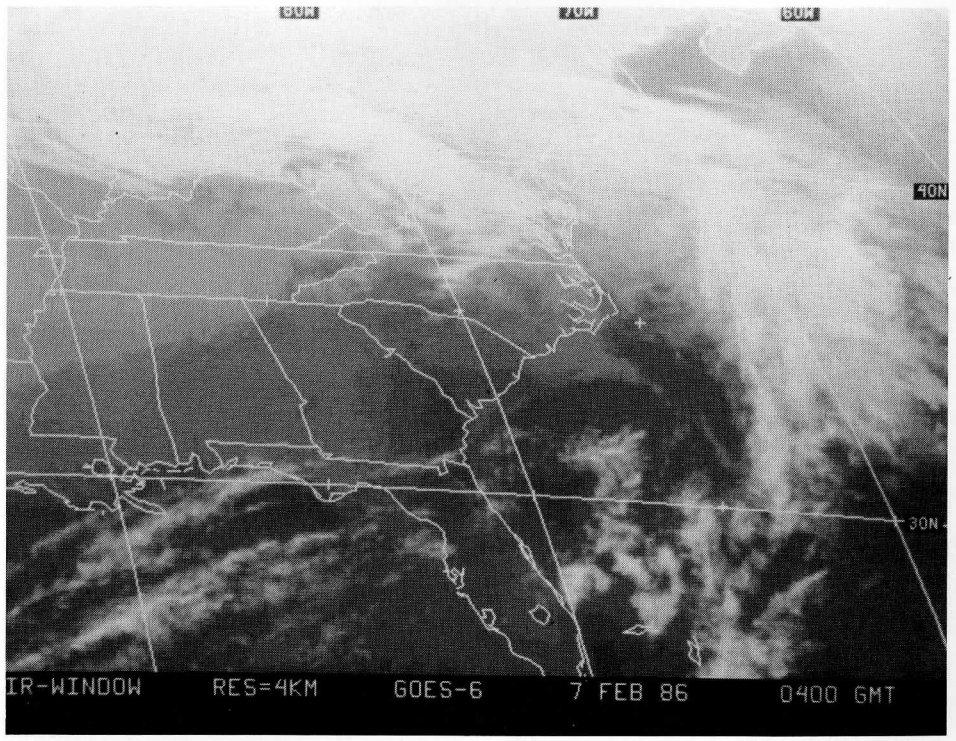
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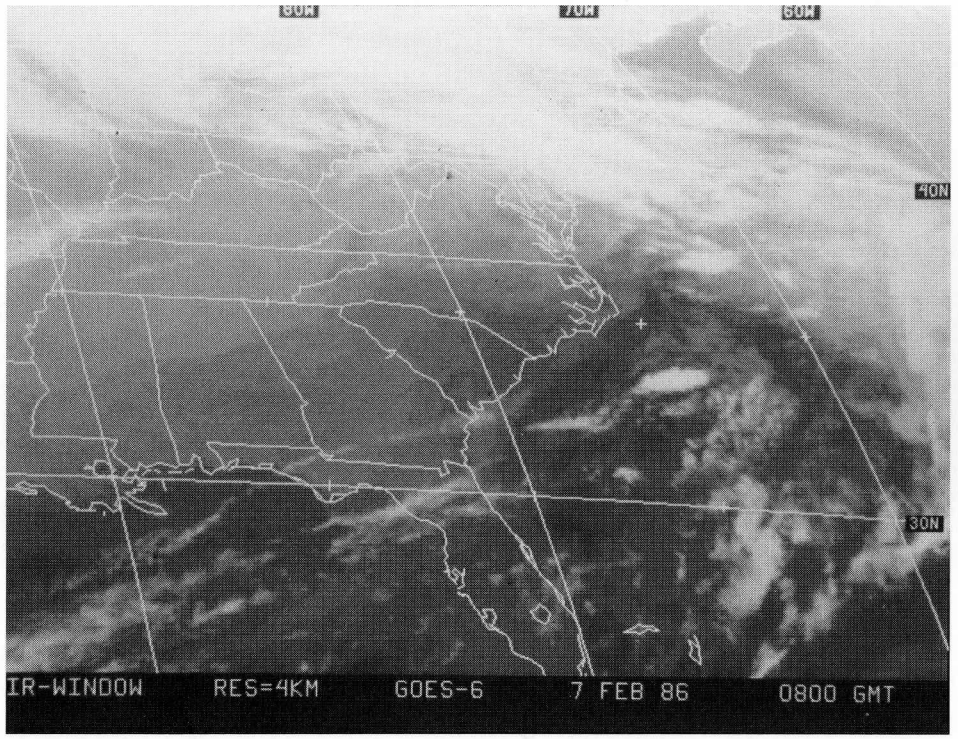
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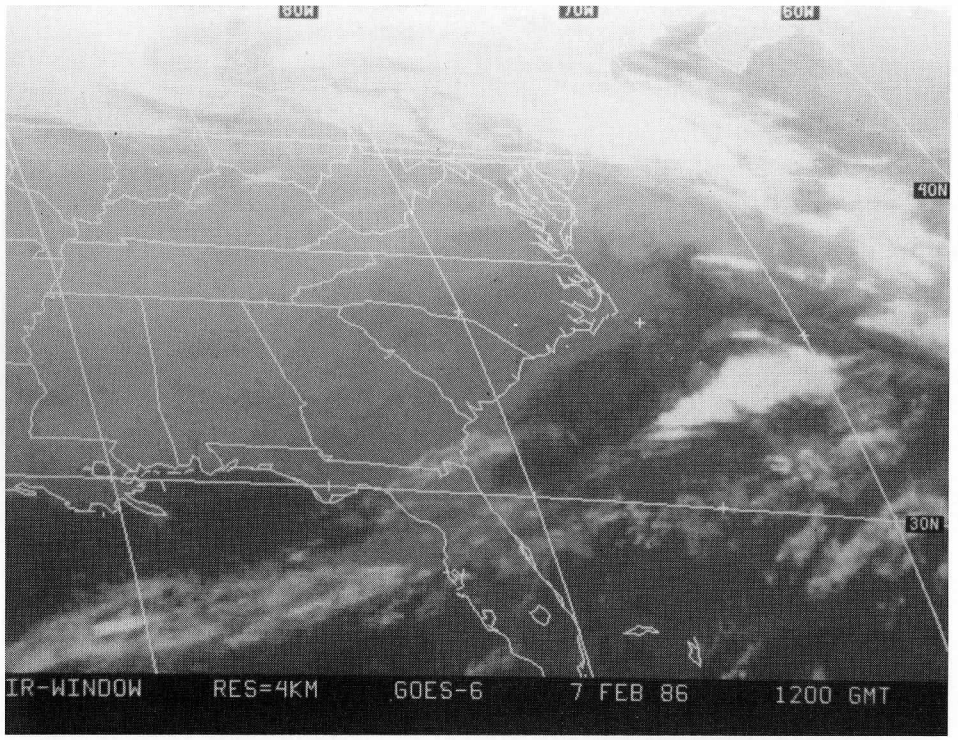
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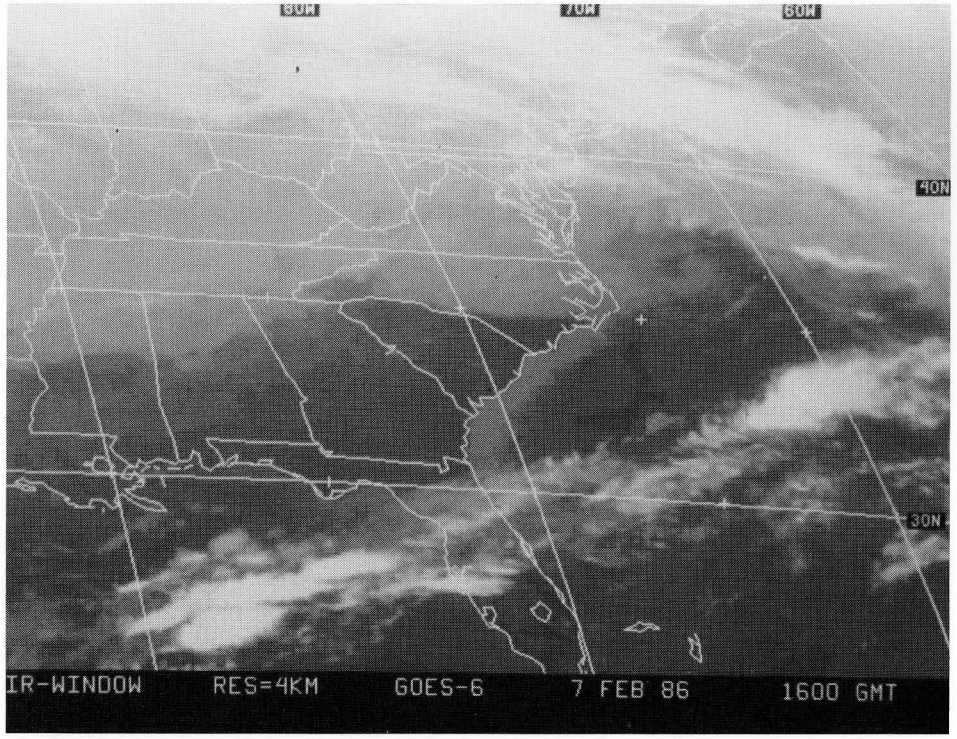
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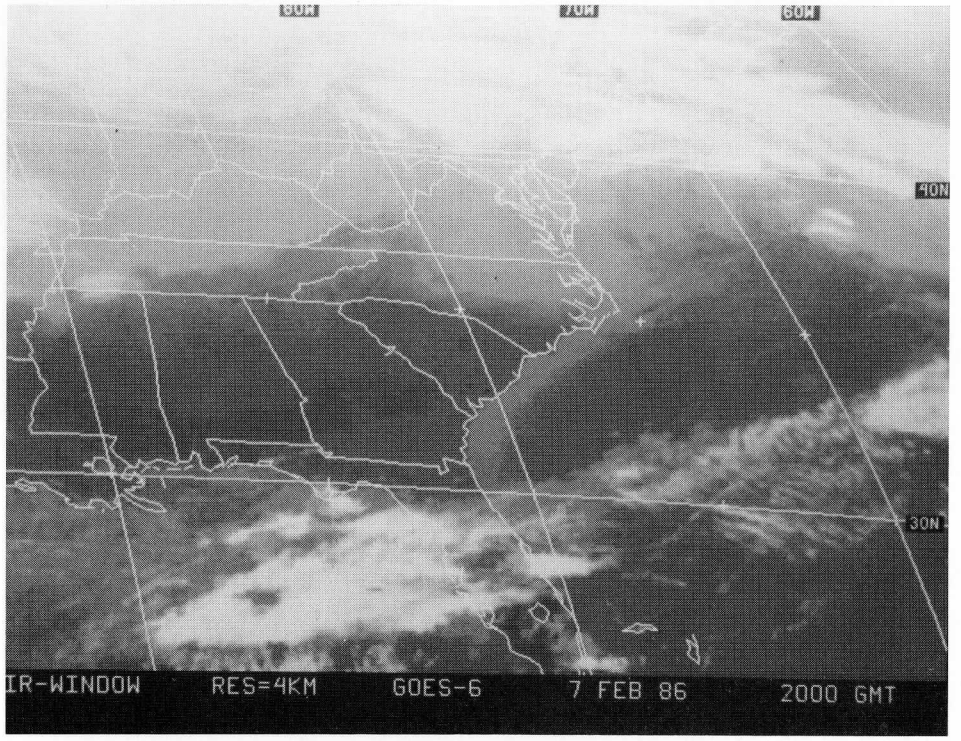
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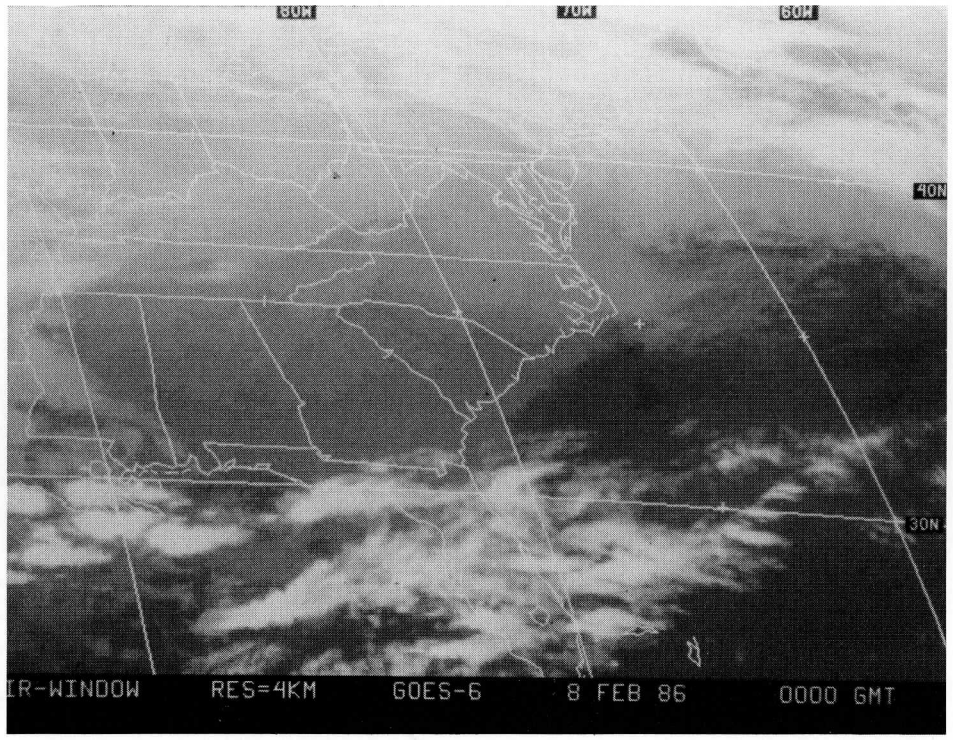
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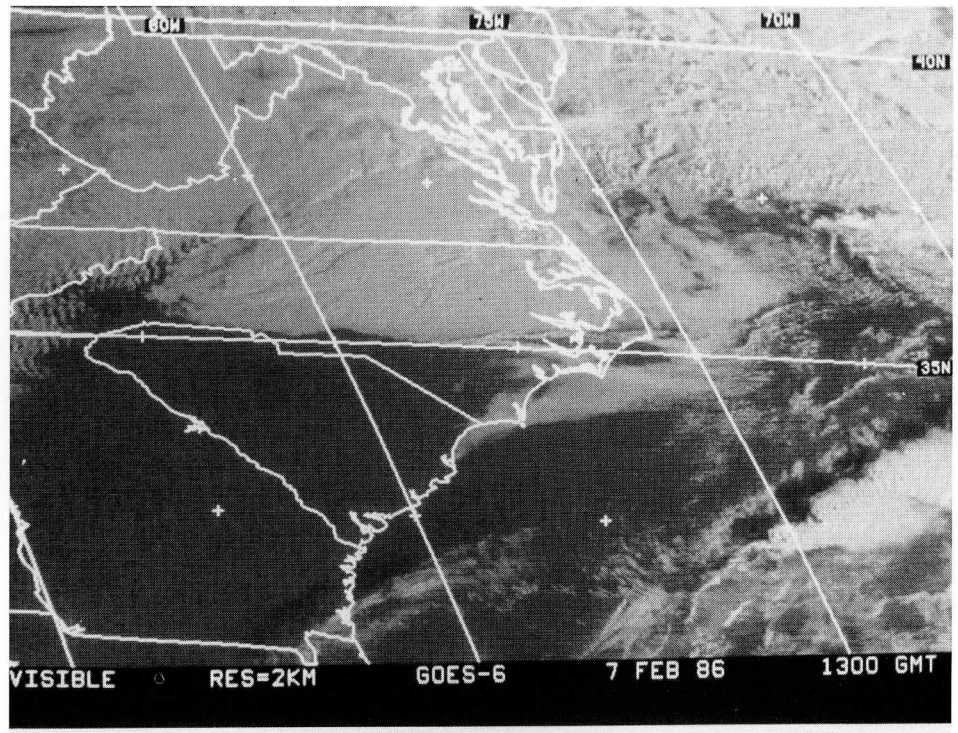
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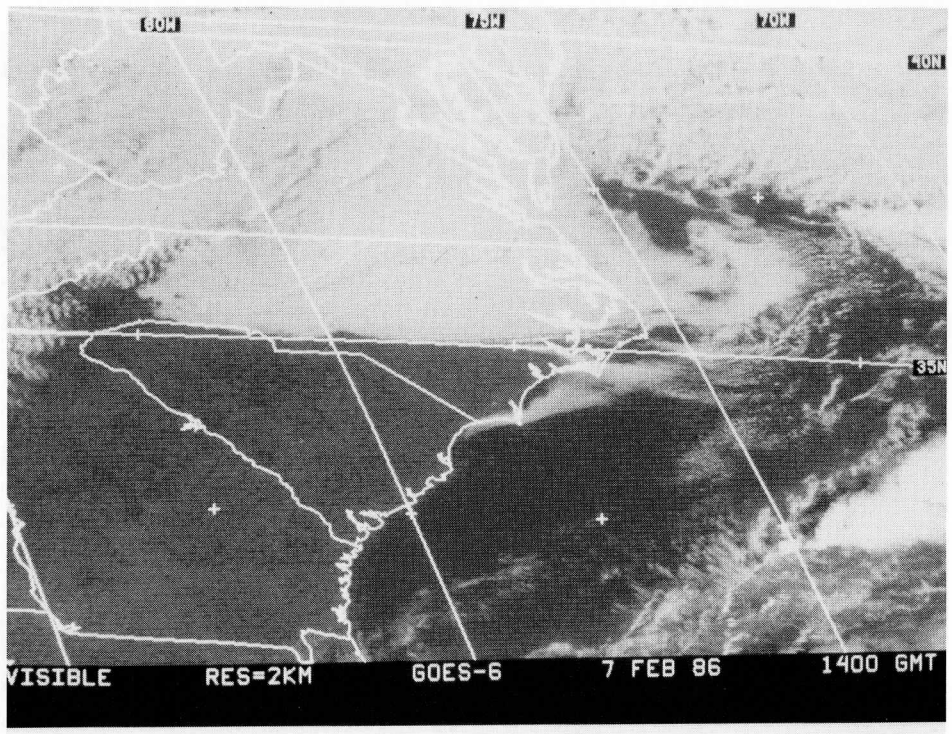
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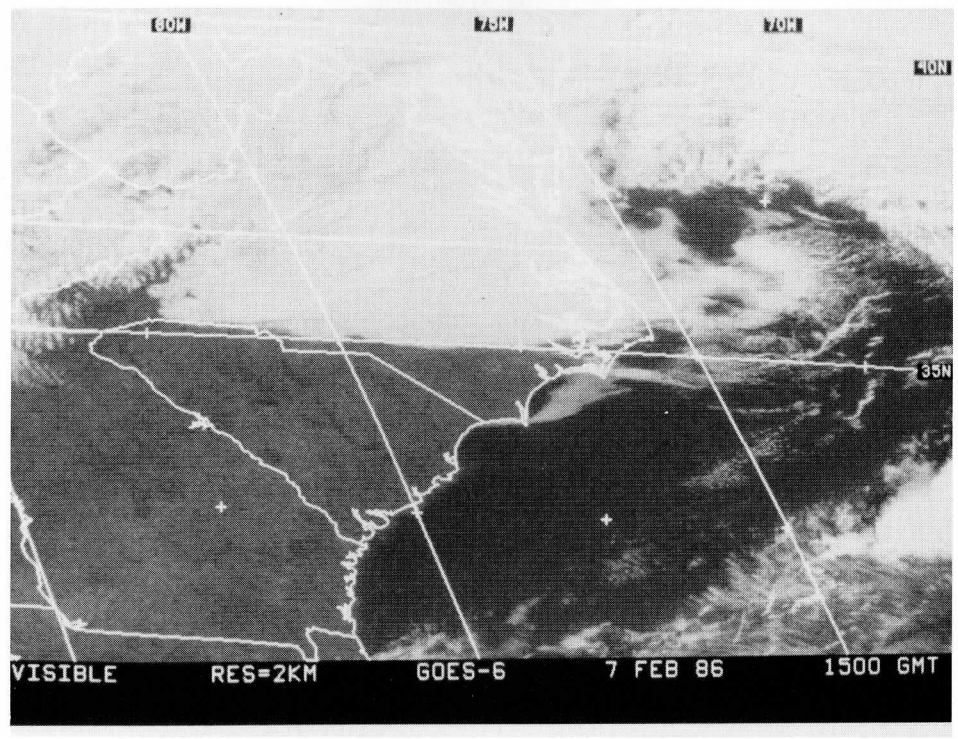
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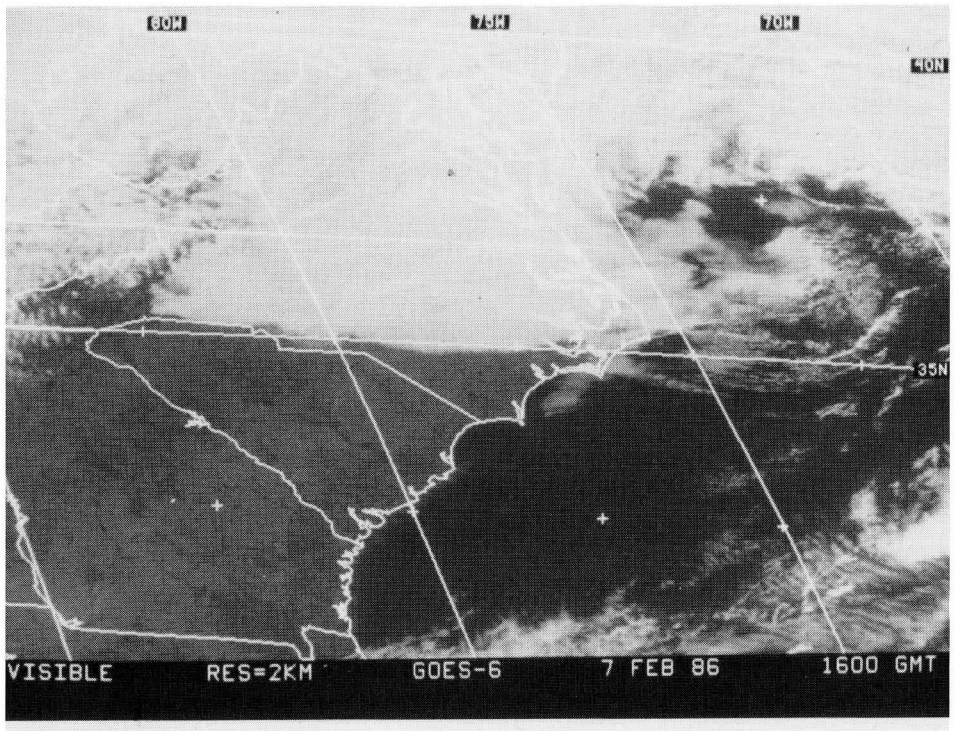
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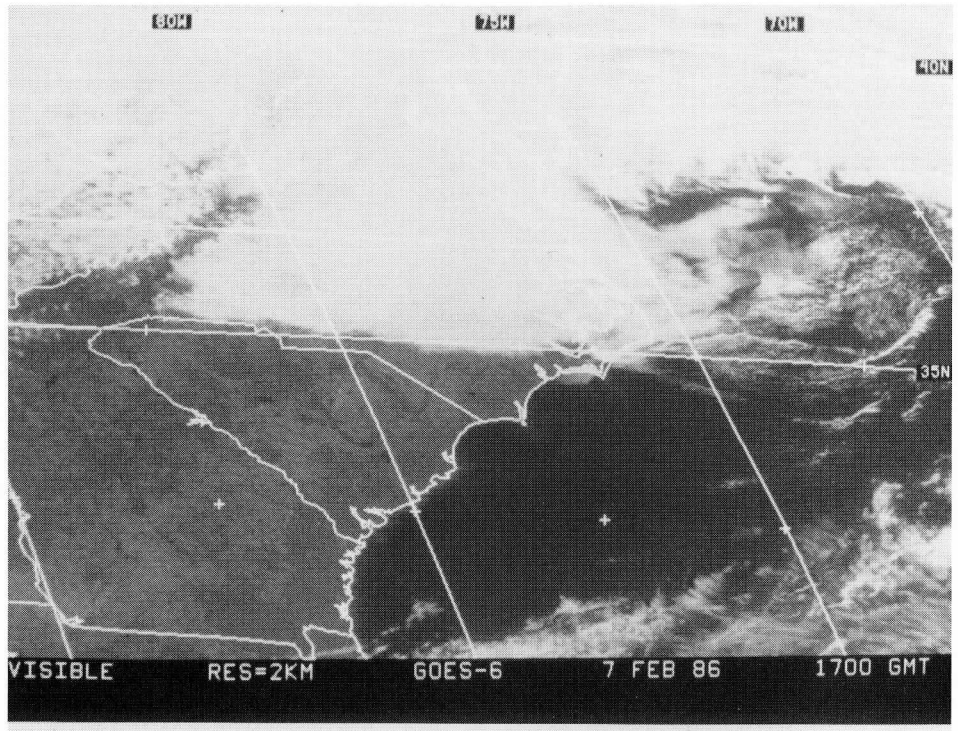
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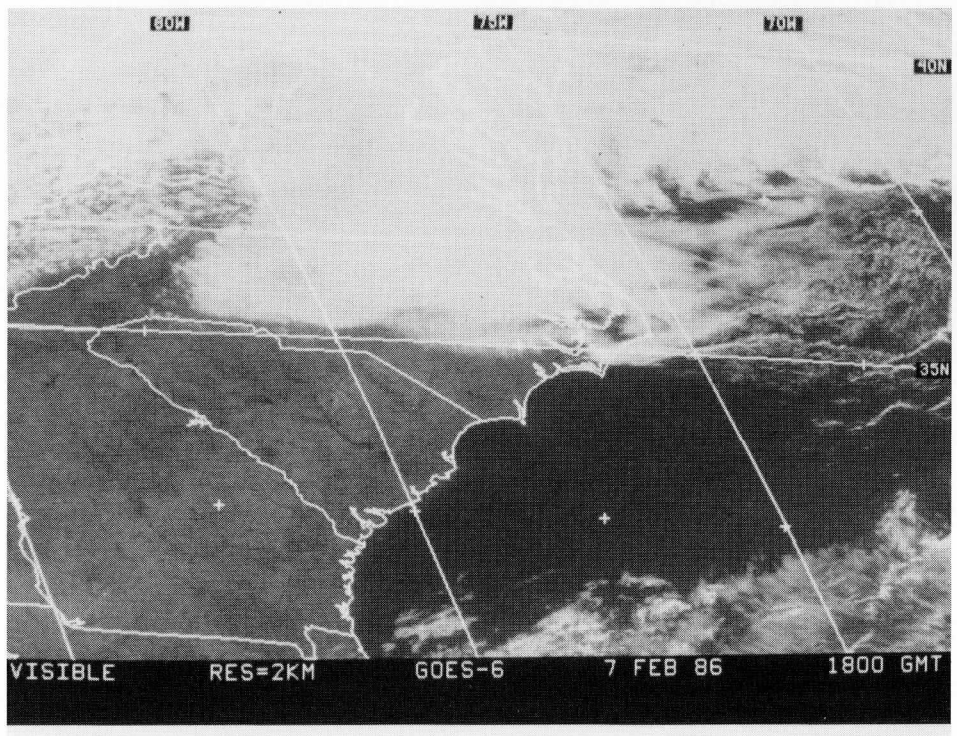
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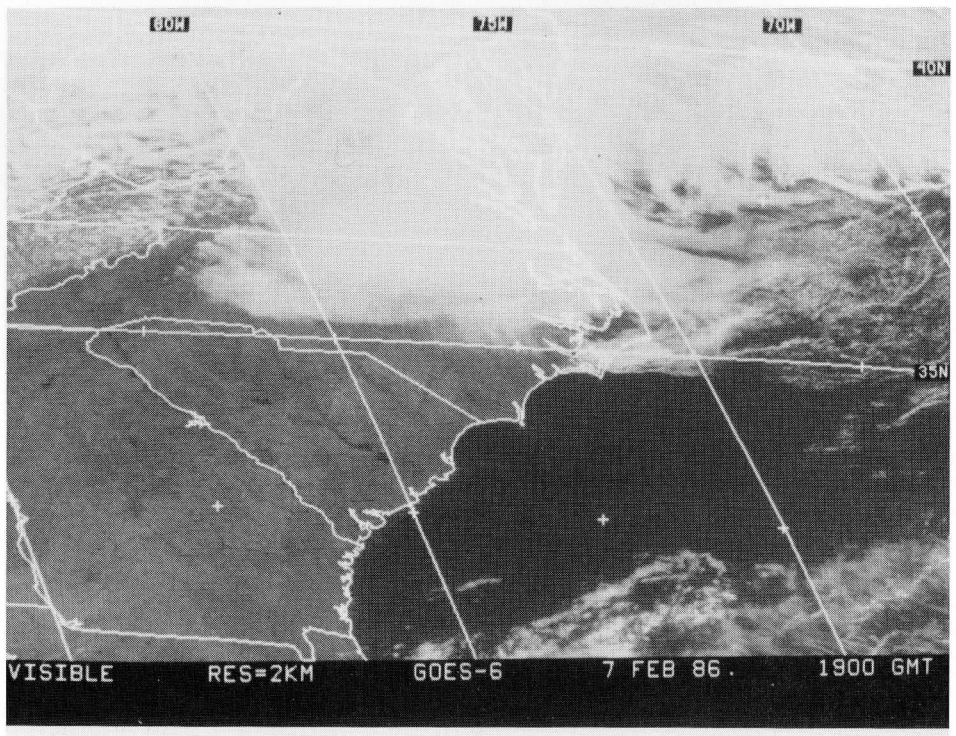
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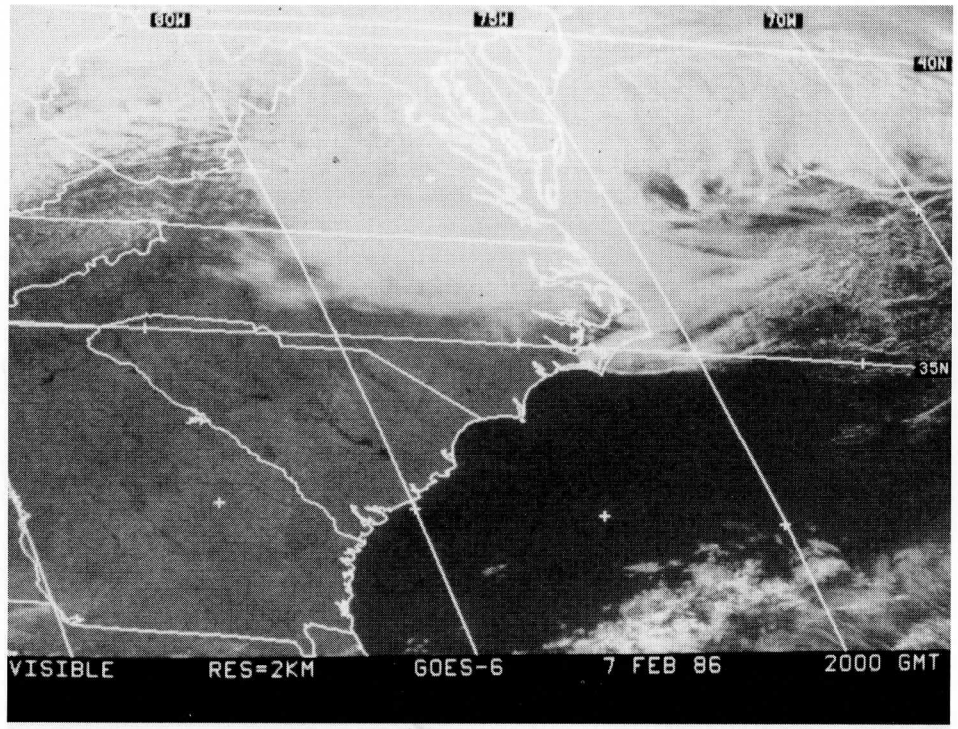
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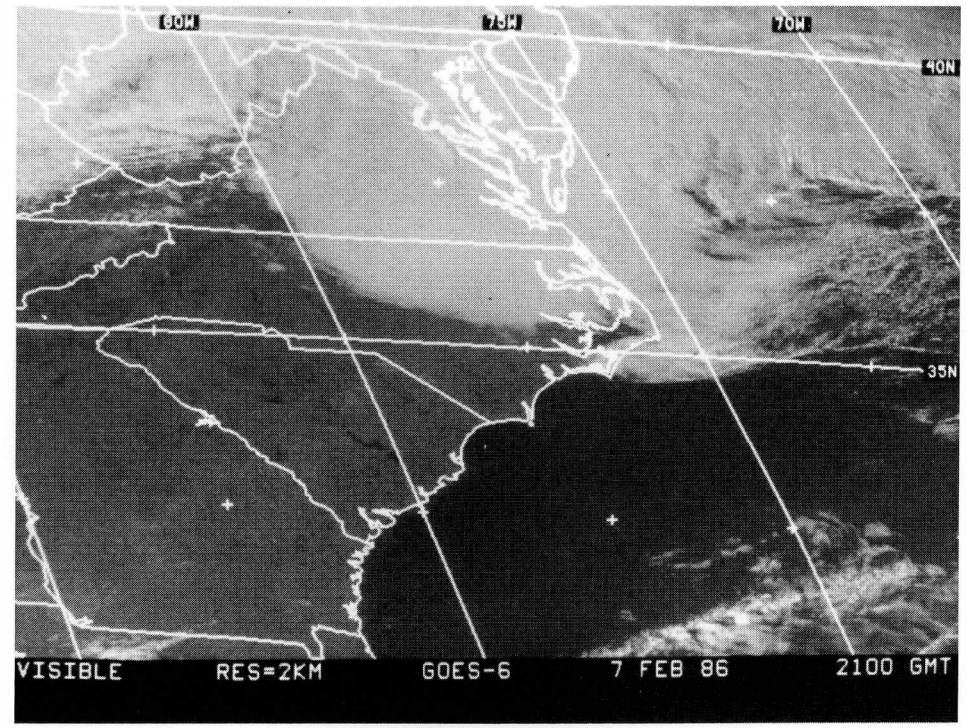
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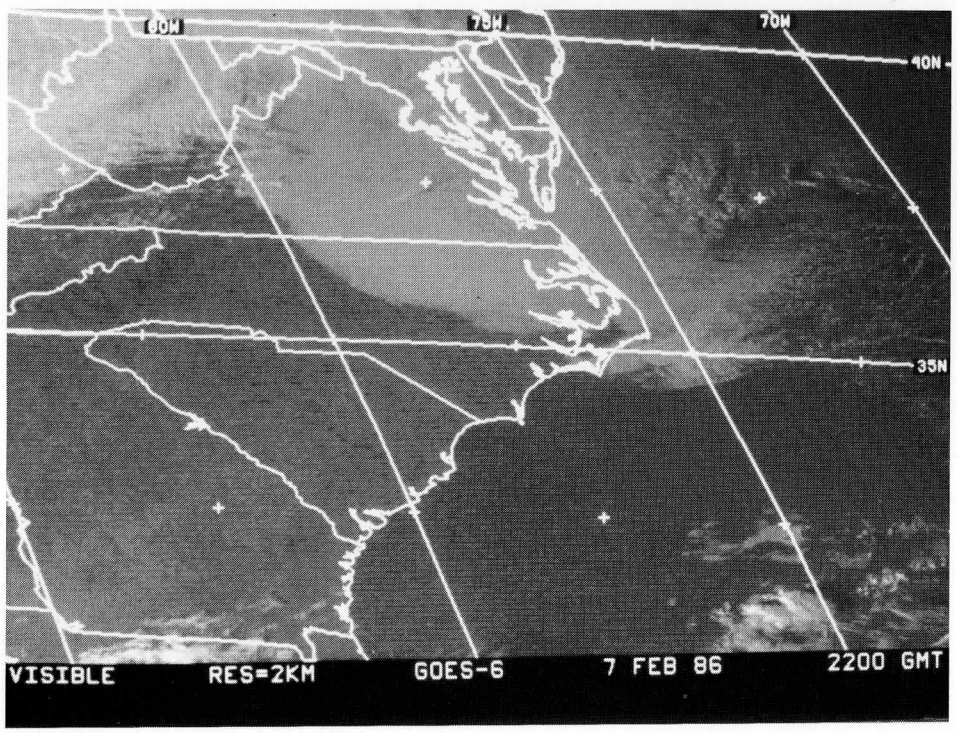
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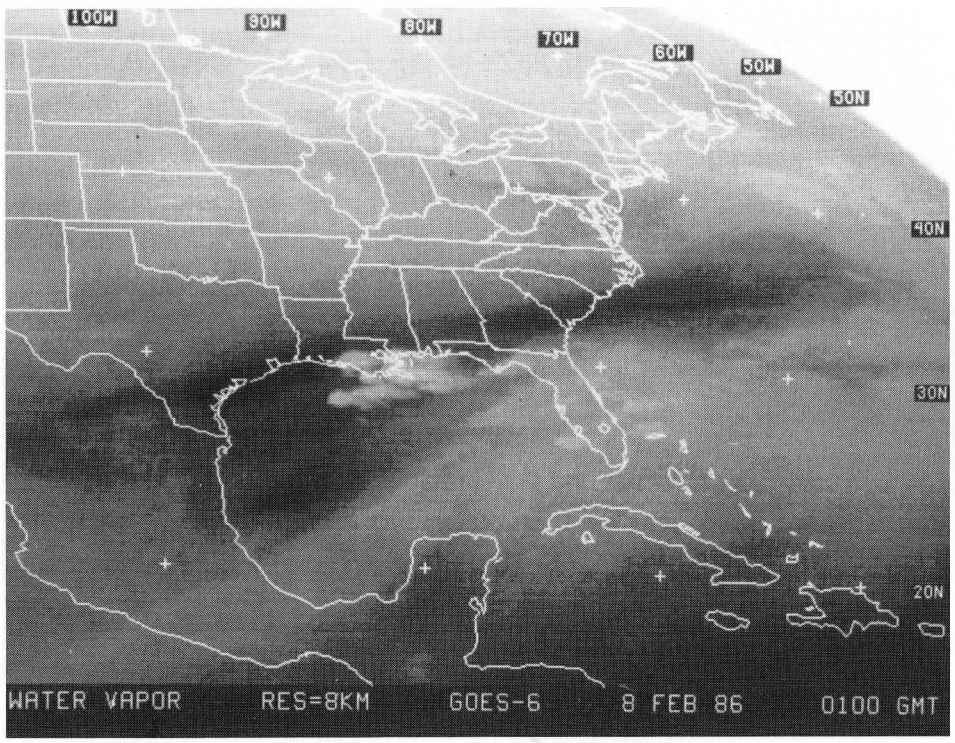
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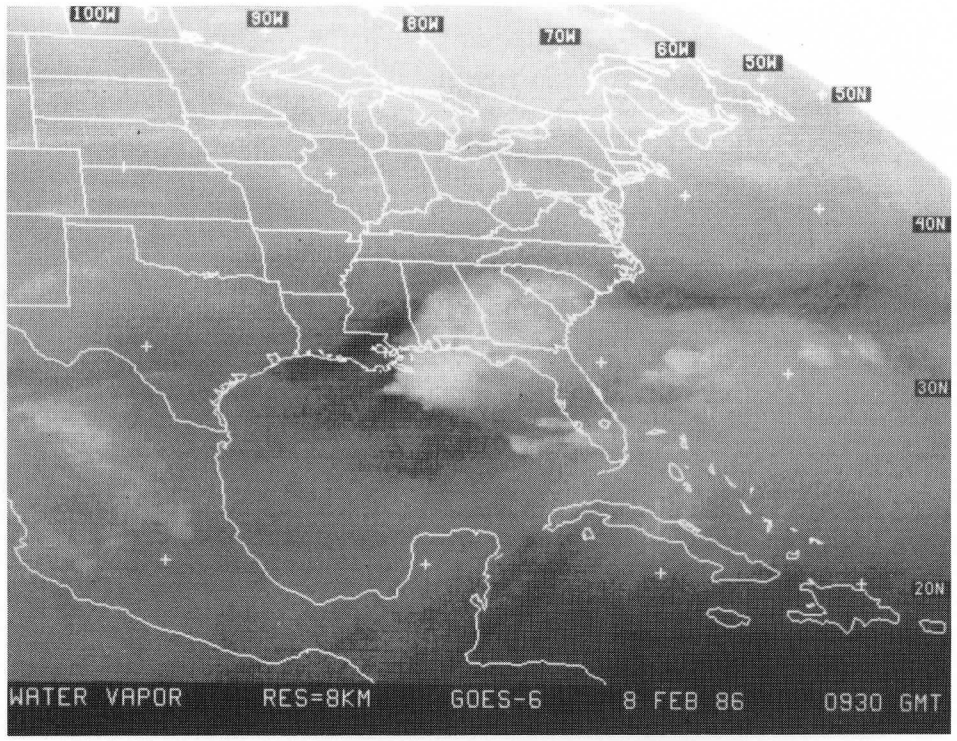
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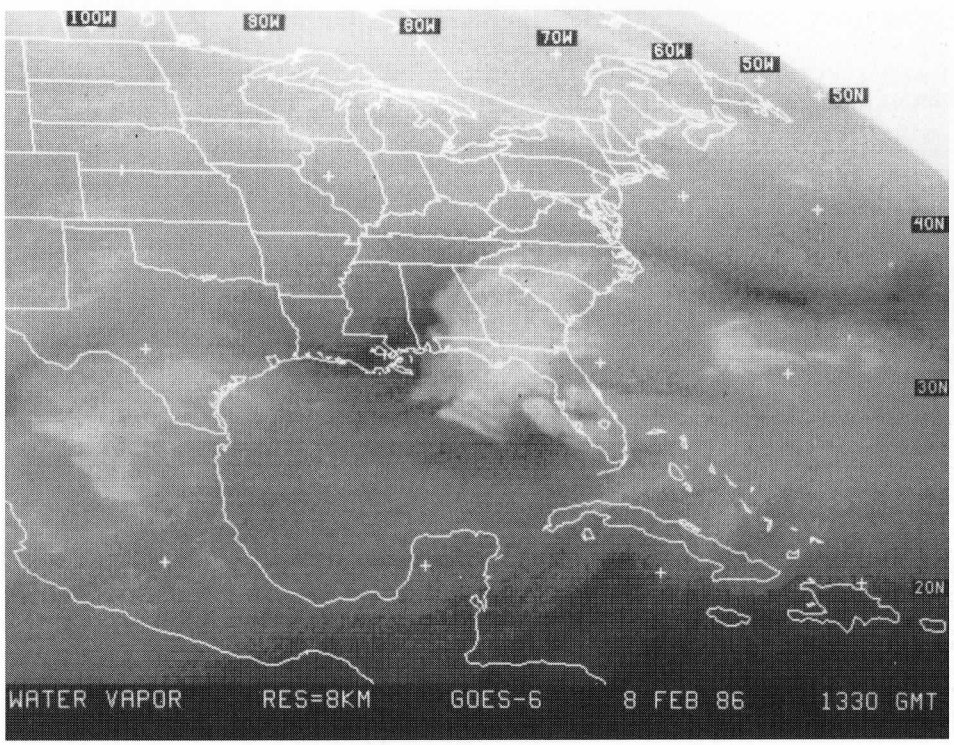
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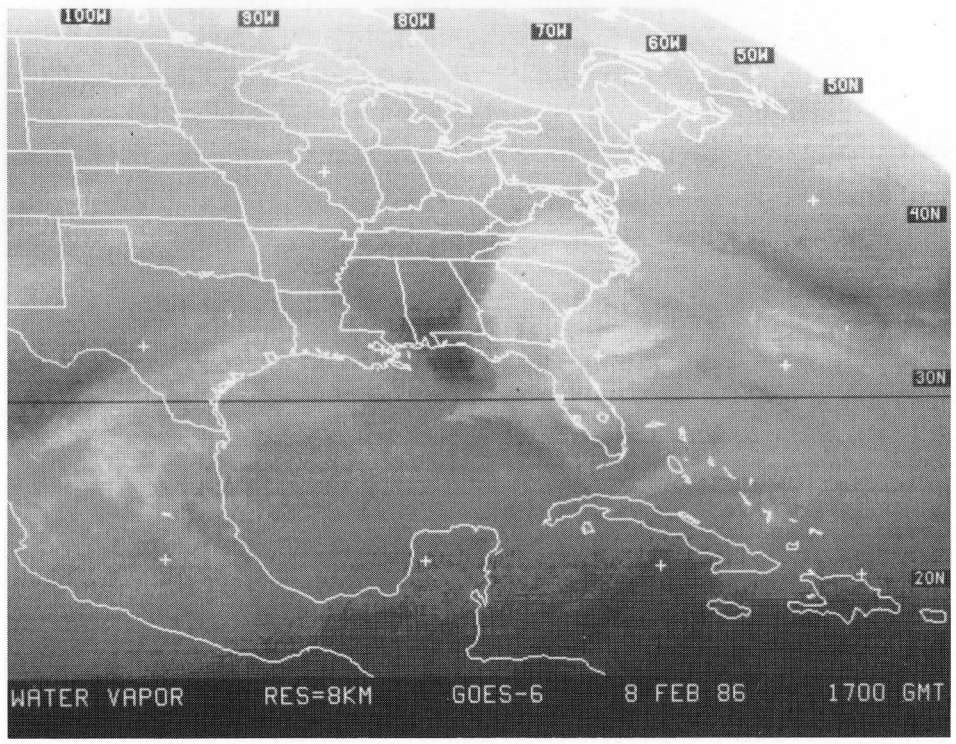
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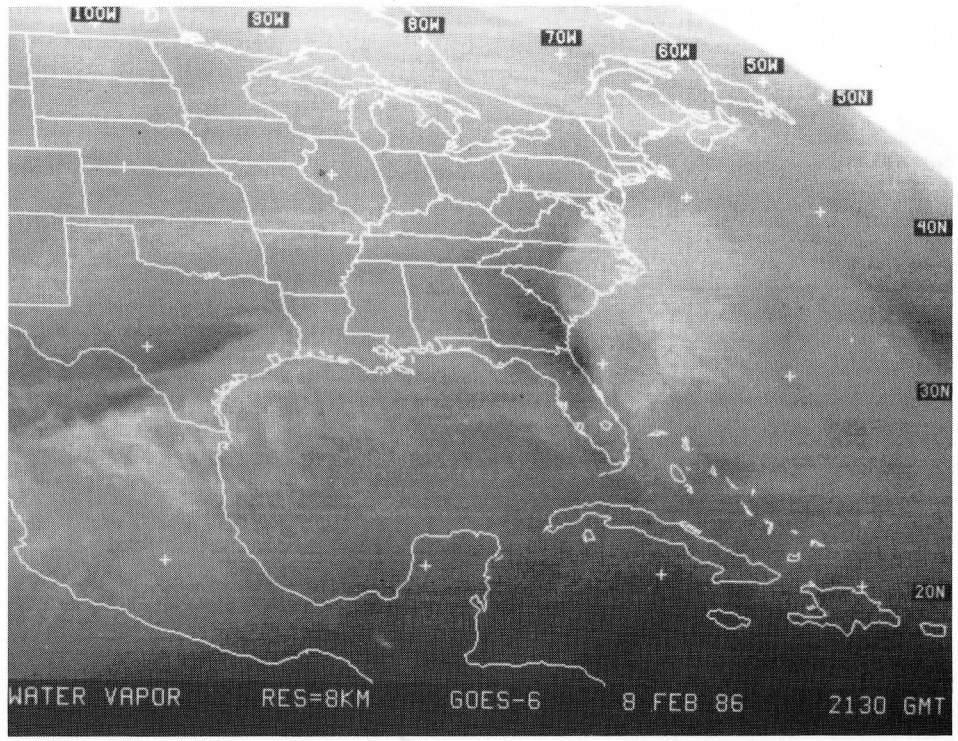
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8 FEB 86
2130 GMT

IOP #5 - Offshore Cyclogenesis / Cold Air Outbreak
February 9 - February 13

Satellite Synopsis

Water Vapor

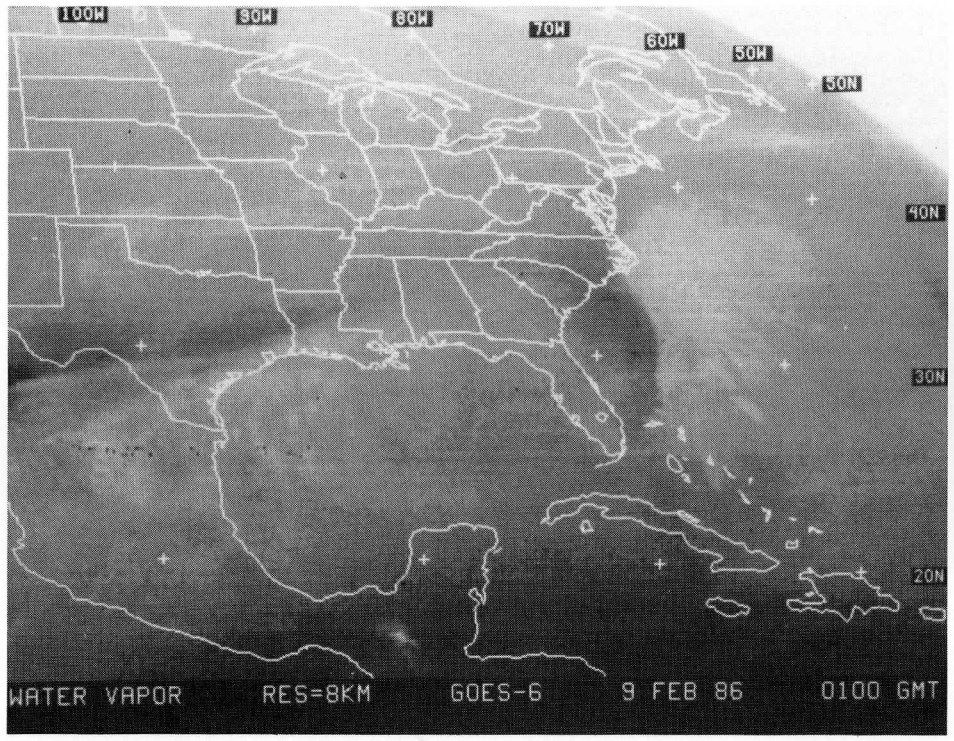
- 10th, a dry area associated with an approaching trough appears in Mexico around 12 GMT which becomes elongated with leading edge to Cape Cod by 17 GMT on the 11th.
- Abundant moisture from Pacific ocean into the Atlantic states finally is cut off by the 12th.
- Comma cloud west of Bermuda on 13th (polar low).

IR

- 9th, weak system off Carolinas moves east.
- 9th, convective activity increases rapidly in Gulf.
- 11th, diffuse squall line along front.
- 12th, bump on cirrus cloud pattern near 35N, 70W at 16 GMT.
- 13th, weak polar low evident in low and mid-level clouds.

Visible

- 9th, some weak Gulf Stream activity.
- 10th, Gulf Stream convection shows strong shearing to the east-southeast.
- 11th, big thunderstorms in southern Georgia.
- 11th, coastal front evident off North Carolina.
- 11th, curious clear circle develops during the day in northeast Georgia and northwest South Carolina (mountain down-slope flow effects).
- 12th, dramatic low level cloud streets and convergence lines.
- 12th, low level wave clouds perpendicular to flow in Virginias.
- 12th and 13th, snow on ground apparent in western hills of Virginia.
- 13th, polar low evident.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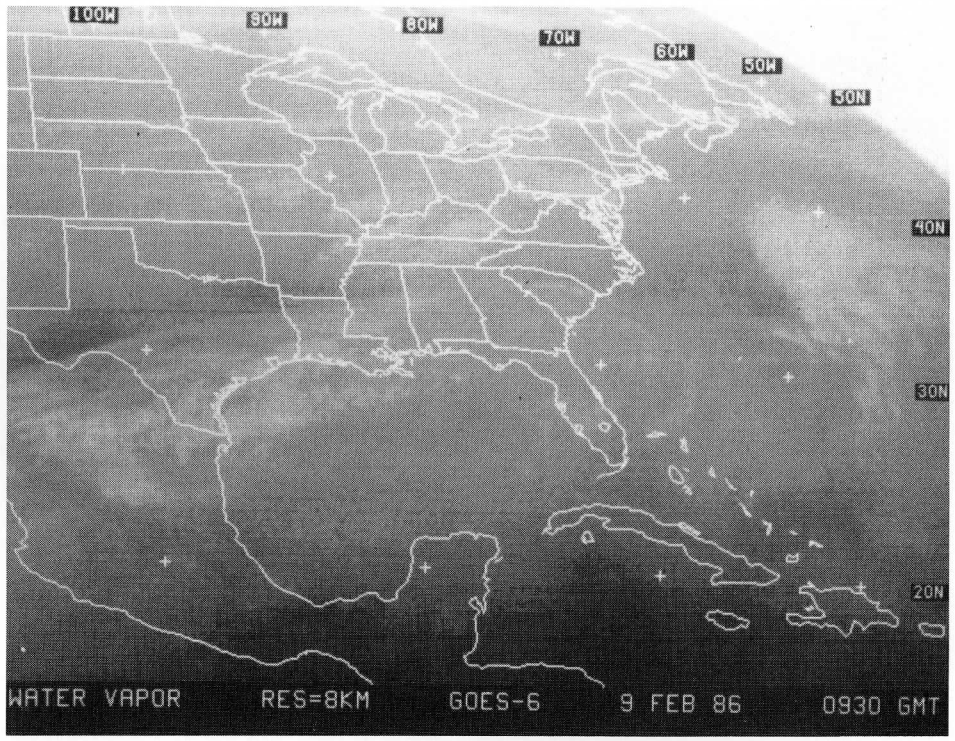
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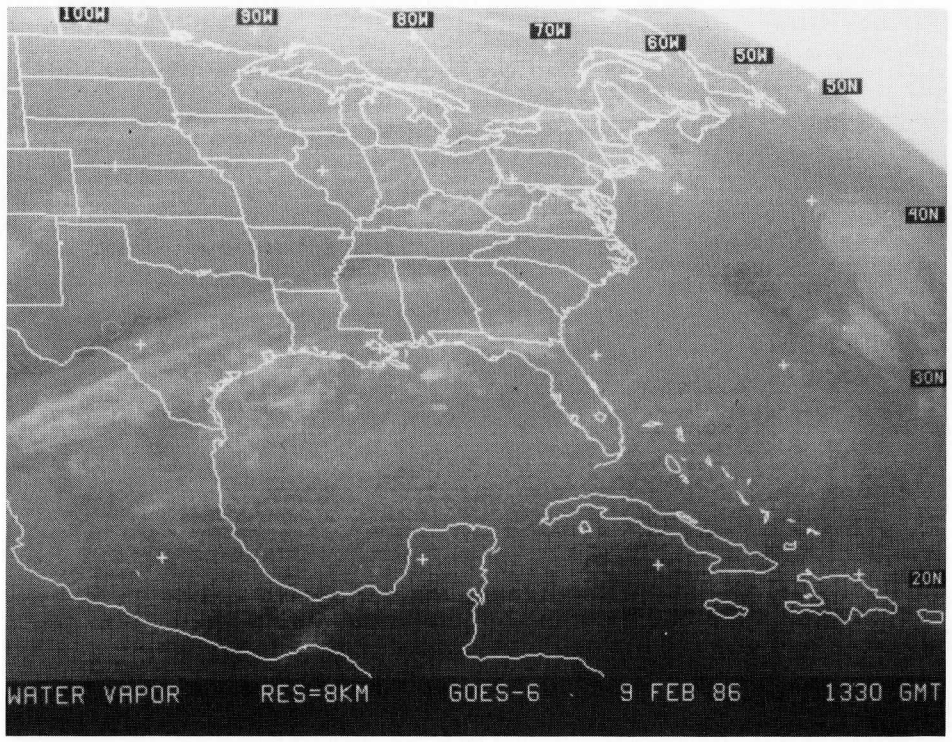
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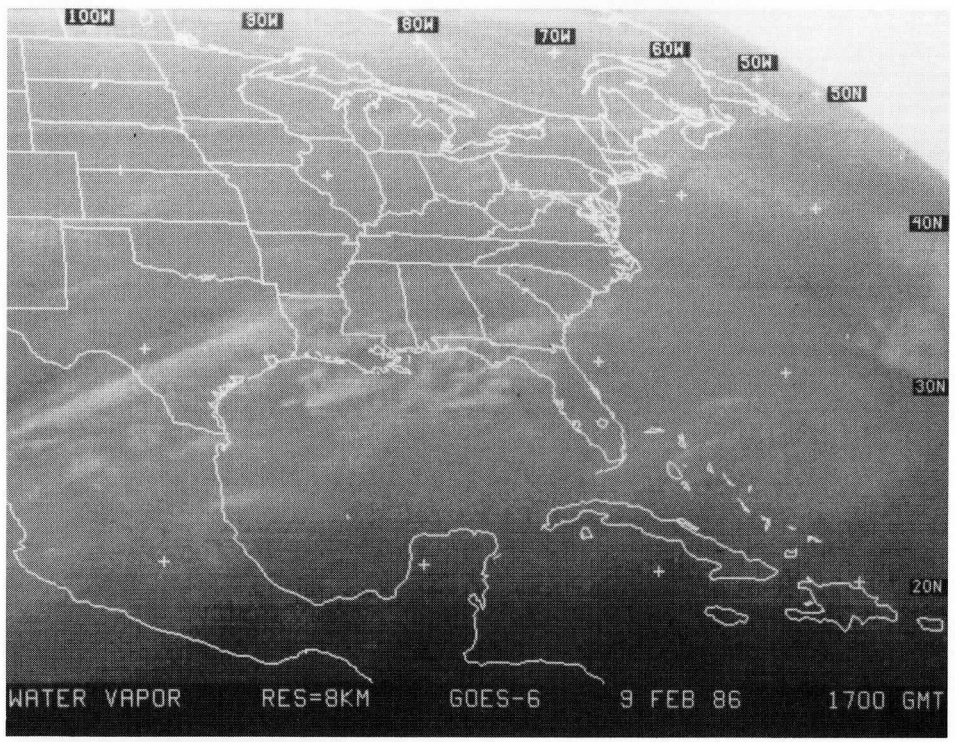
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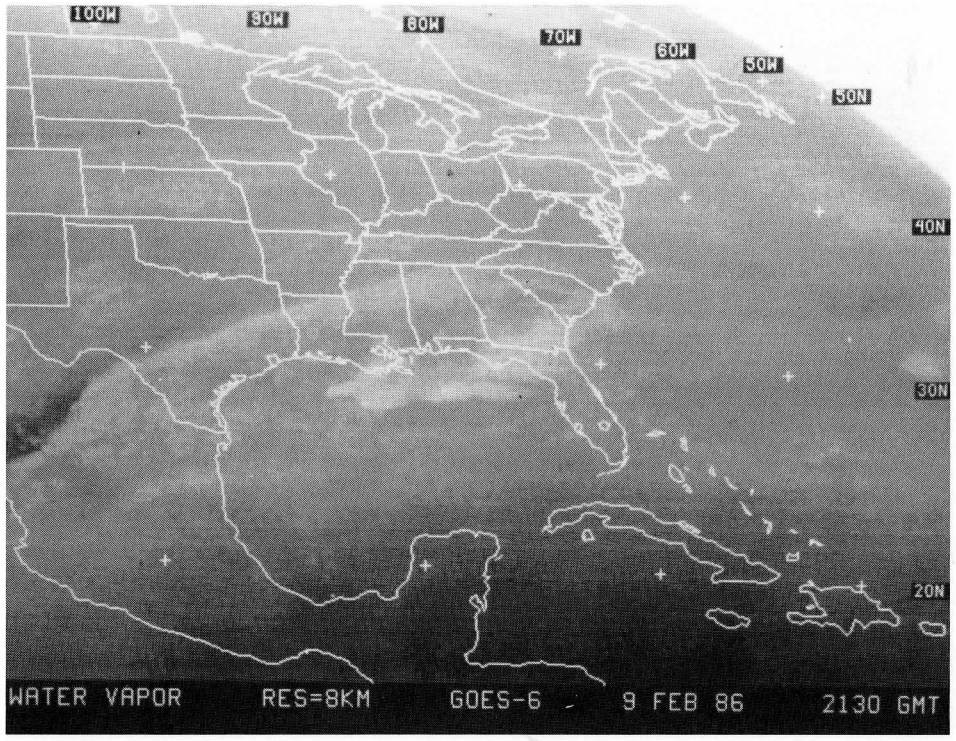
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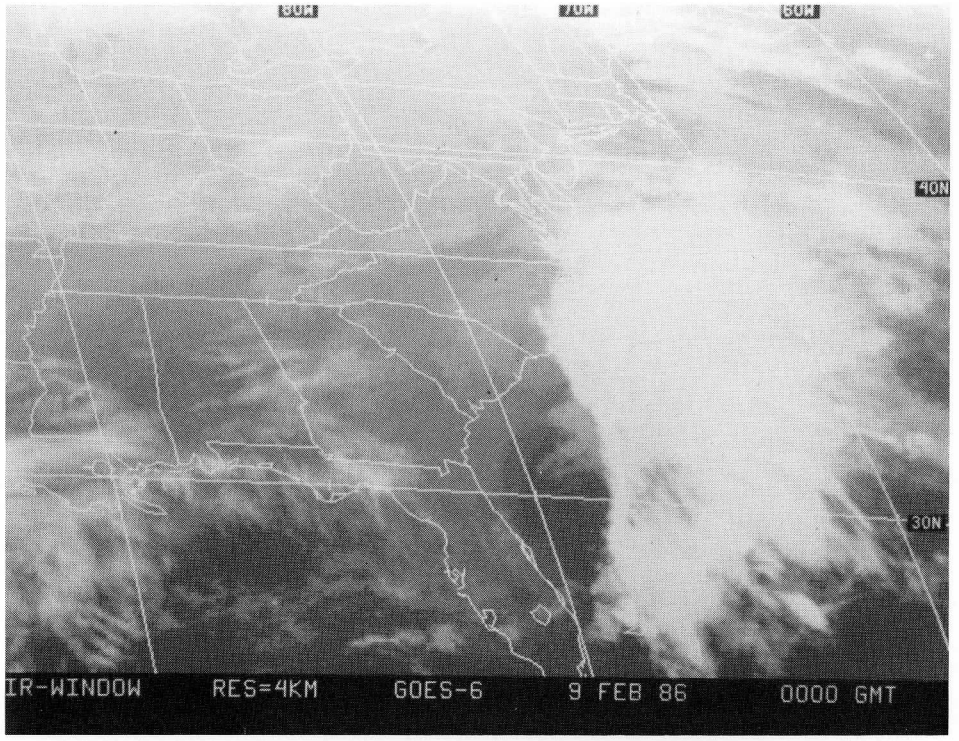
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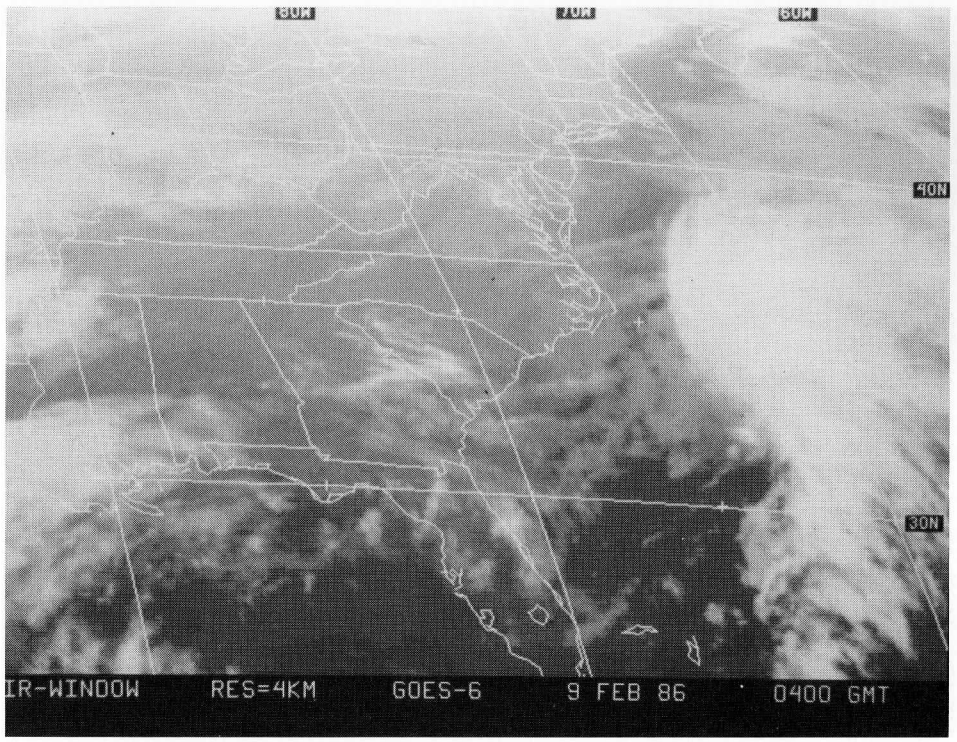
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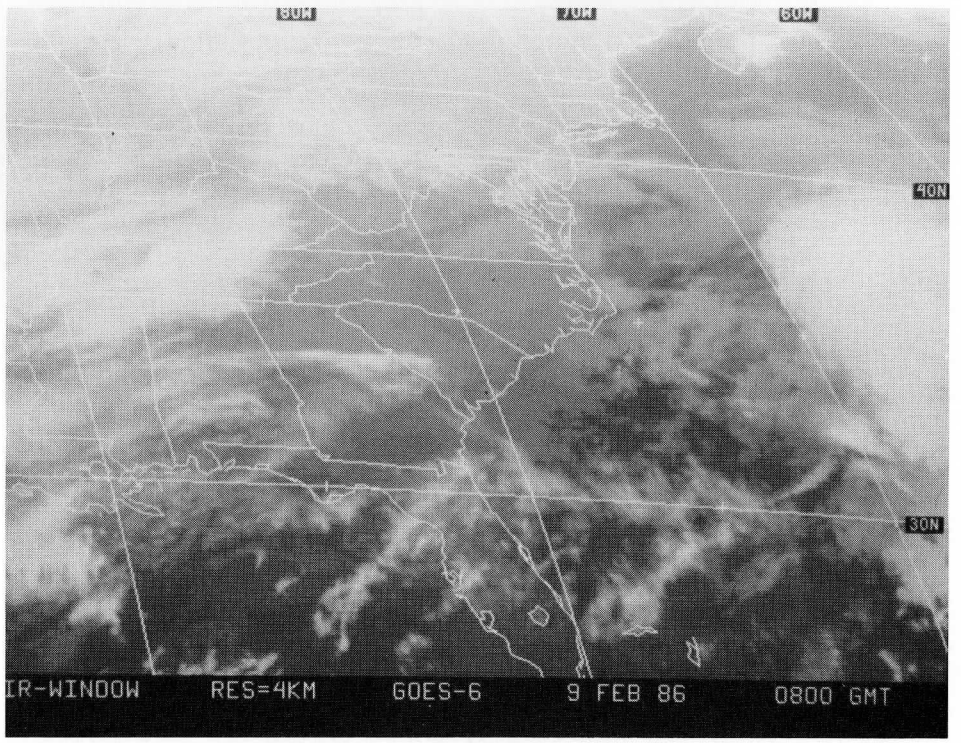
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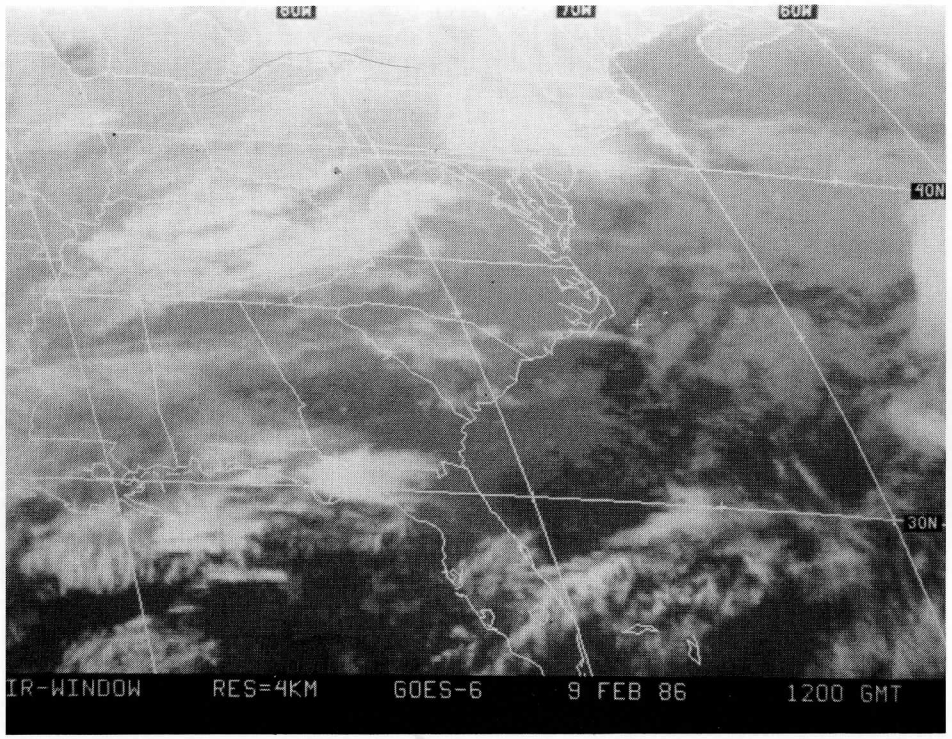
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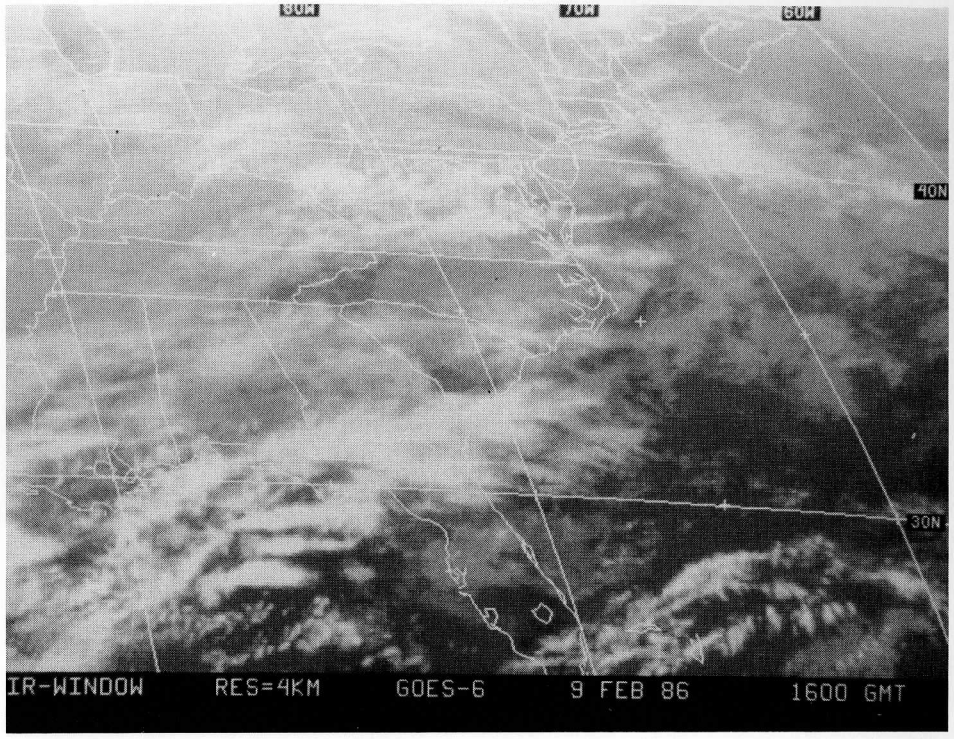
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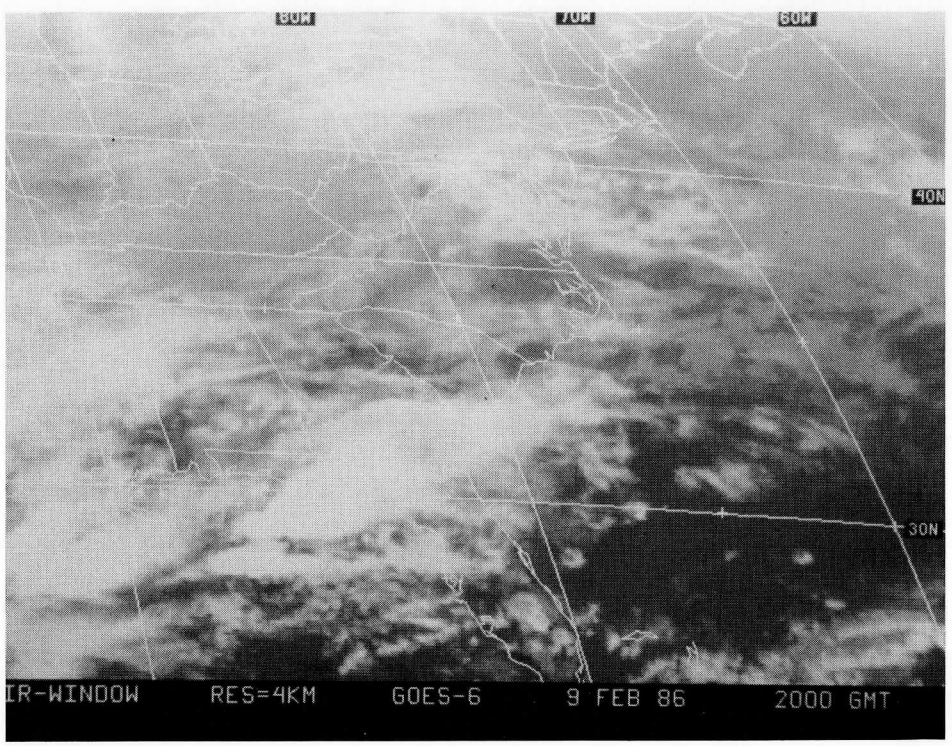
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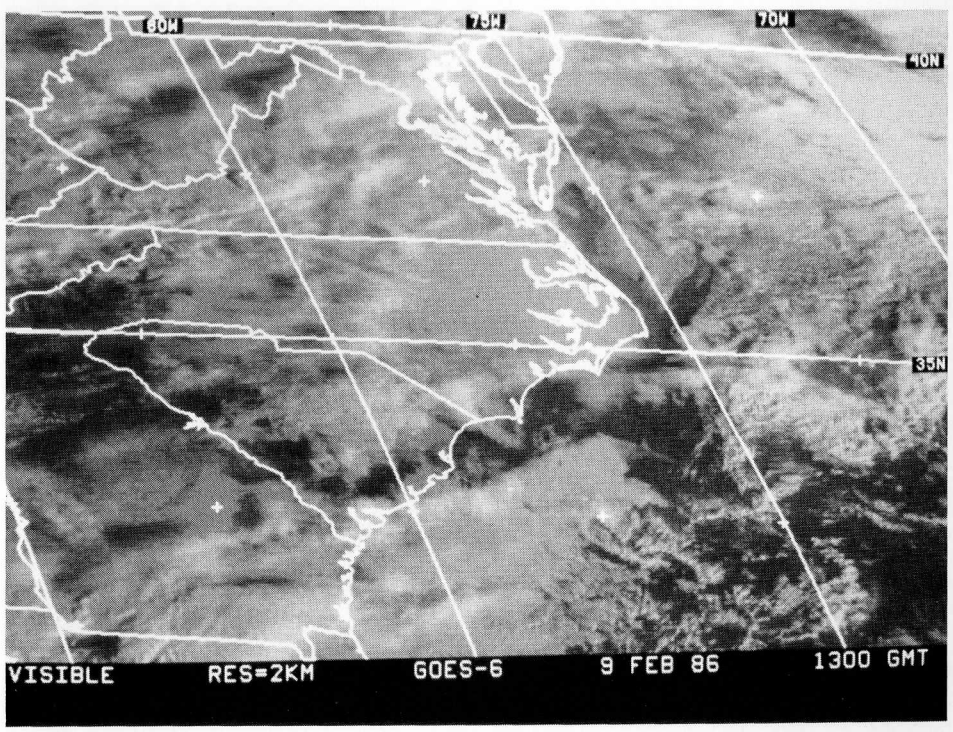
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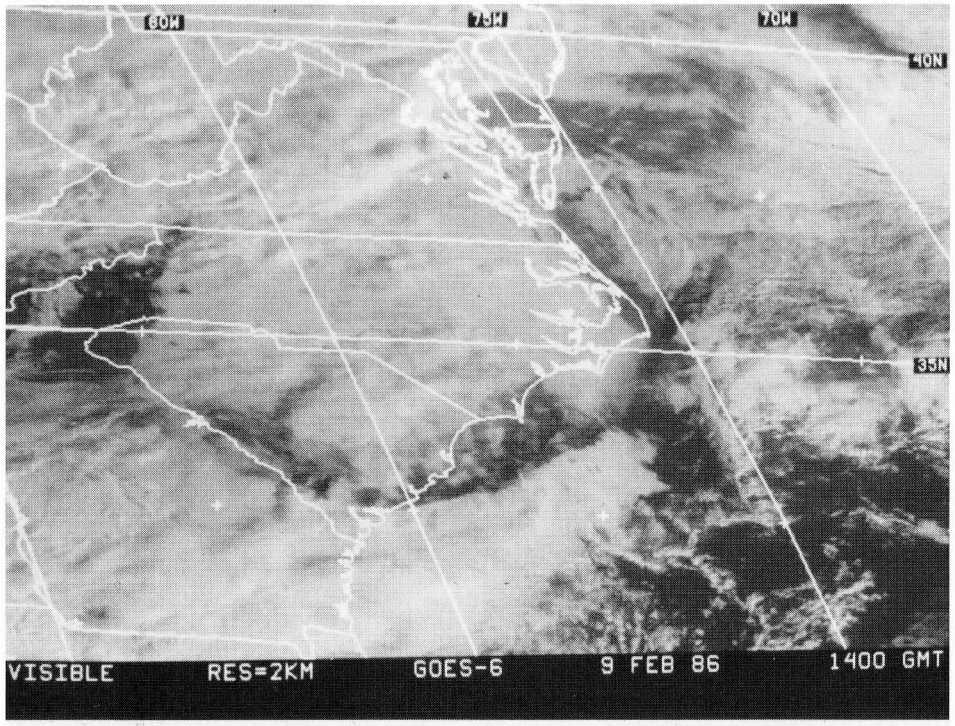
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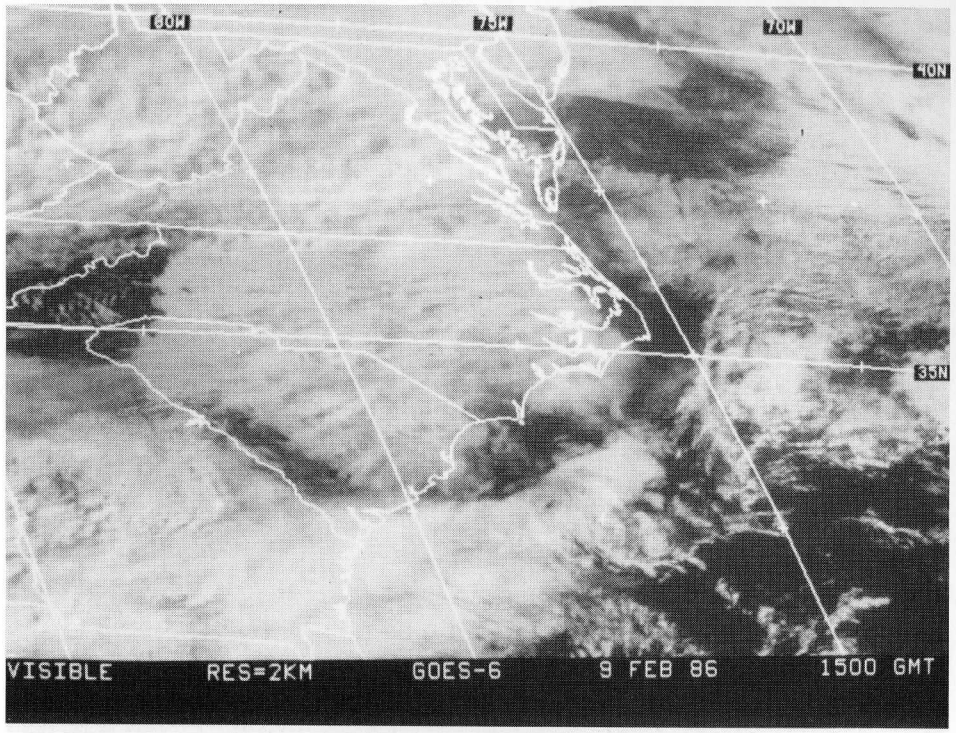
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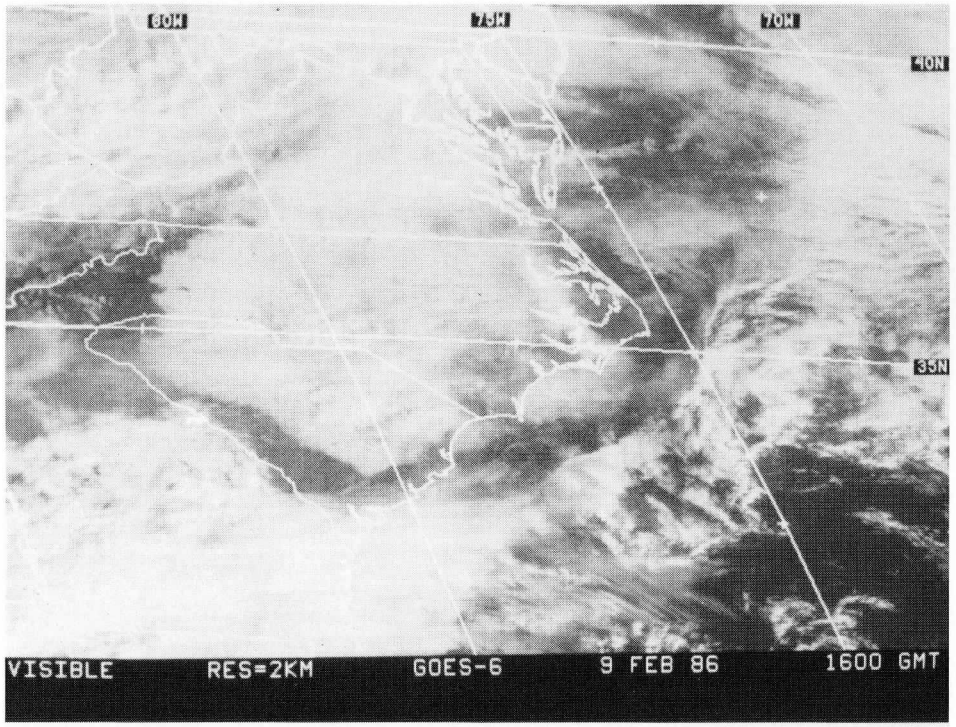
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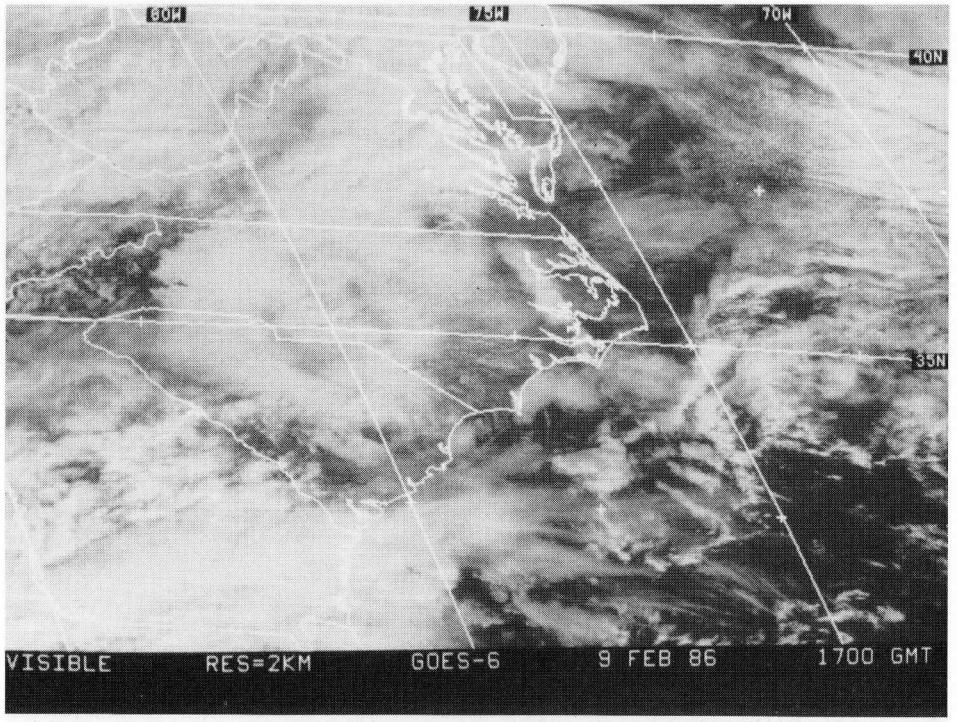
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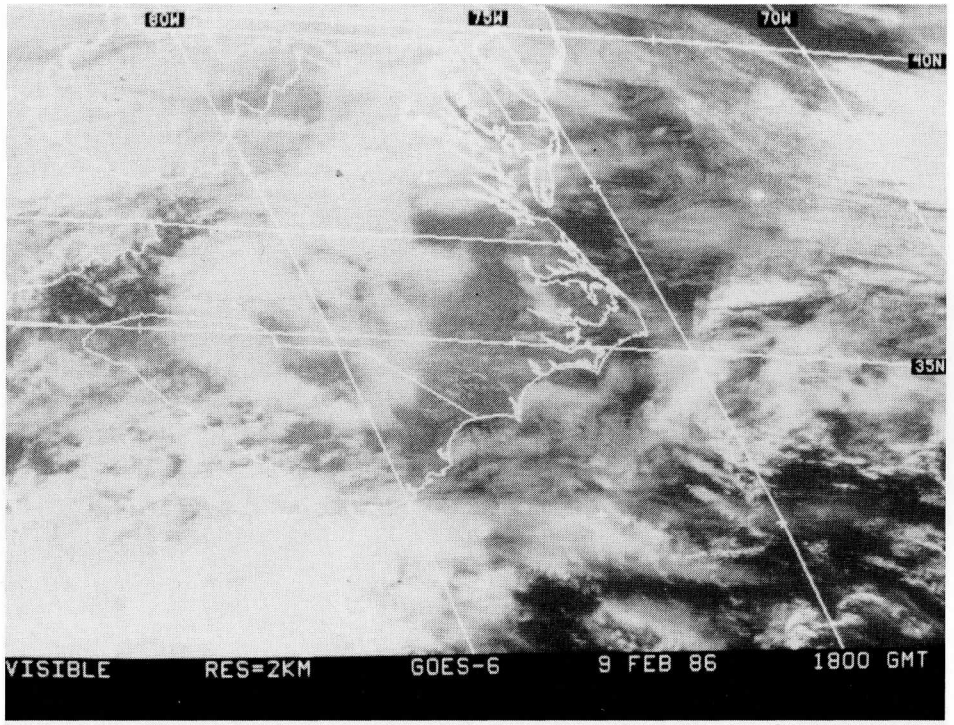
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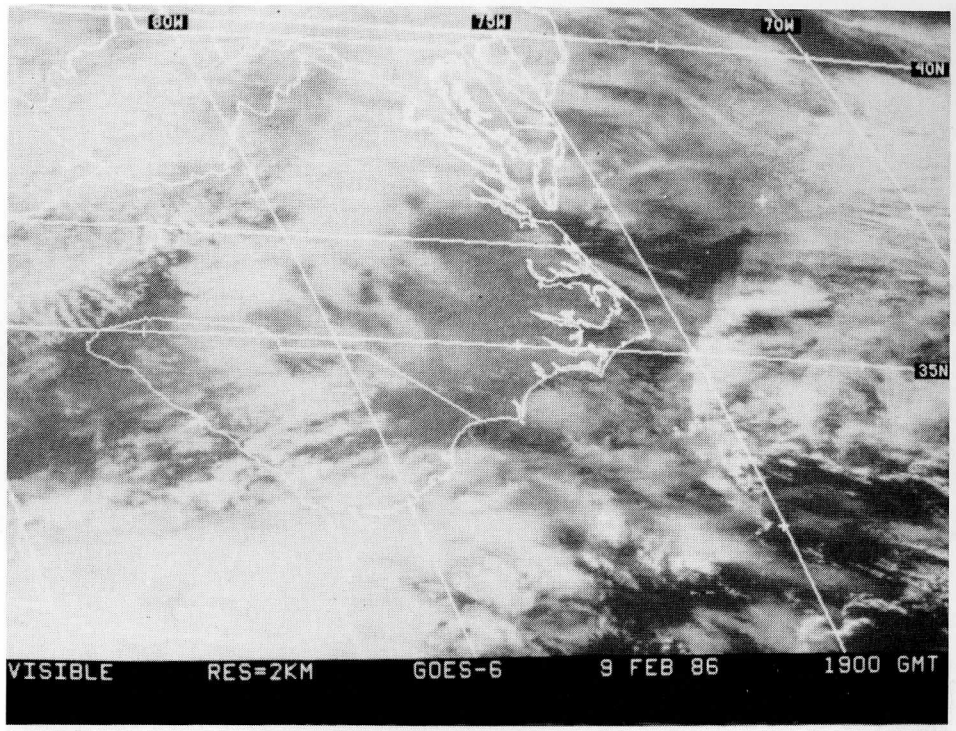
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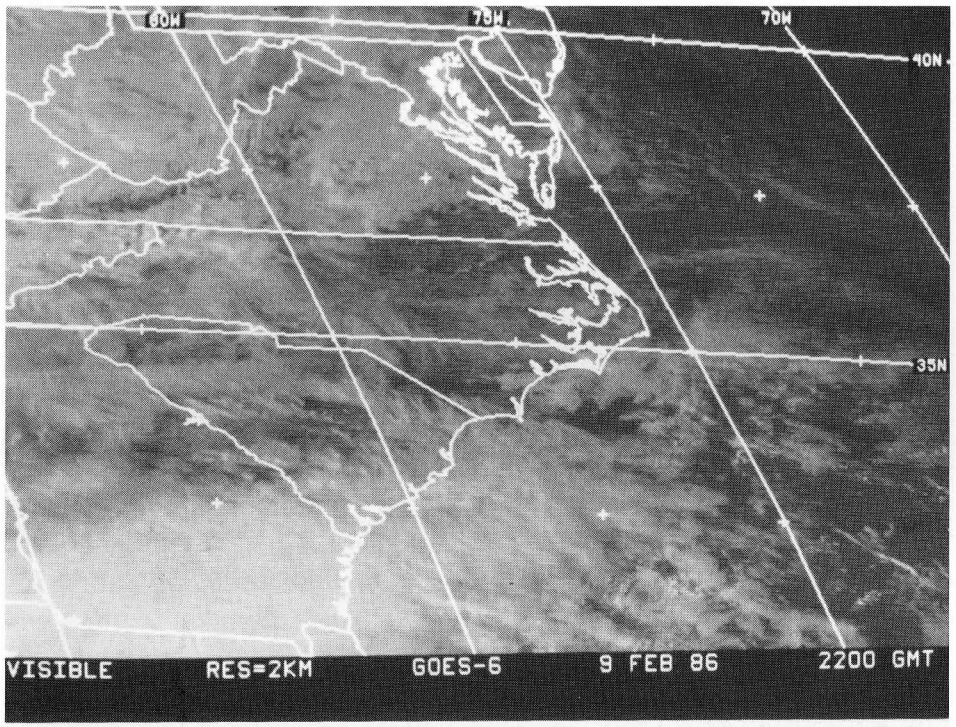
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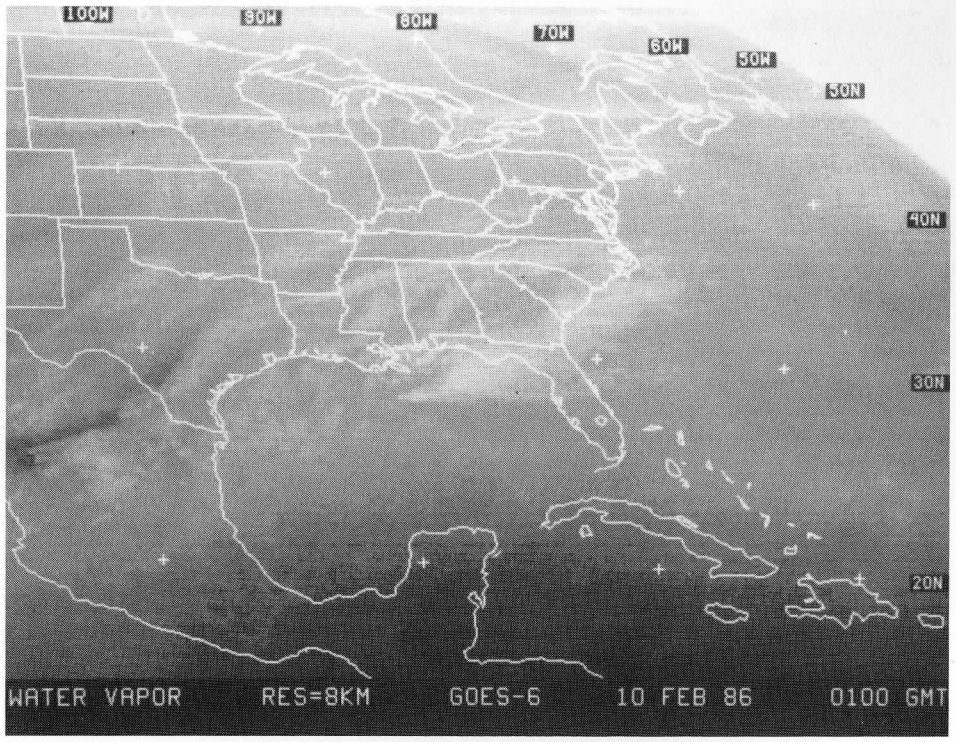
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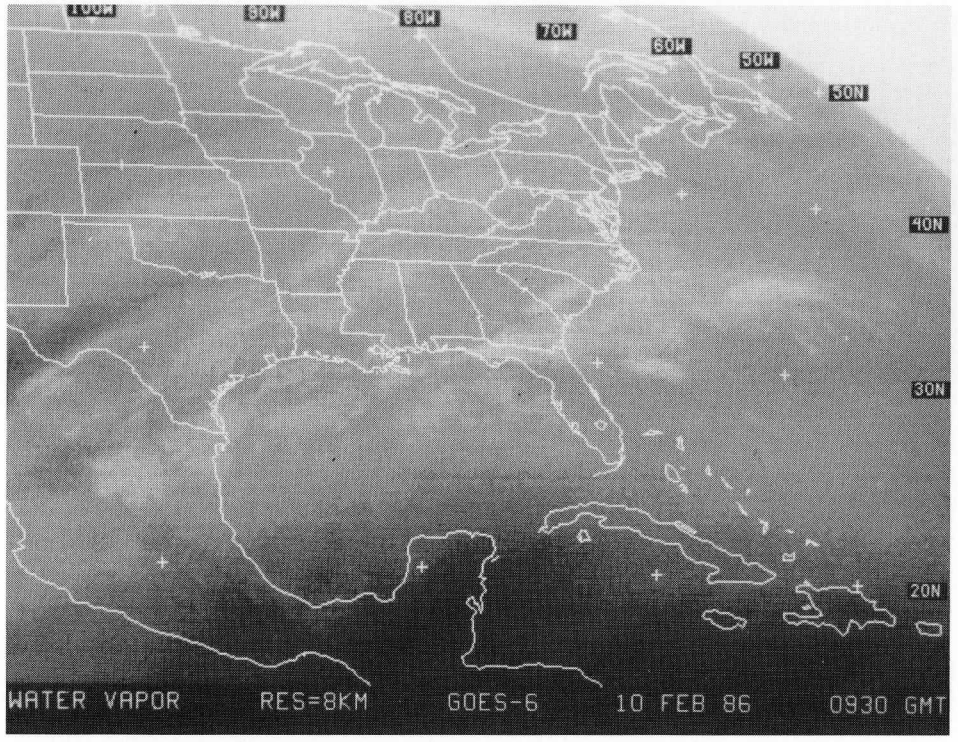
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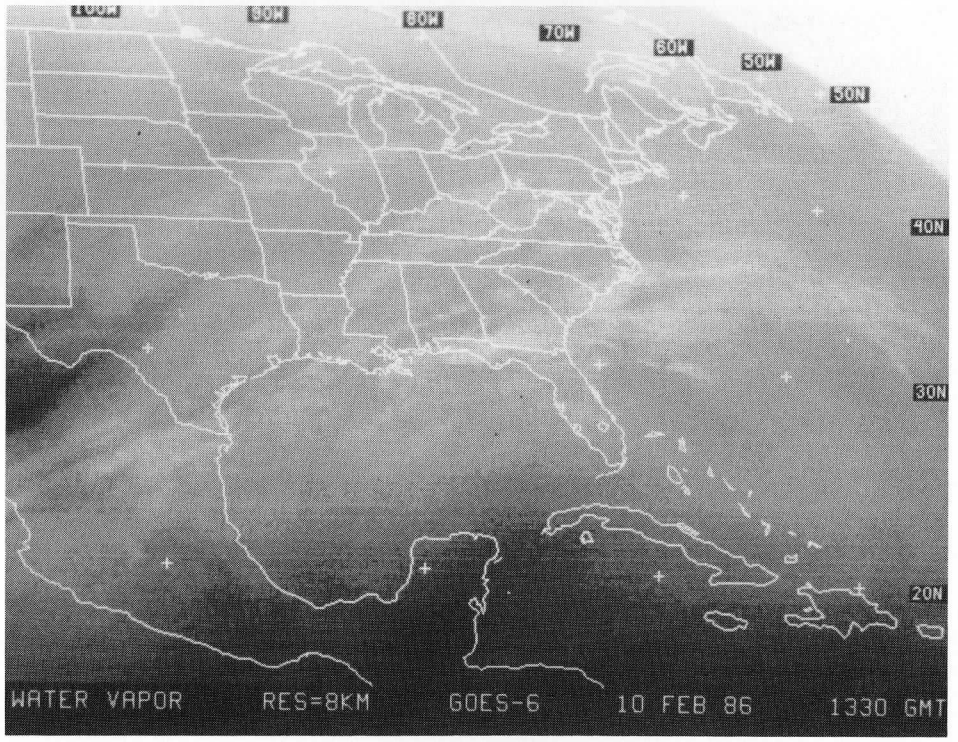
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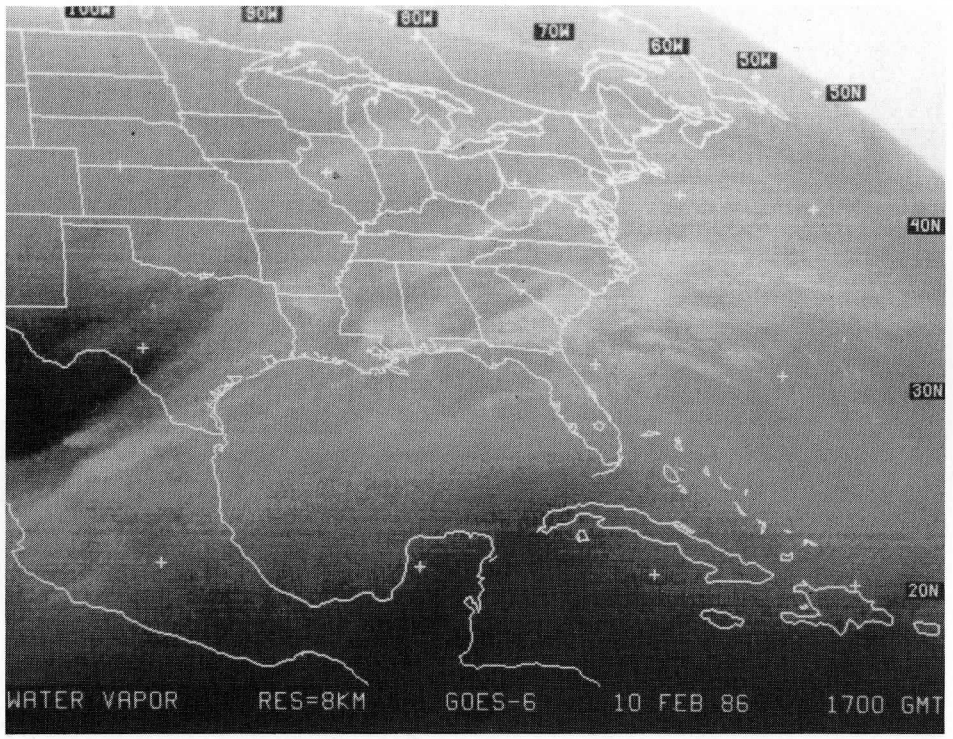
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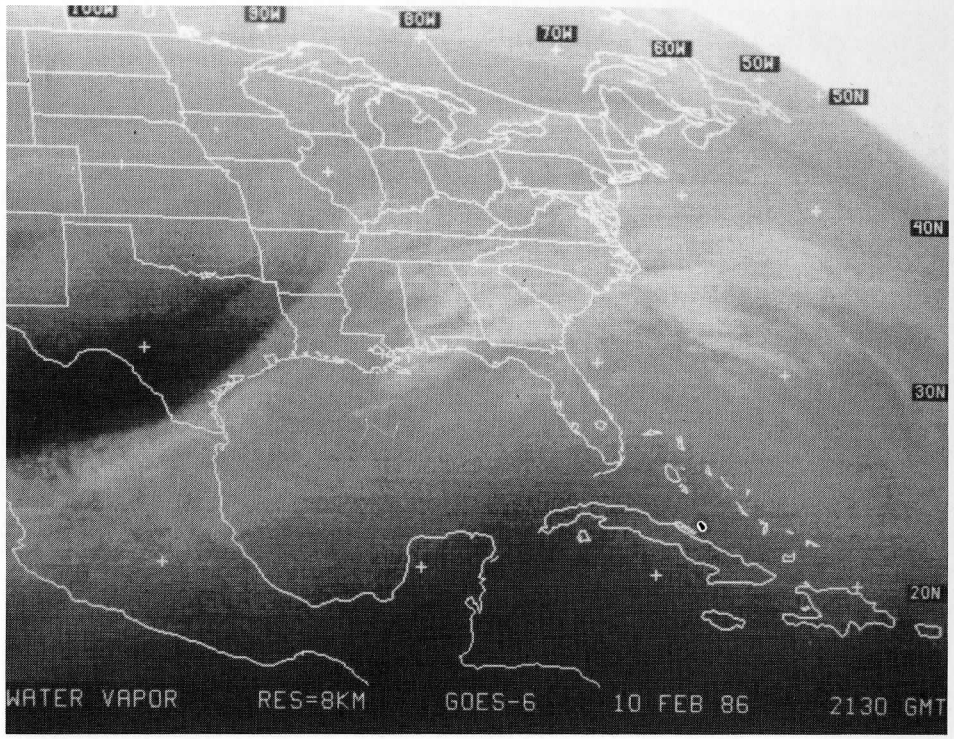
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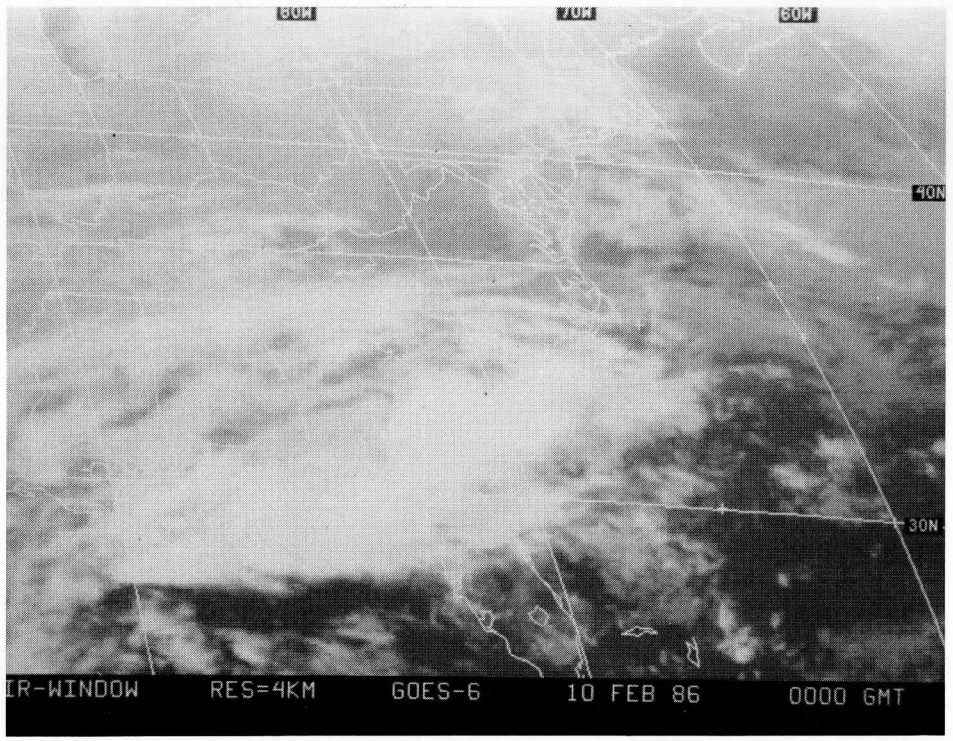
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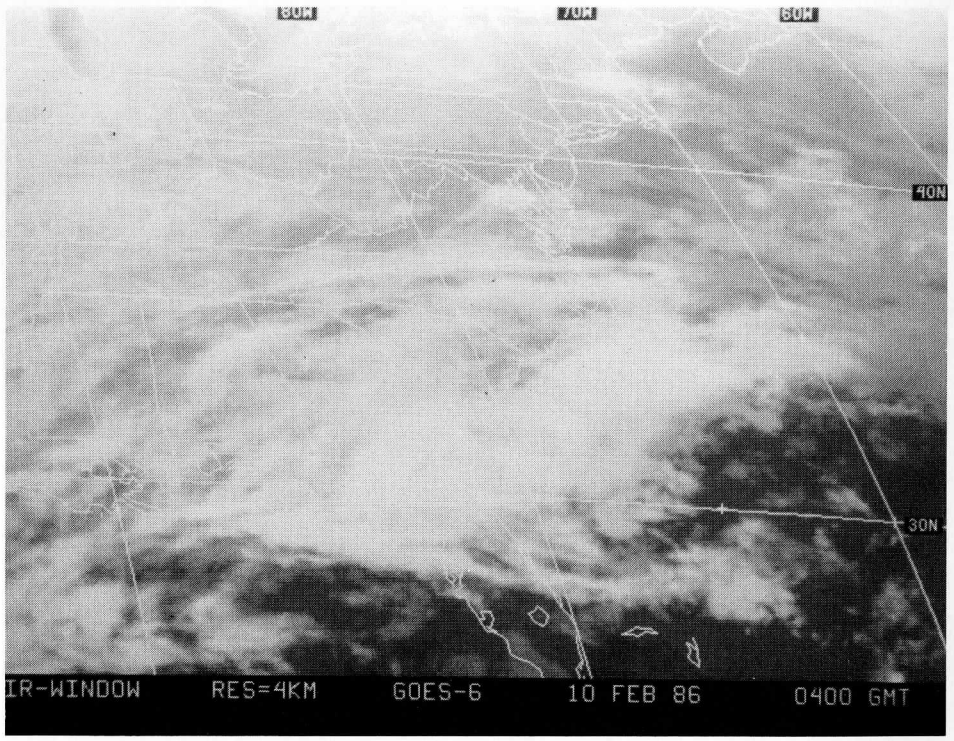
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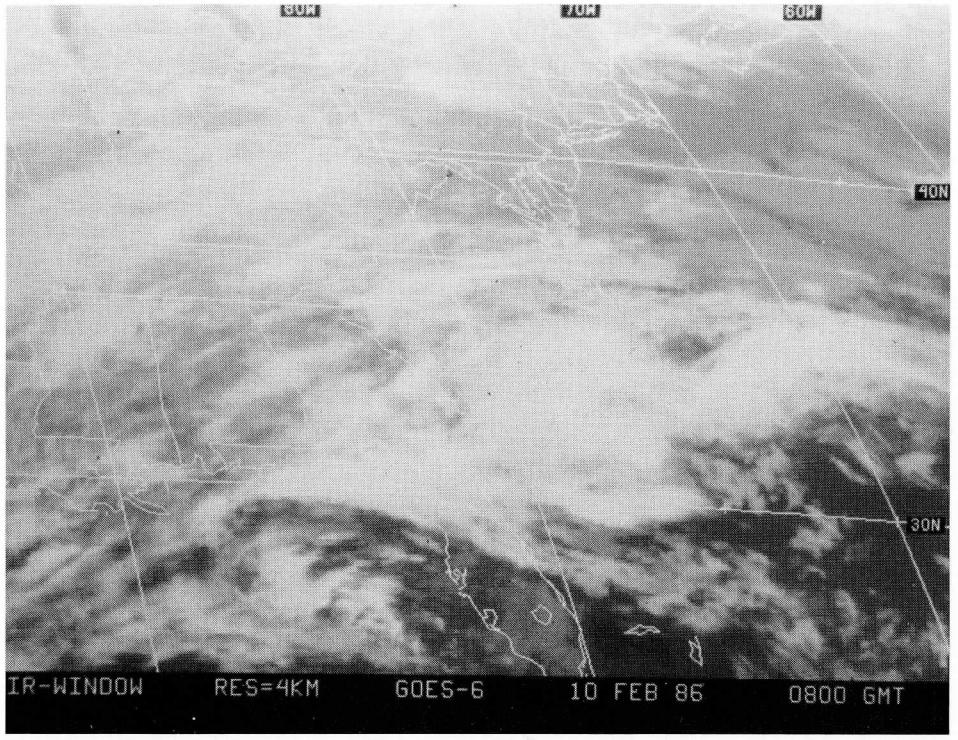
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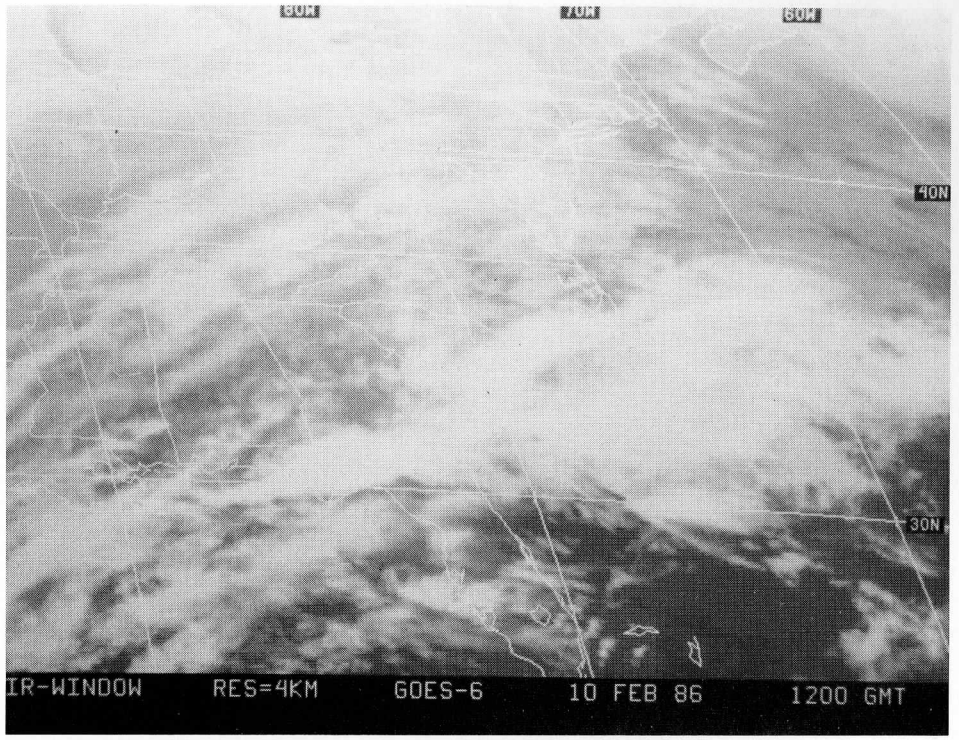
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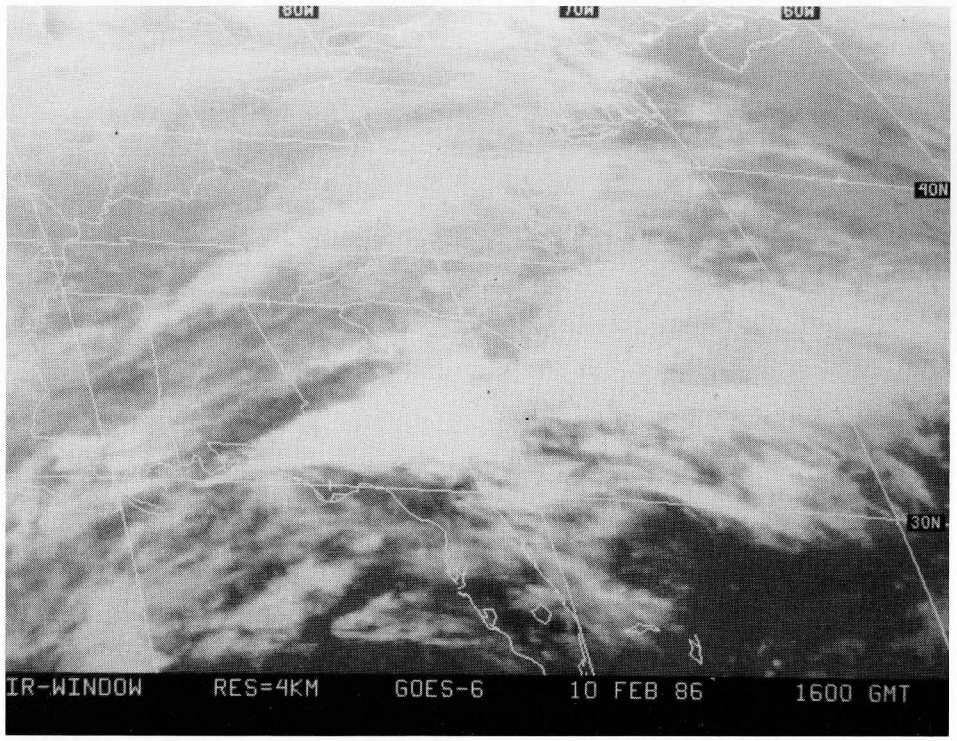
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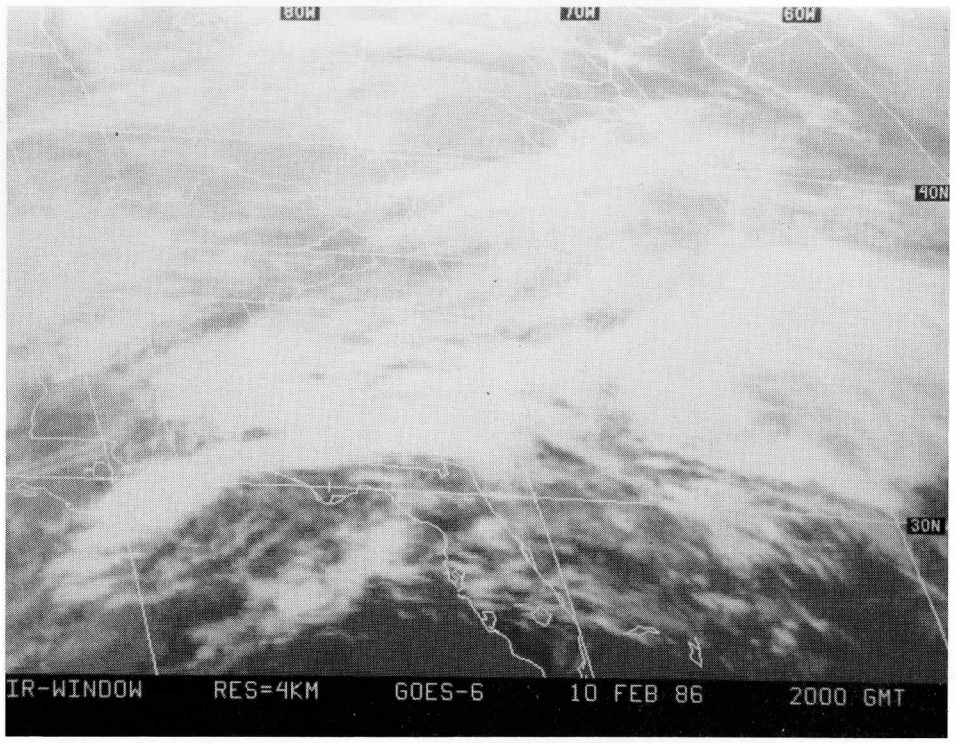
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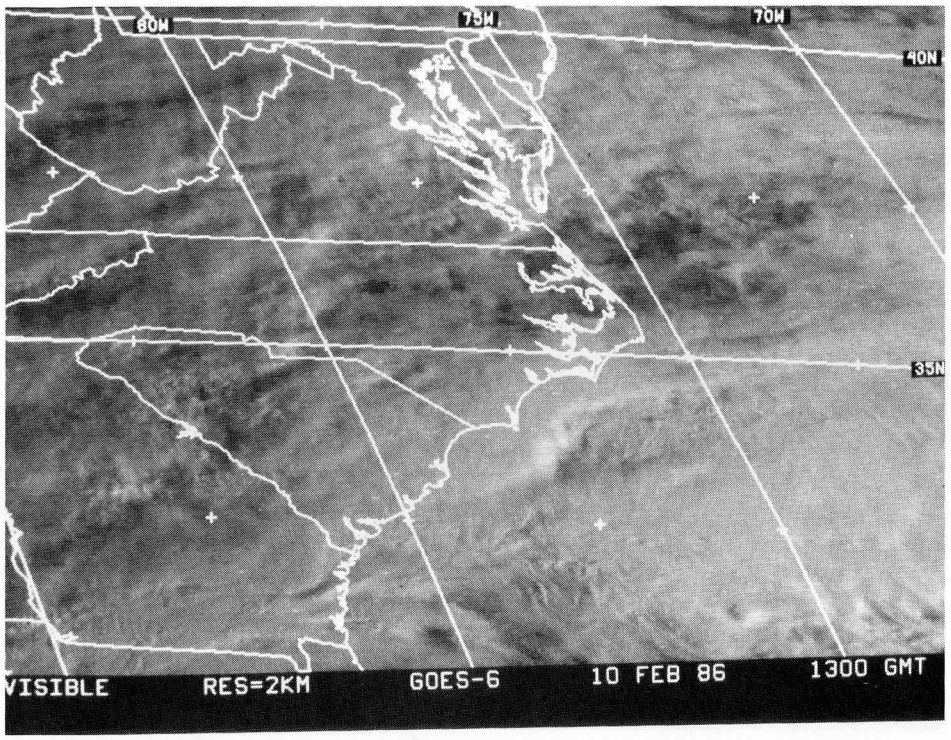
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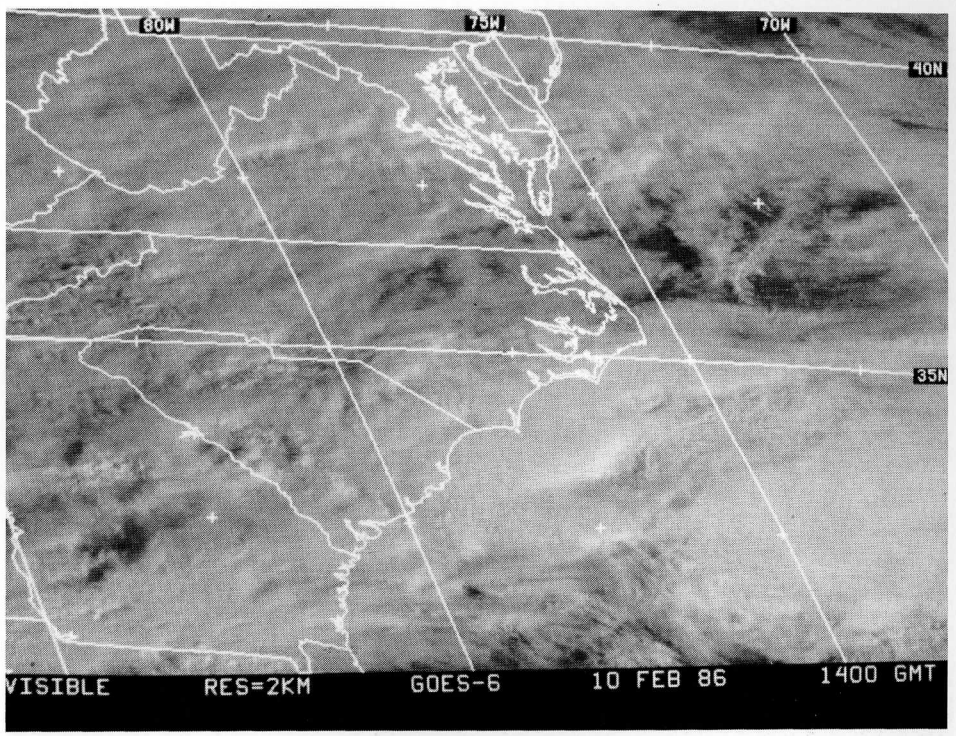
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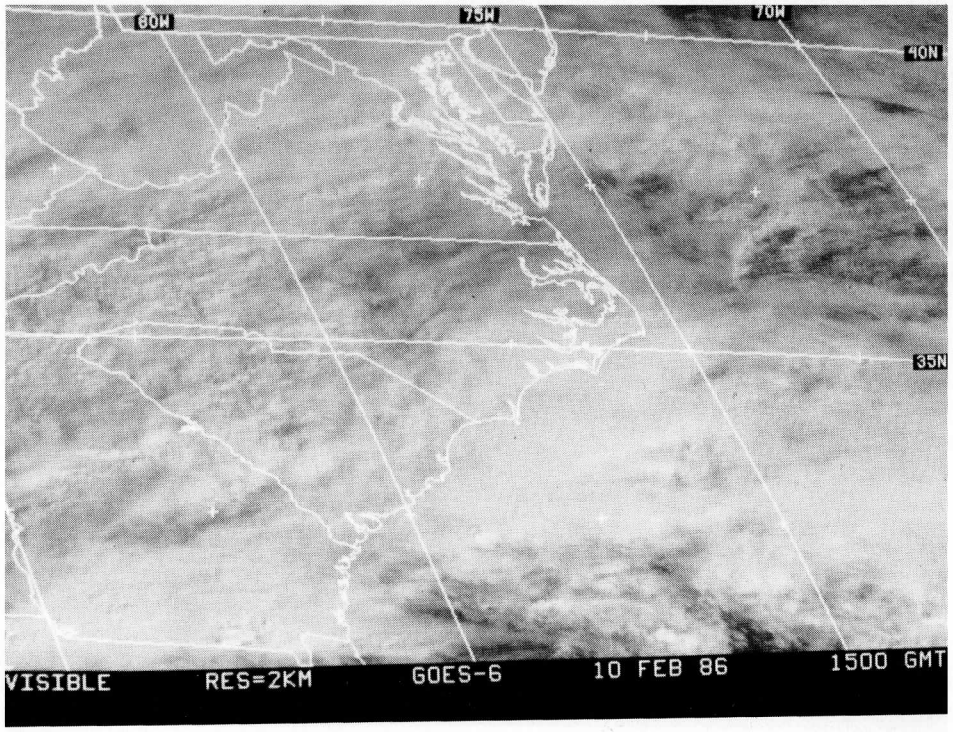
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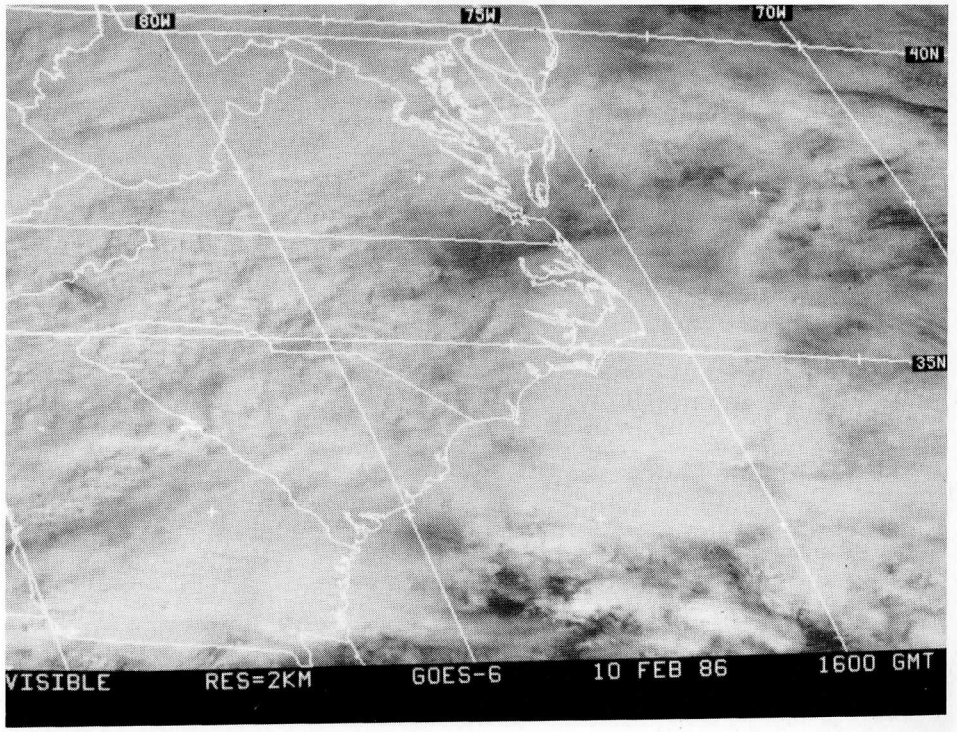
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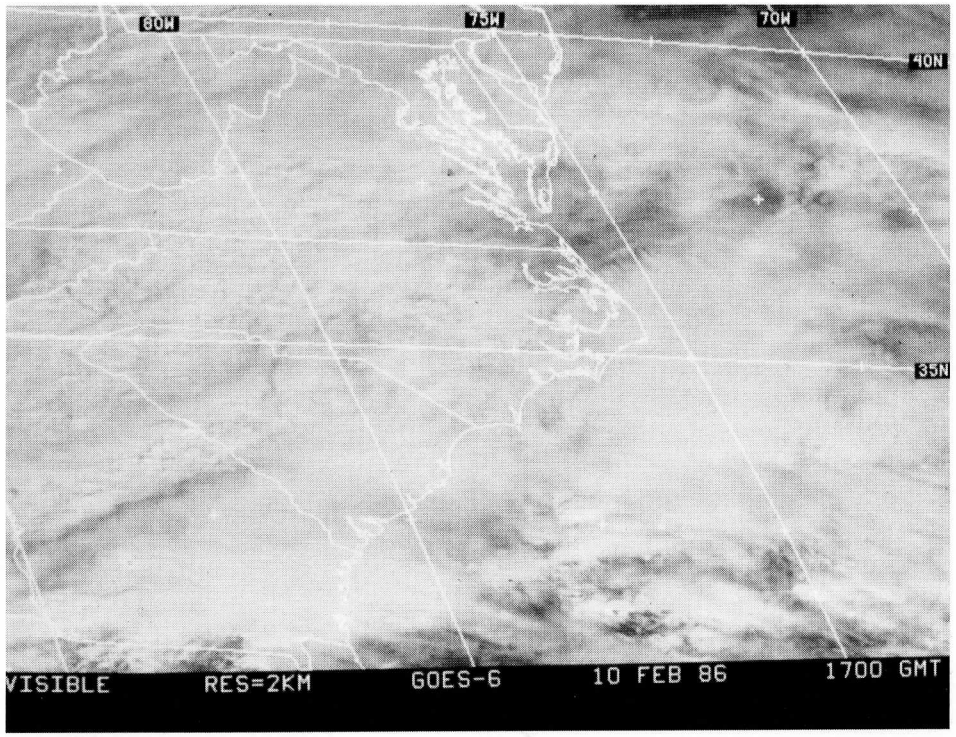
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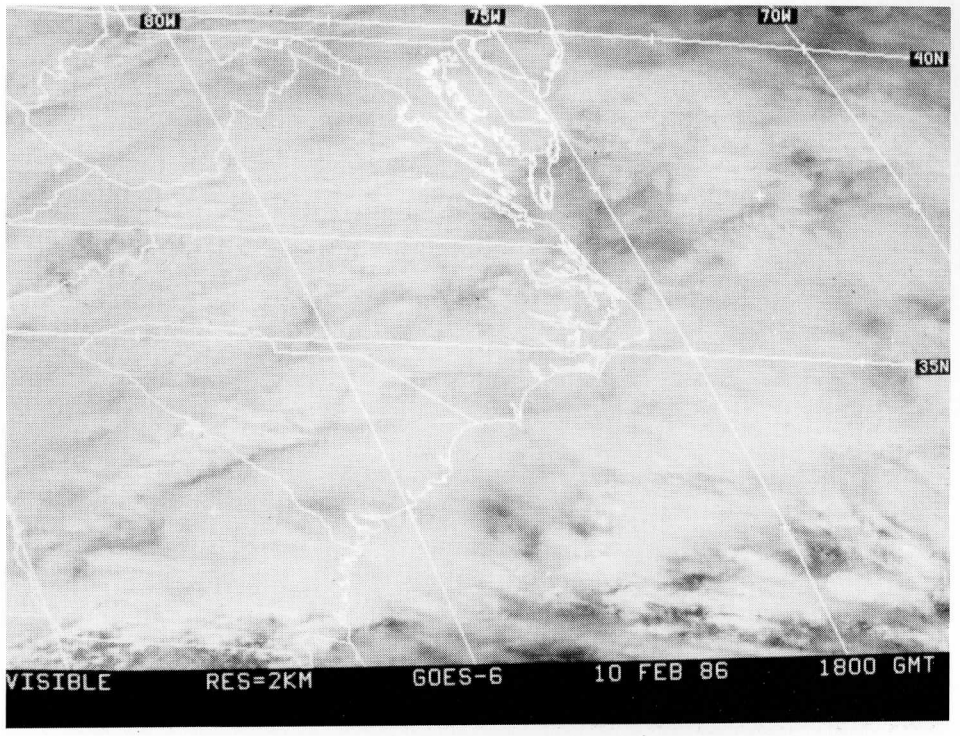
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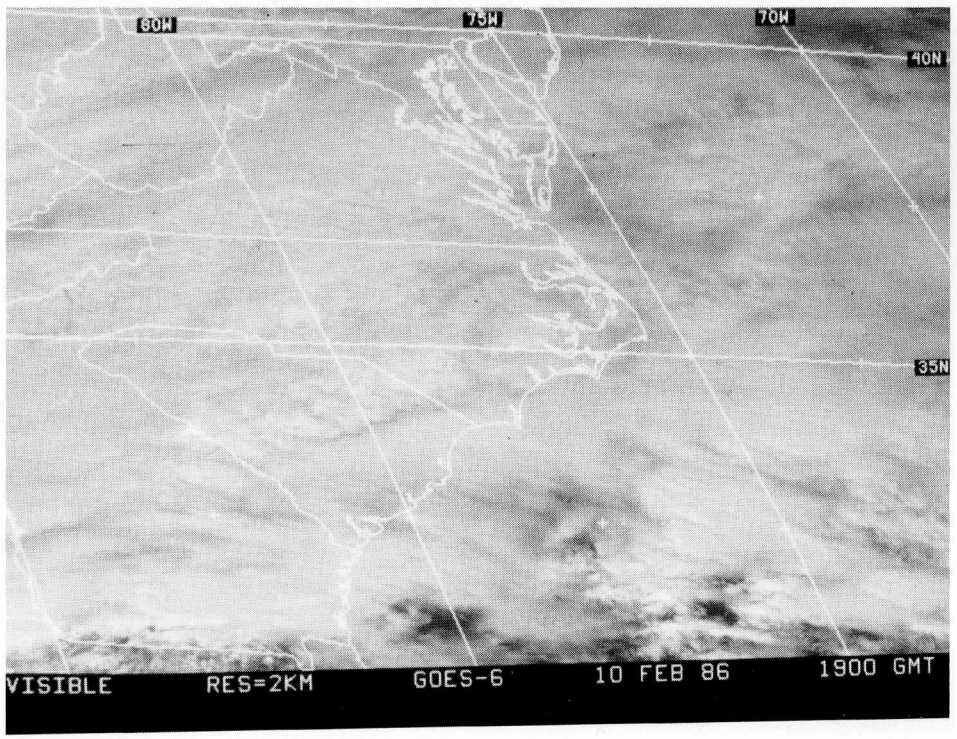
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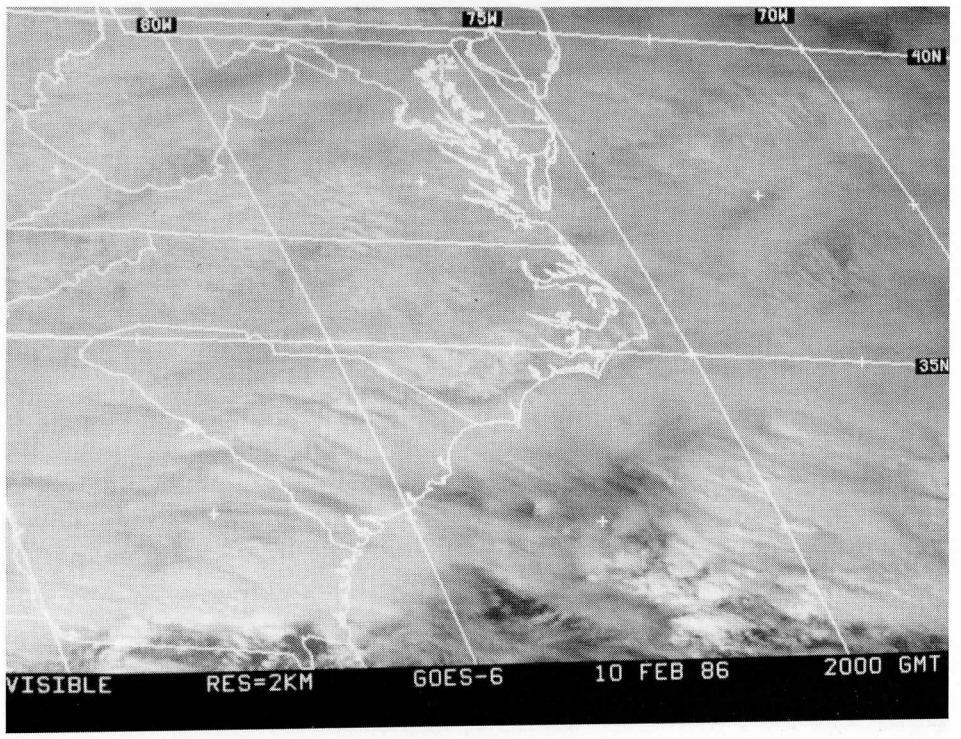
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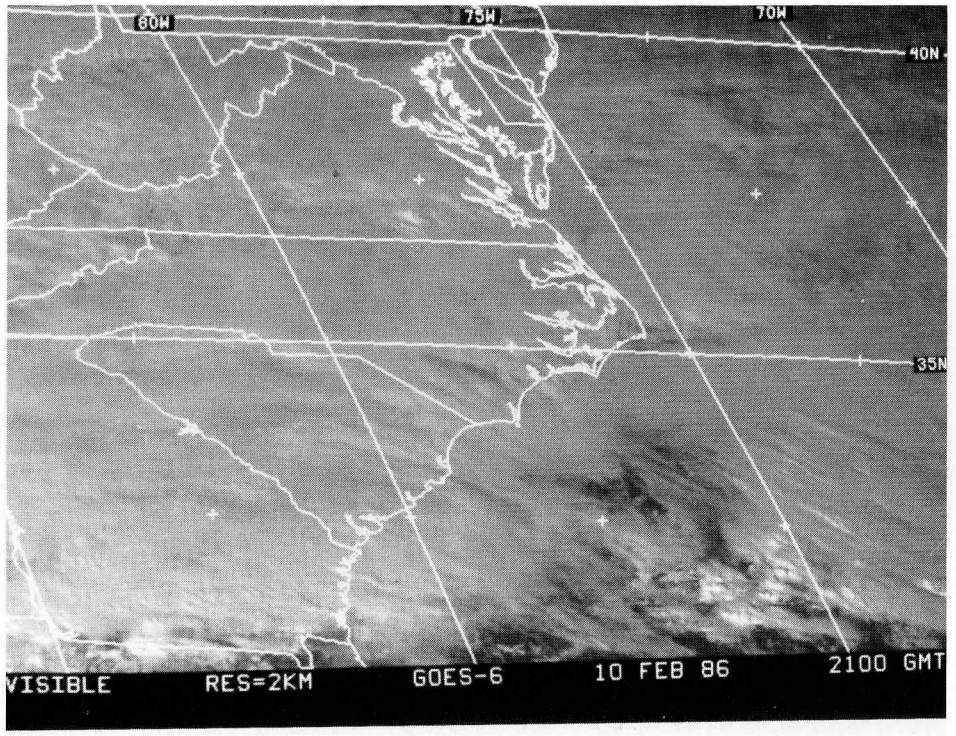
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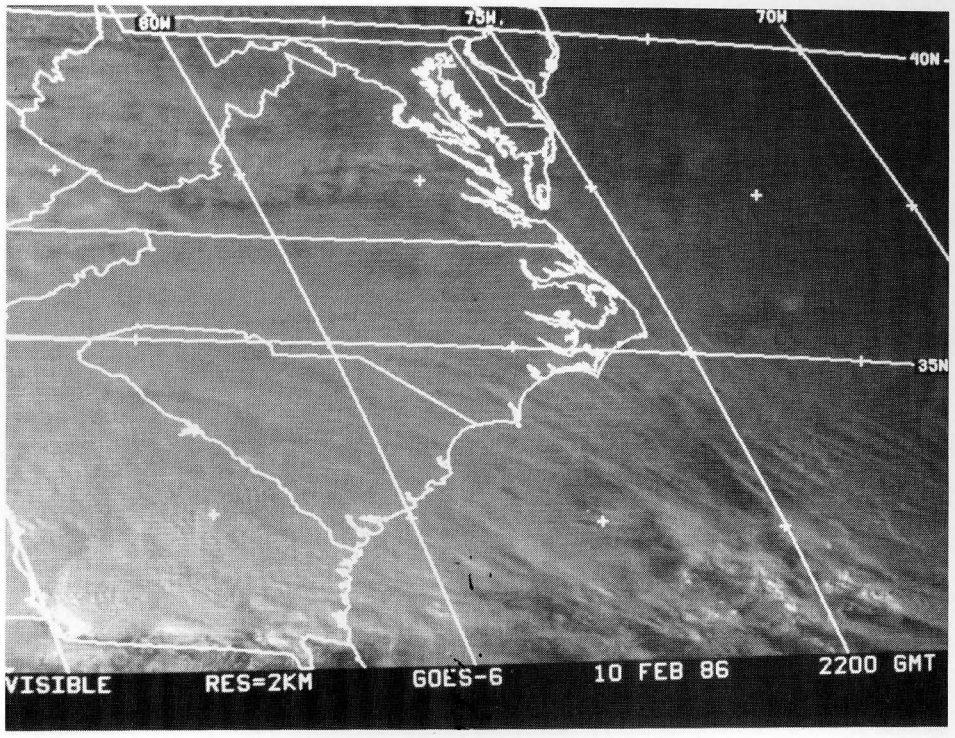
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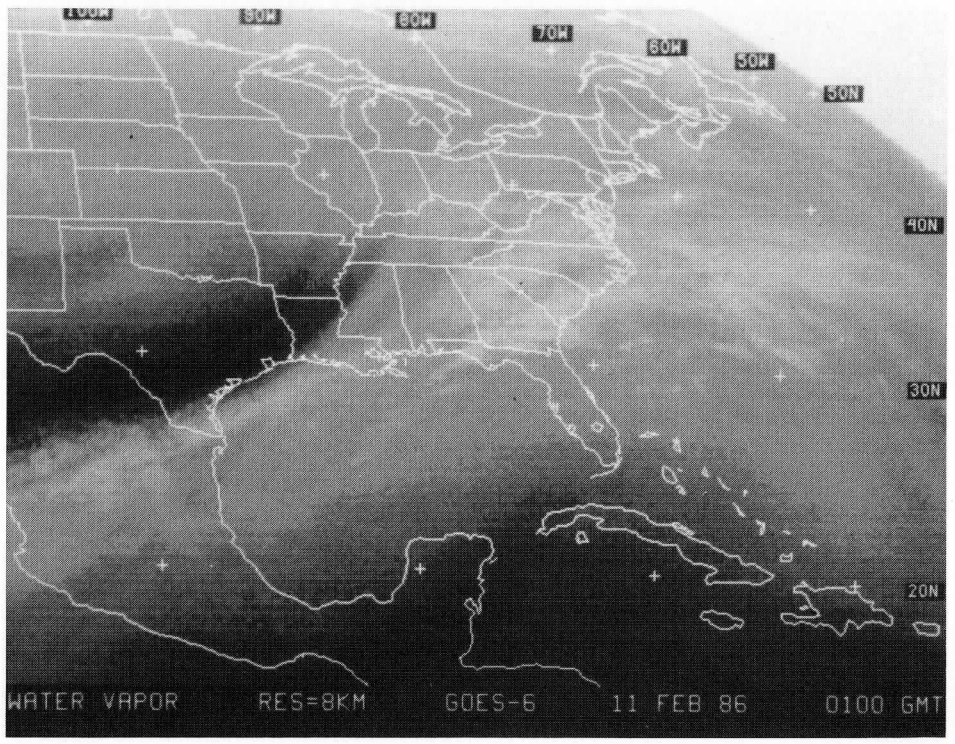
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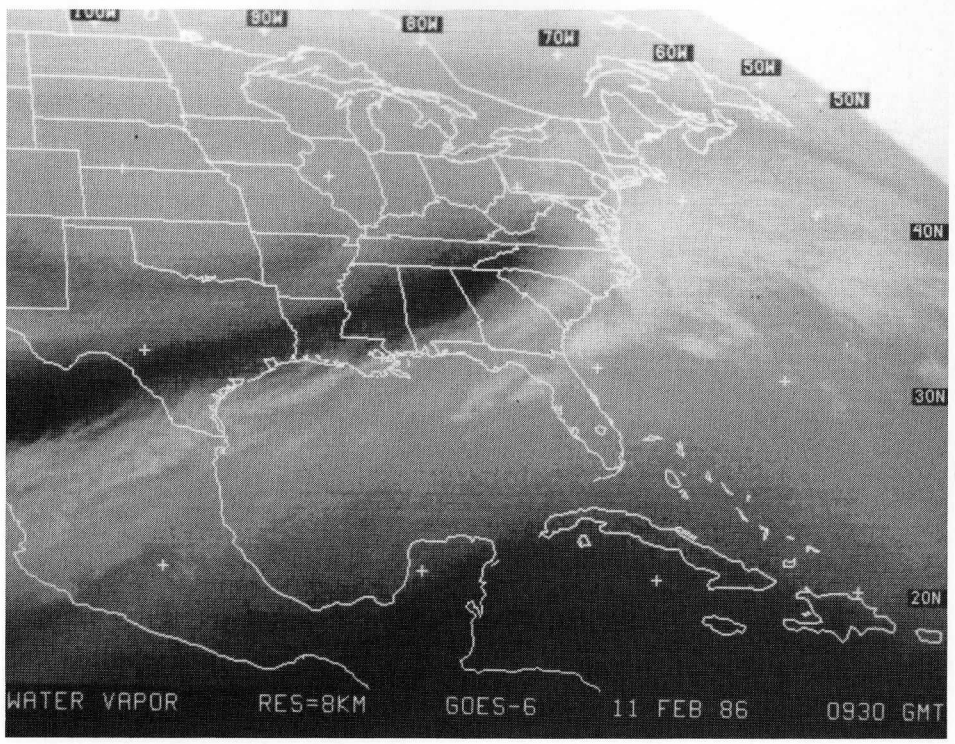
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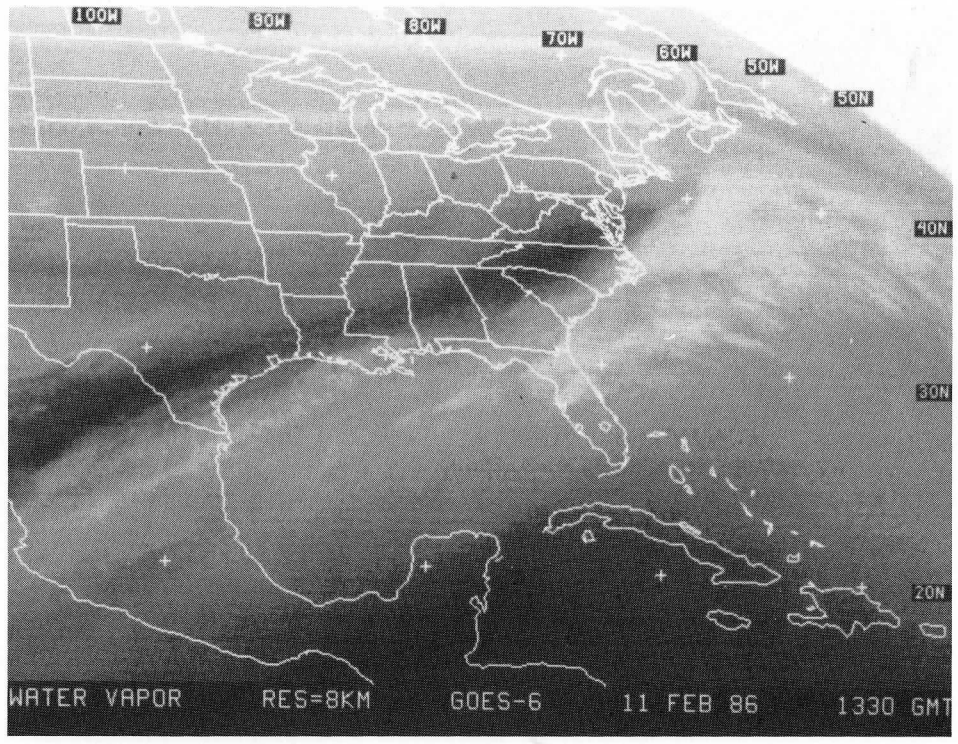
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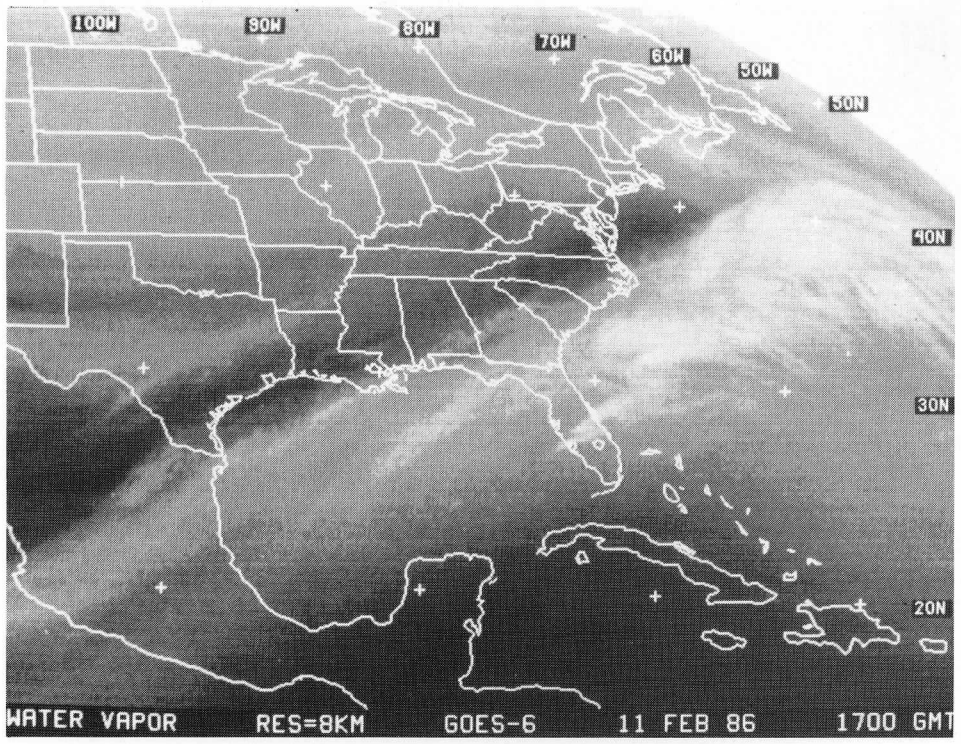
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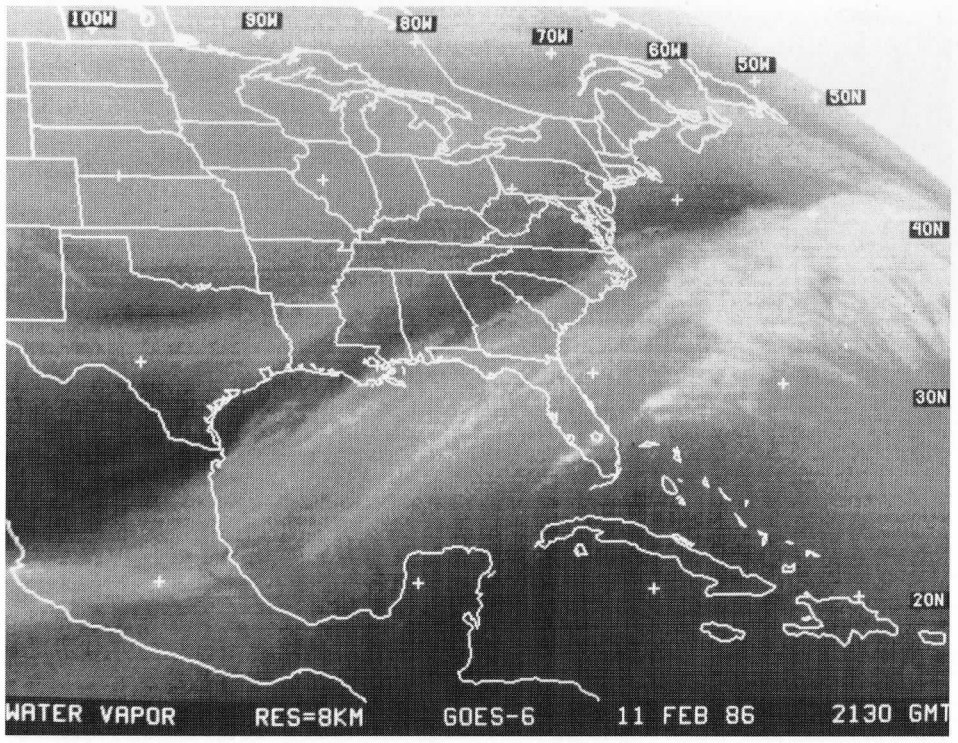
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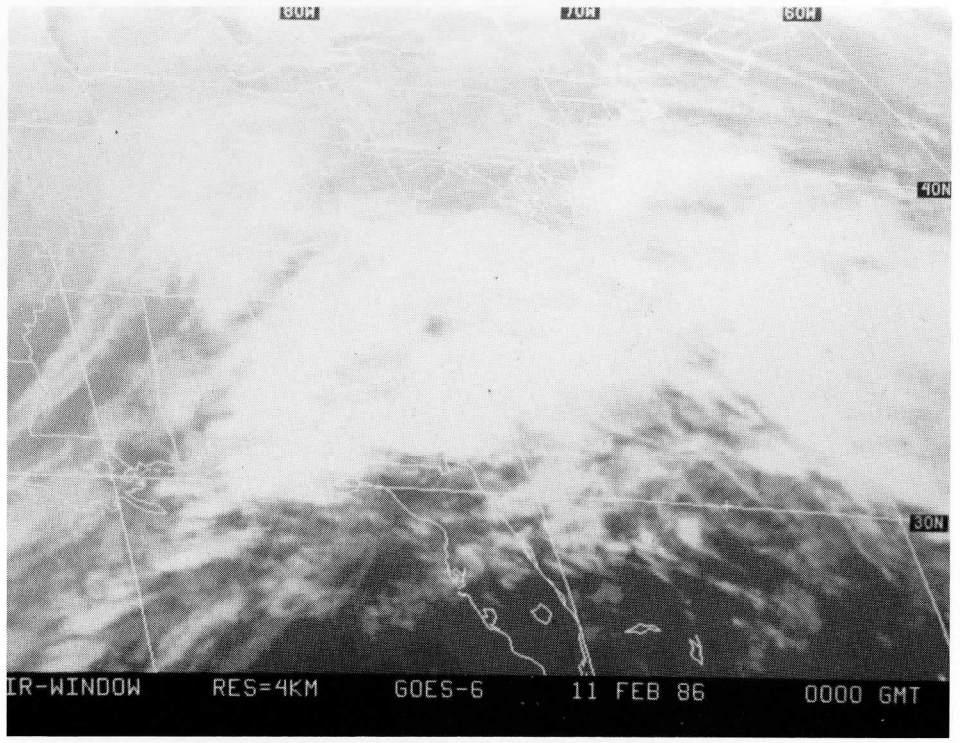
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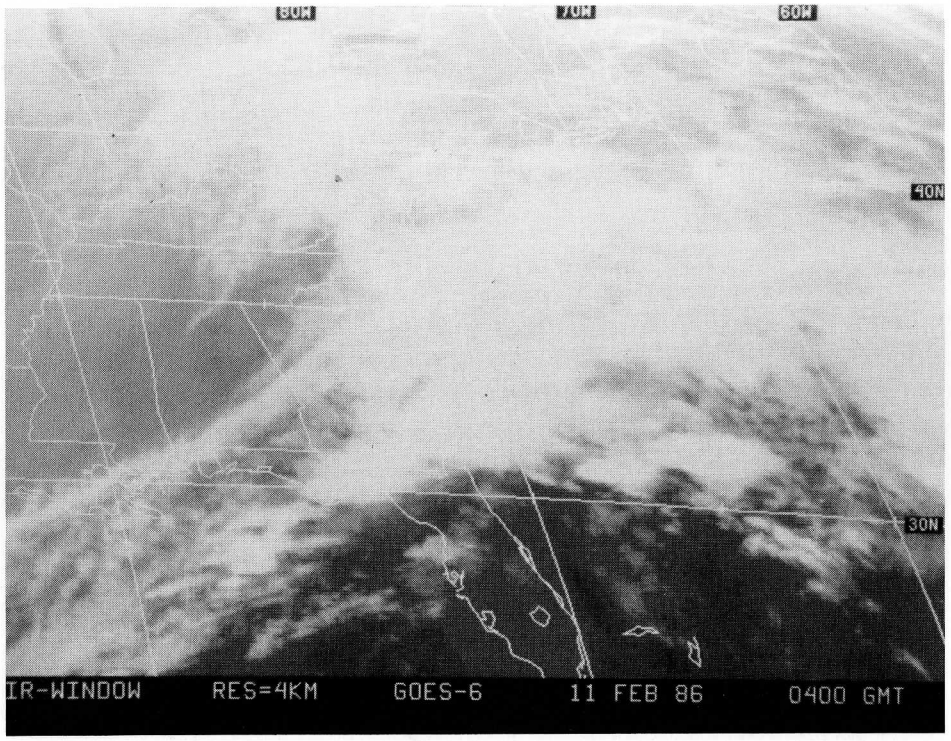
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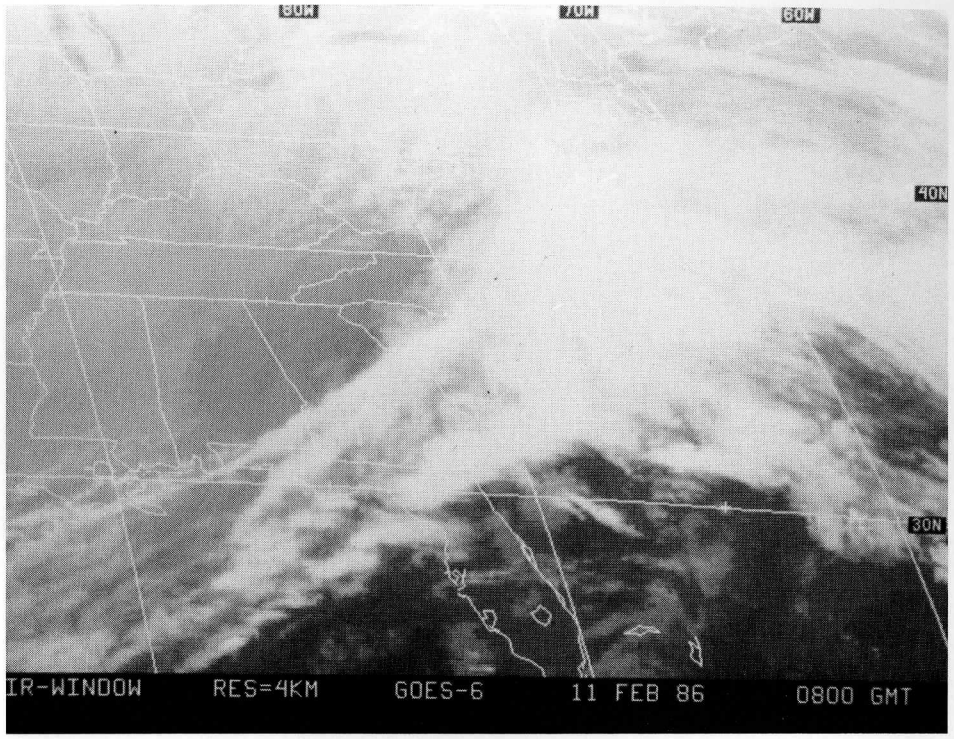
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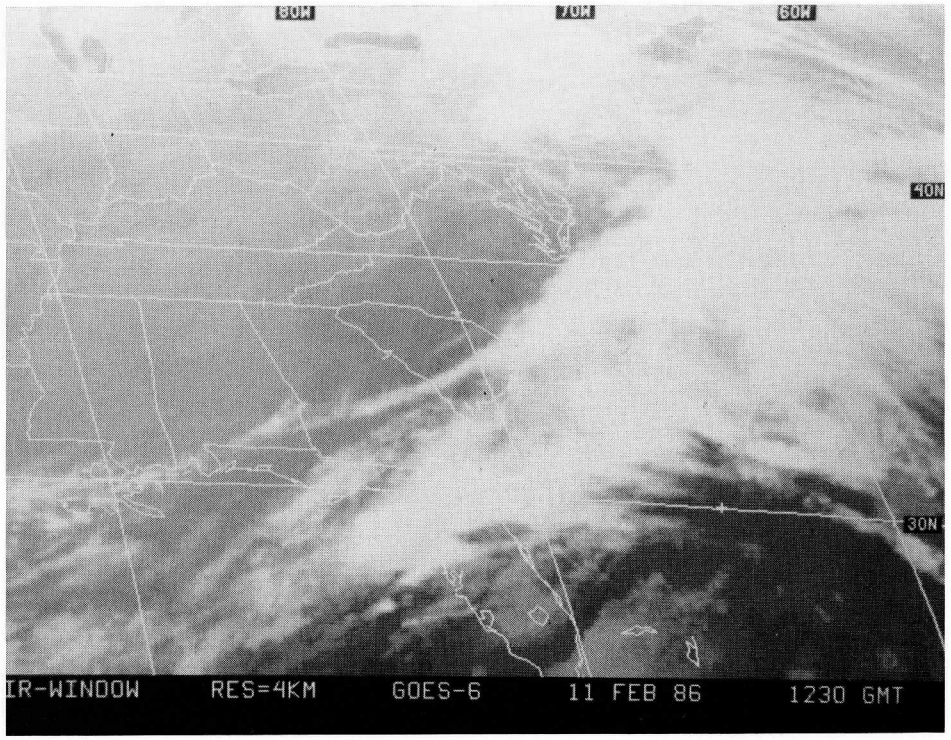
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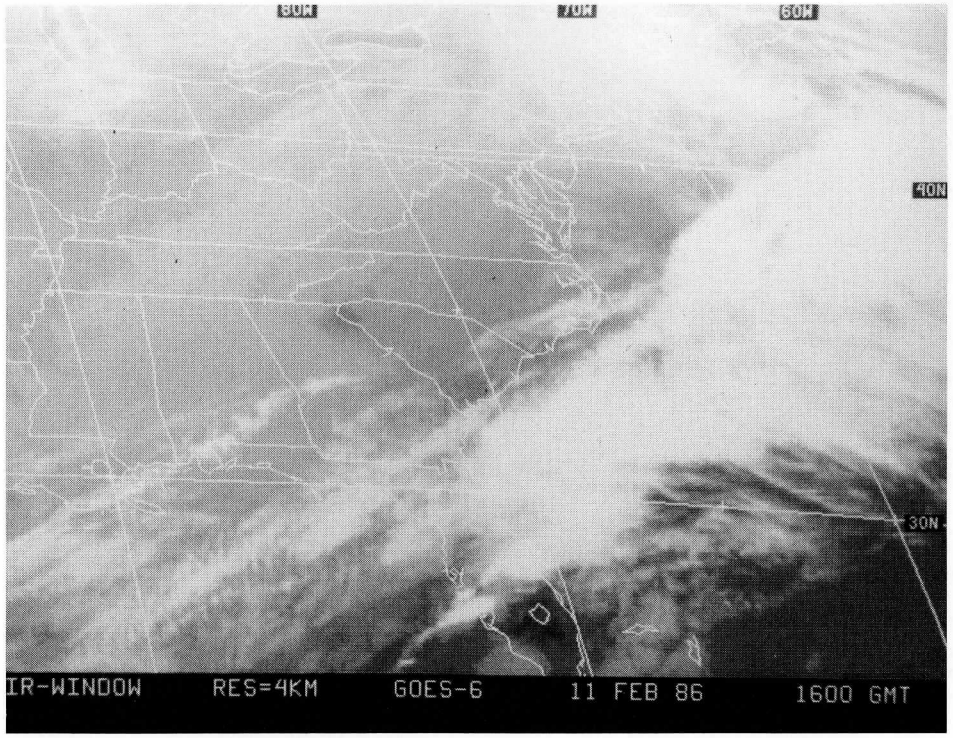
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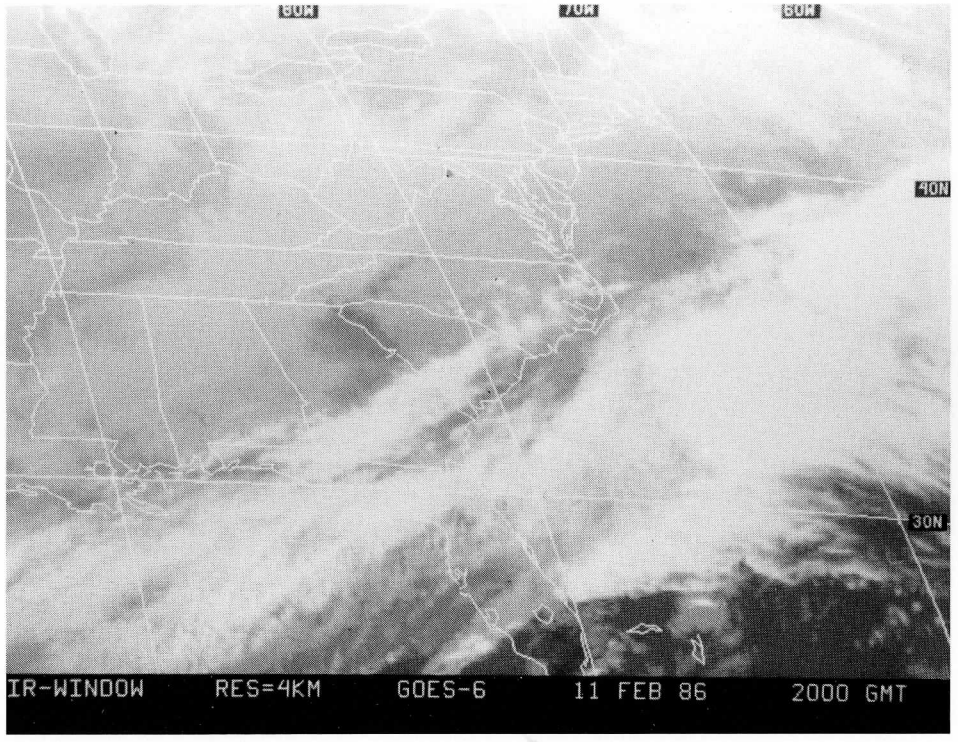
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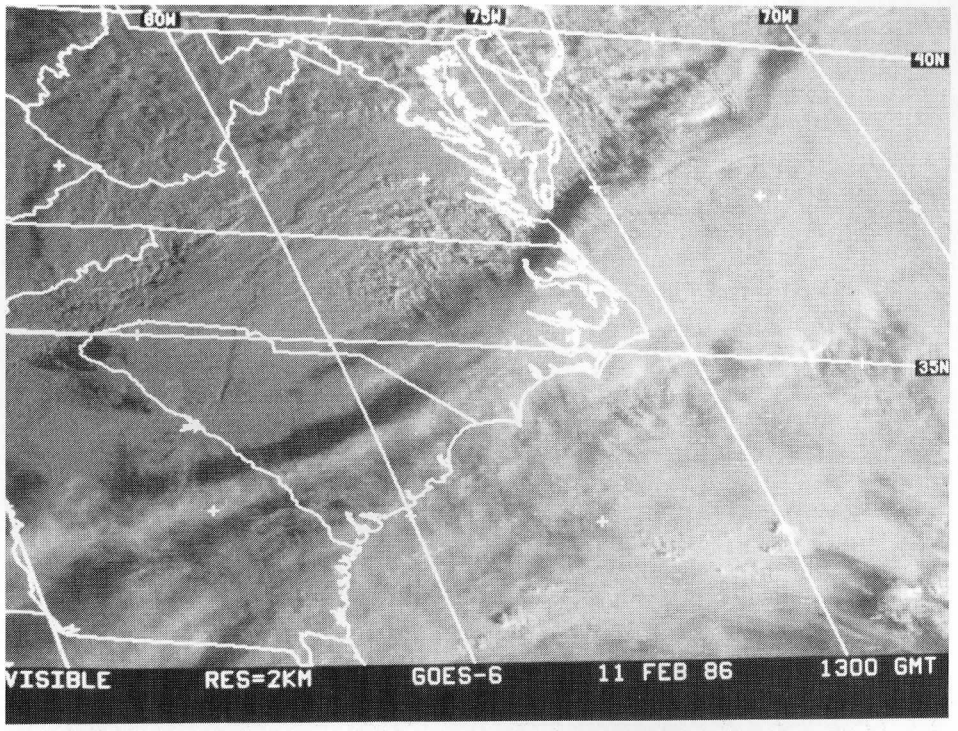
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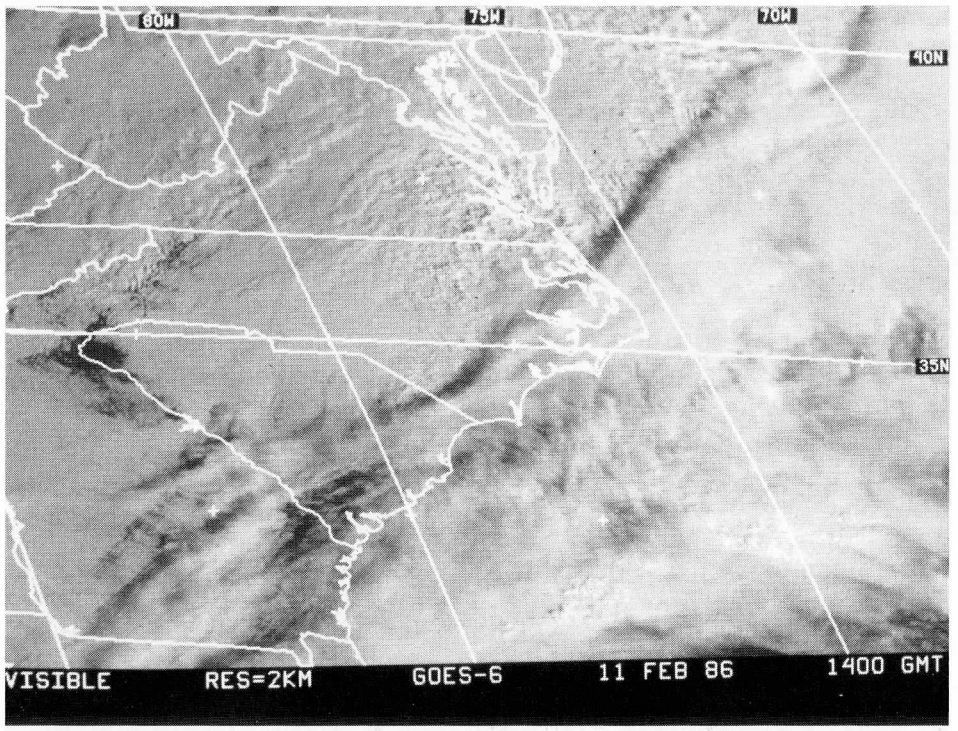
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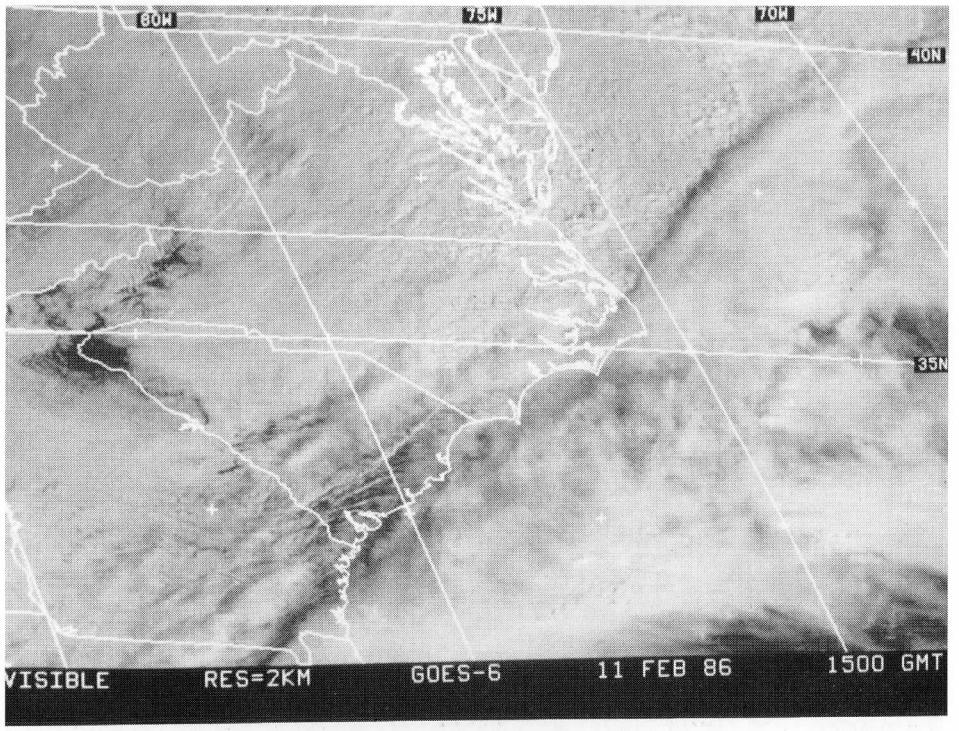
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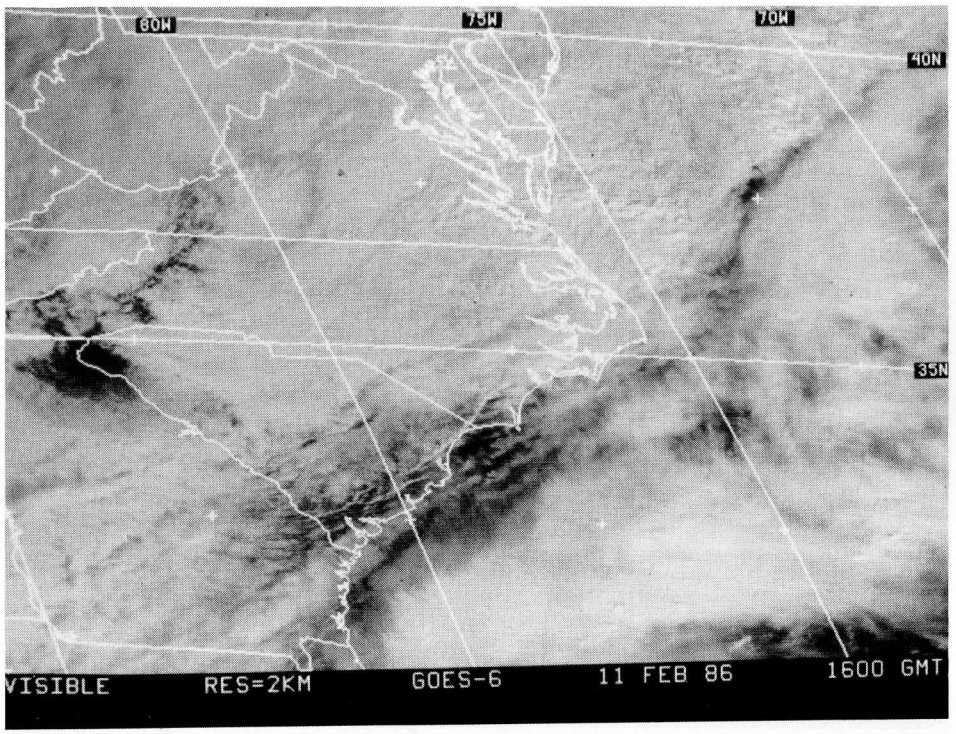
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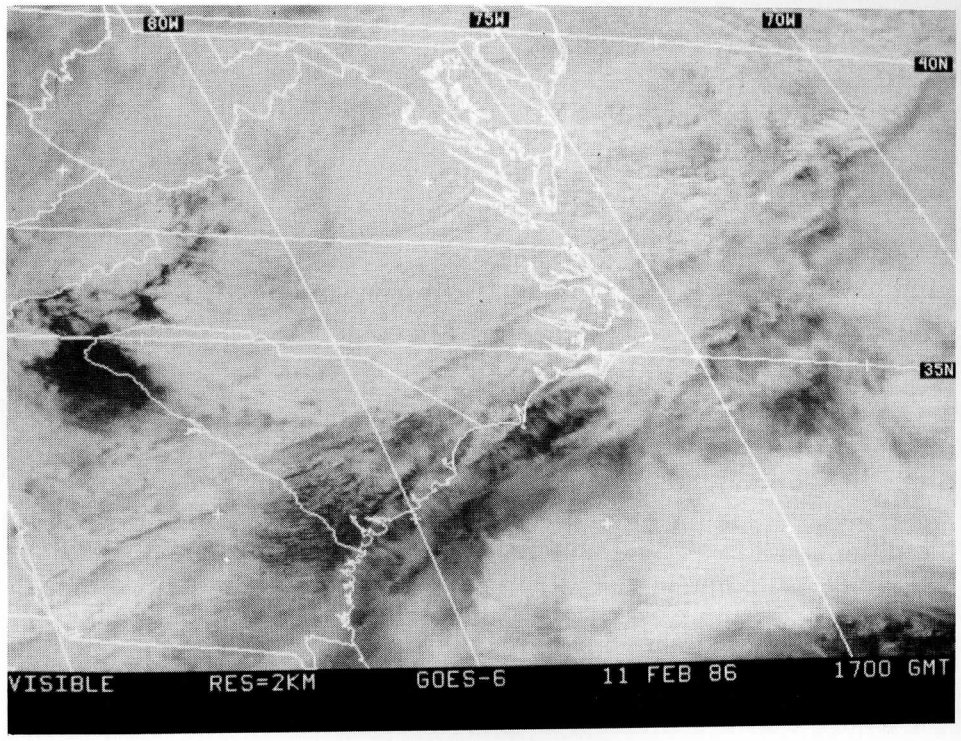
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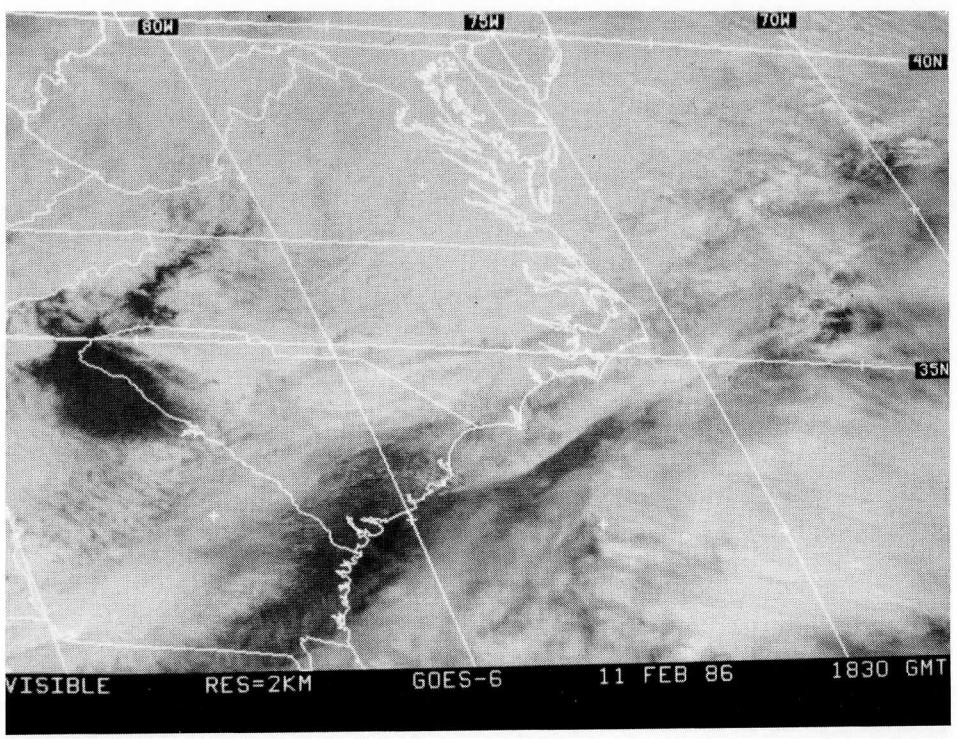
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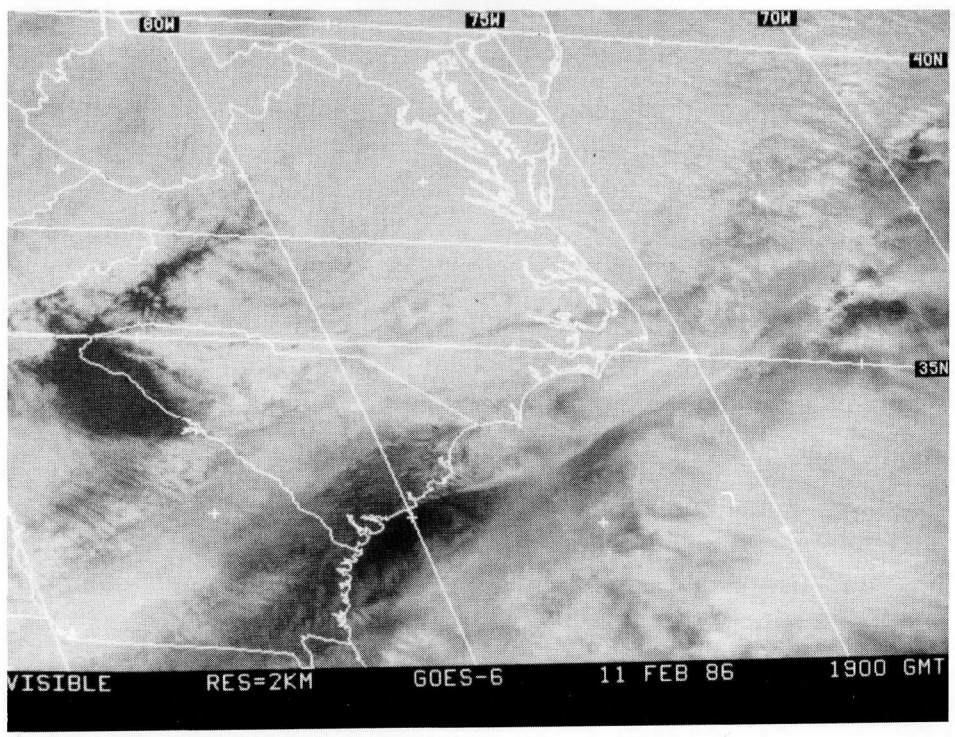
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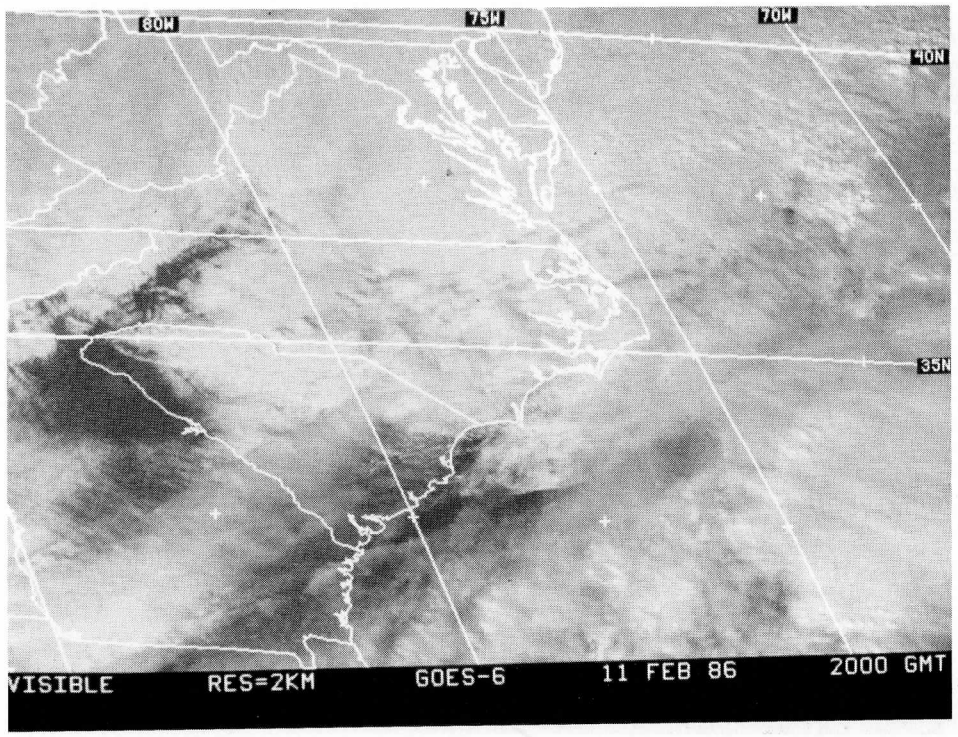
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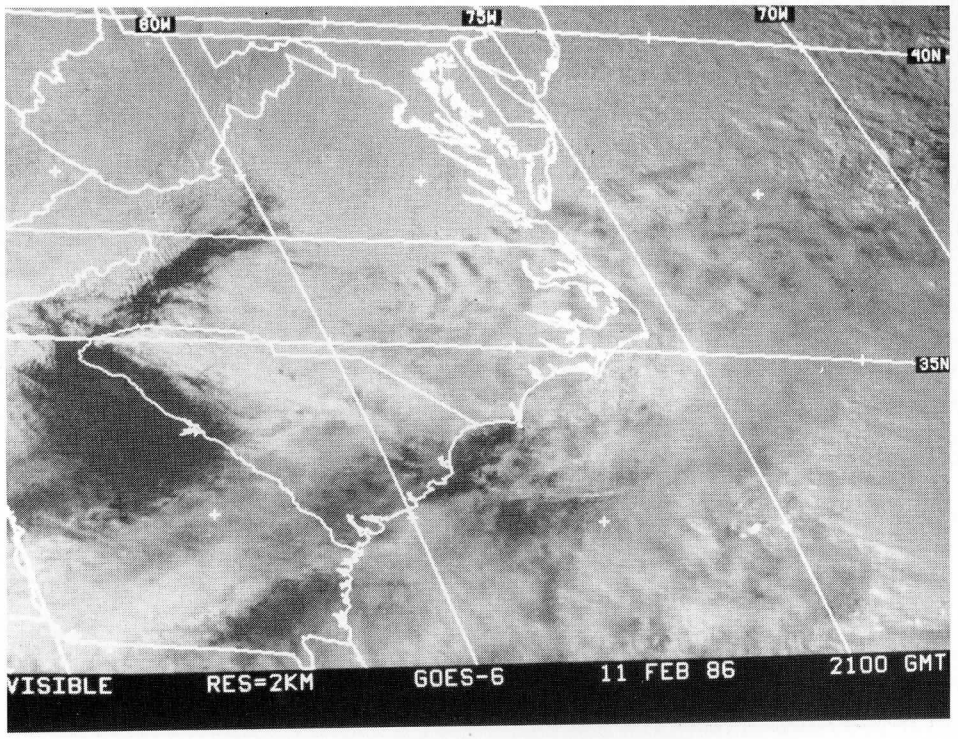
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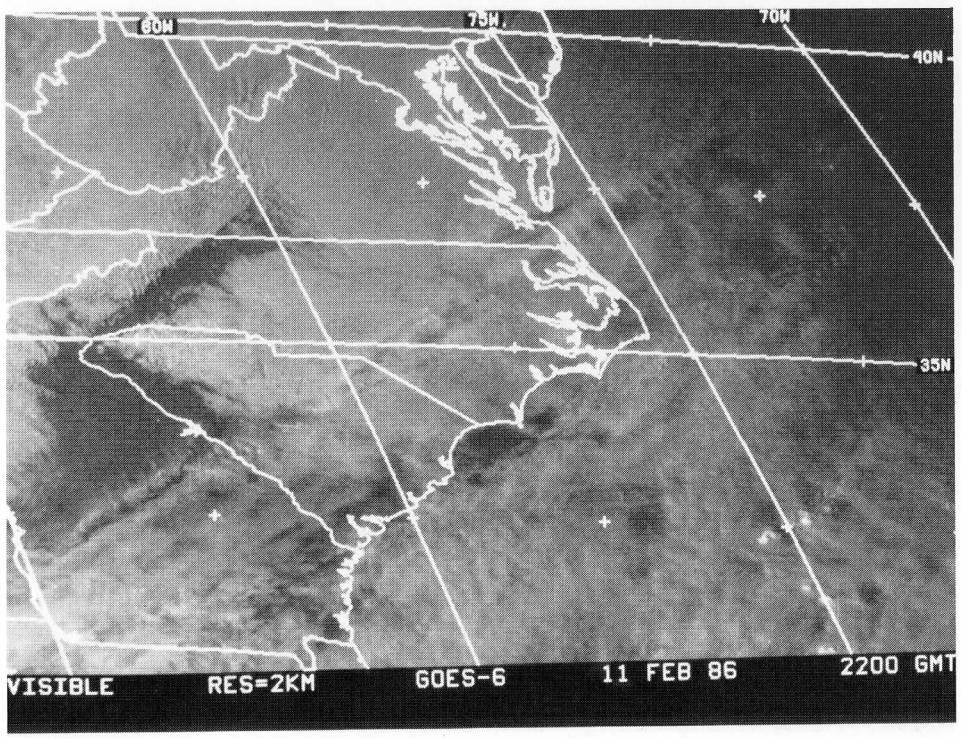
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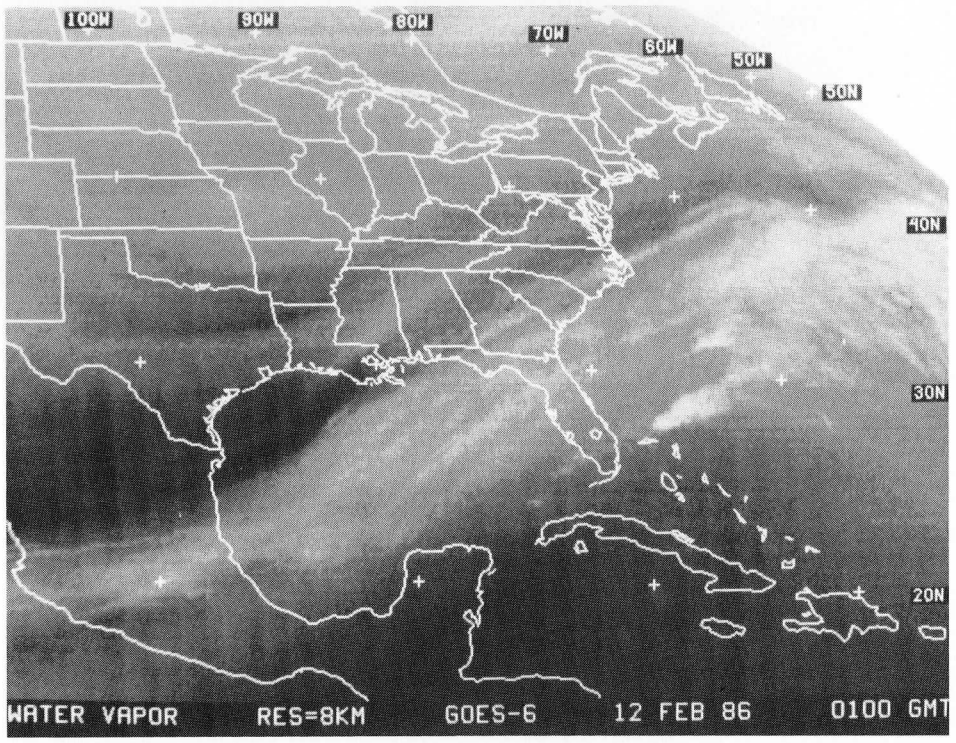
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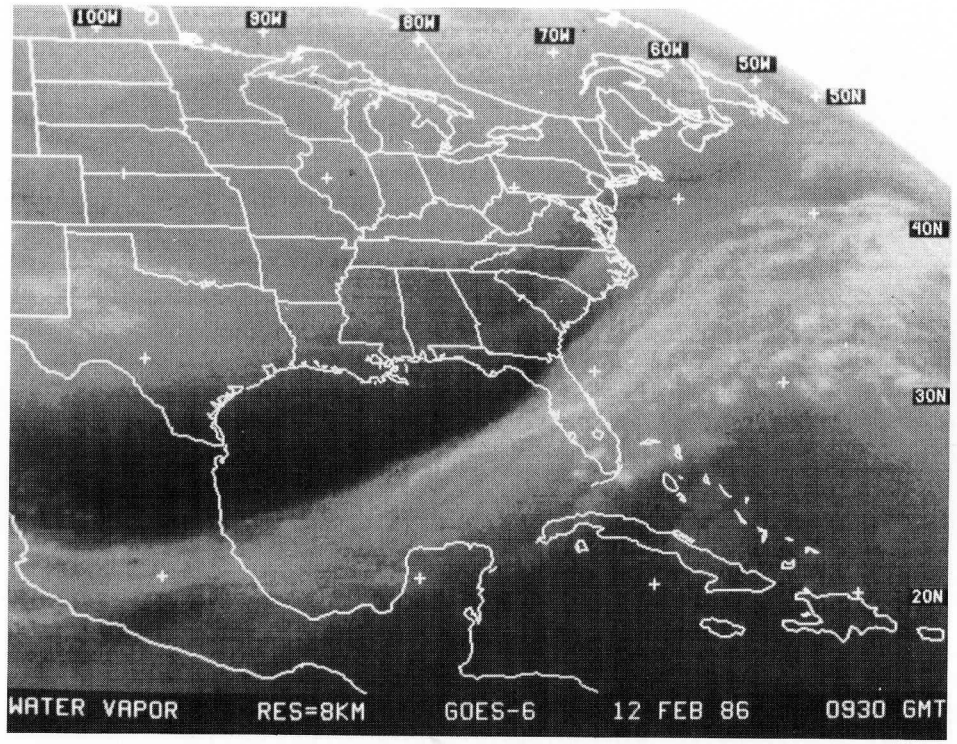
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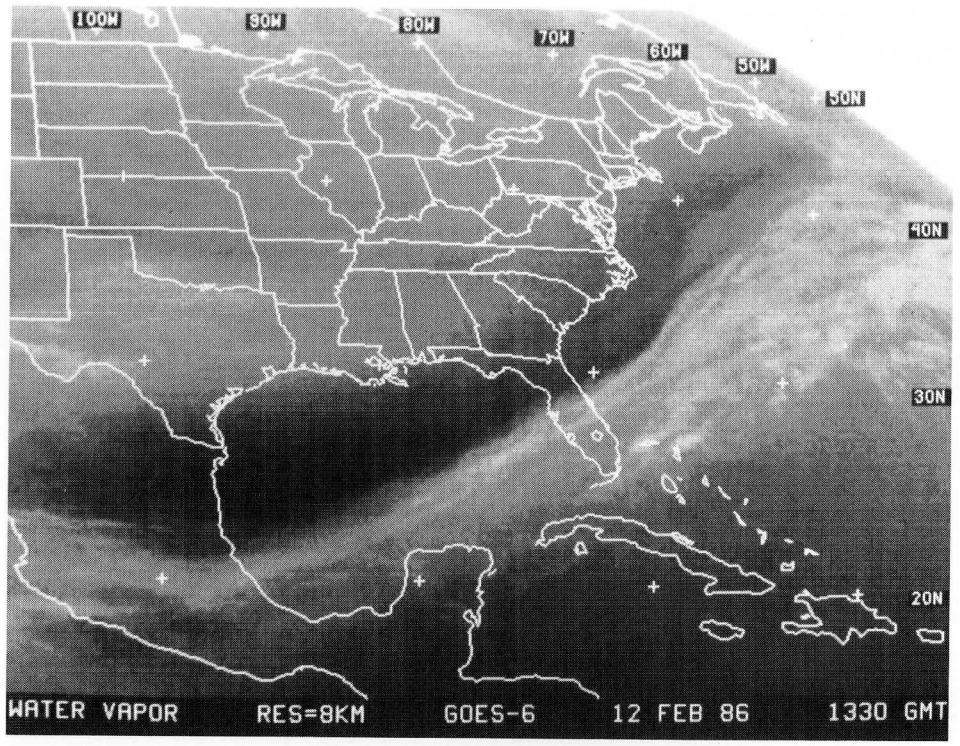
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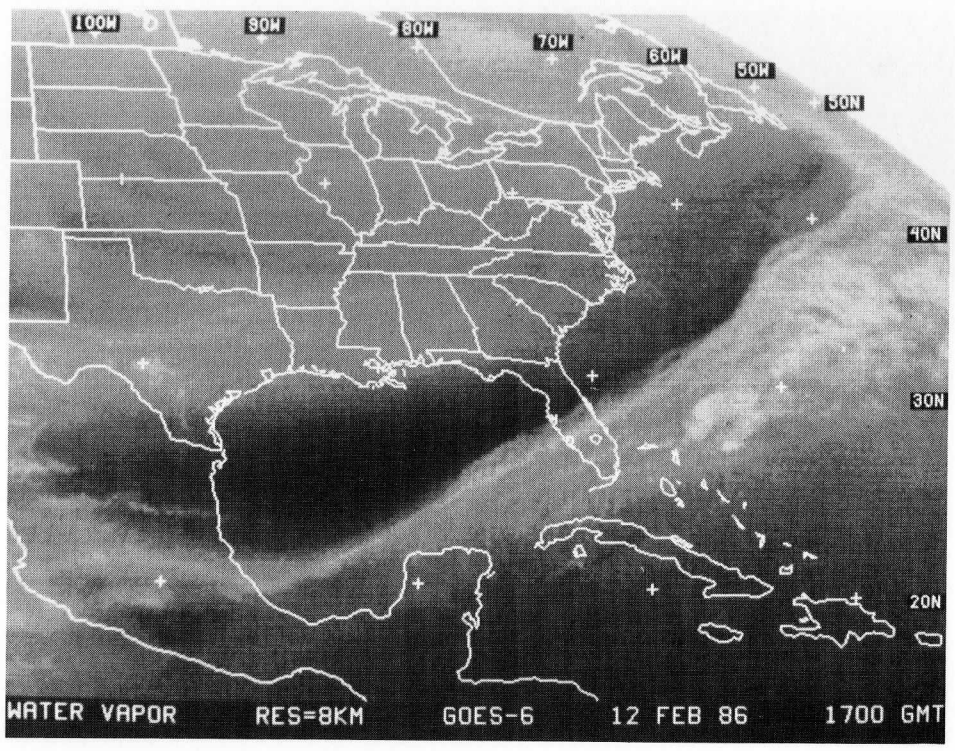
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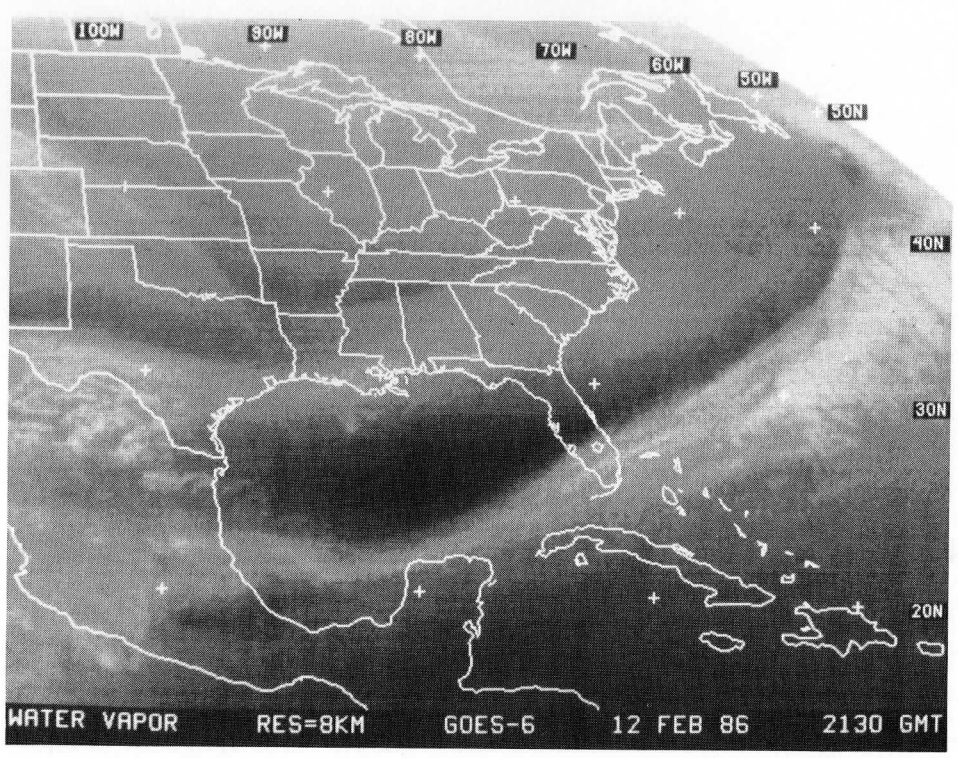
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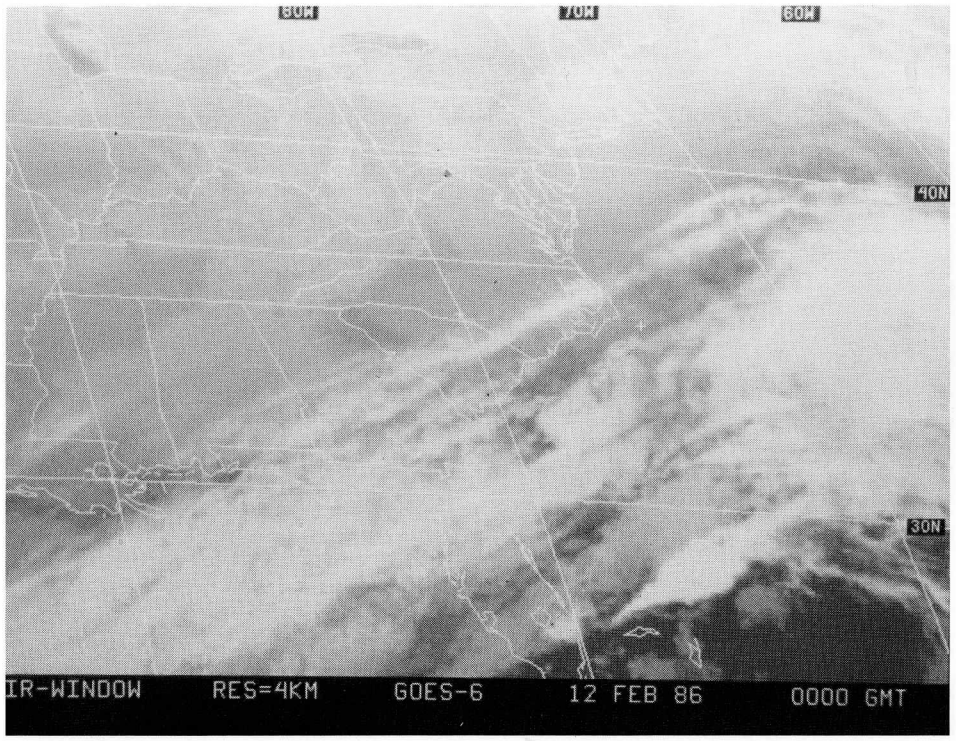
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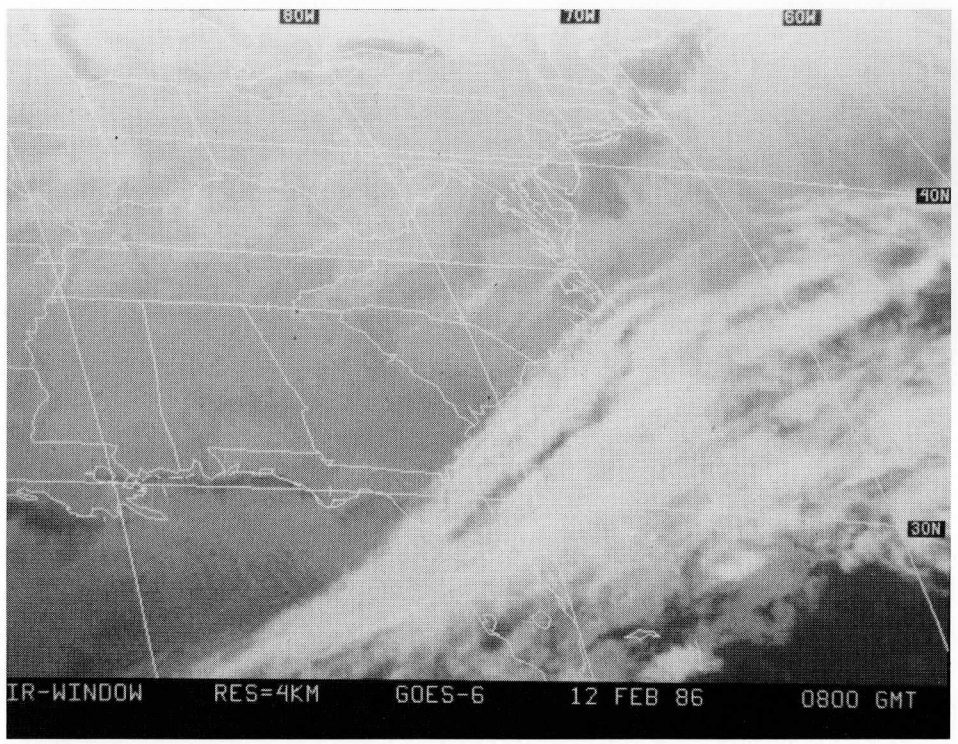
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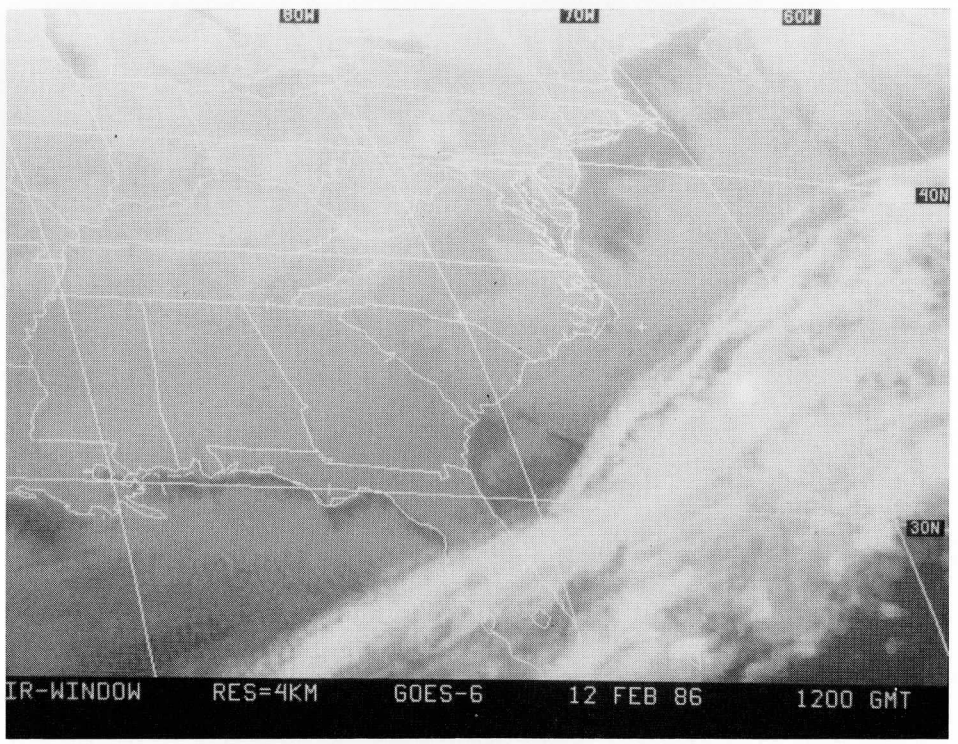
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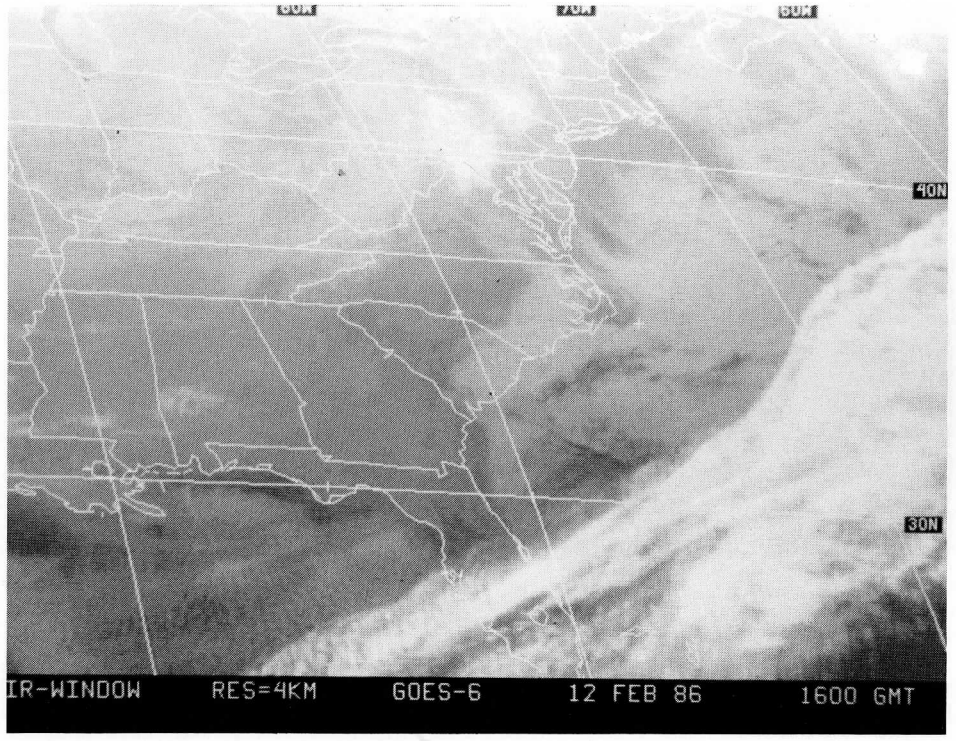
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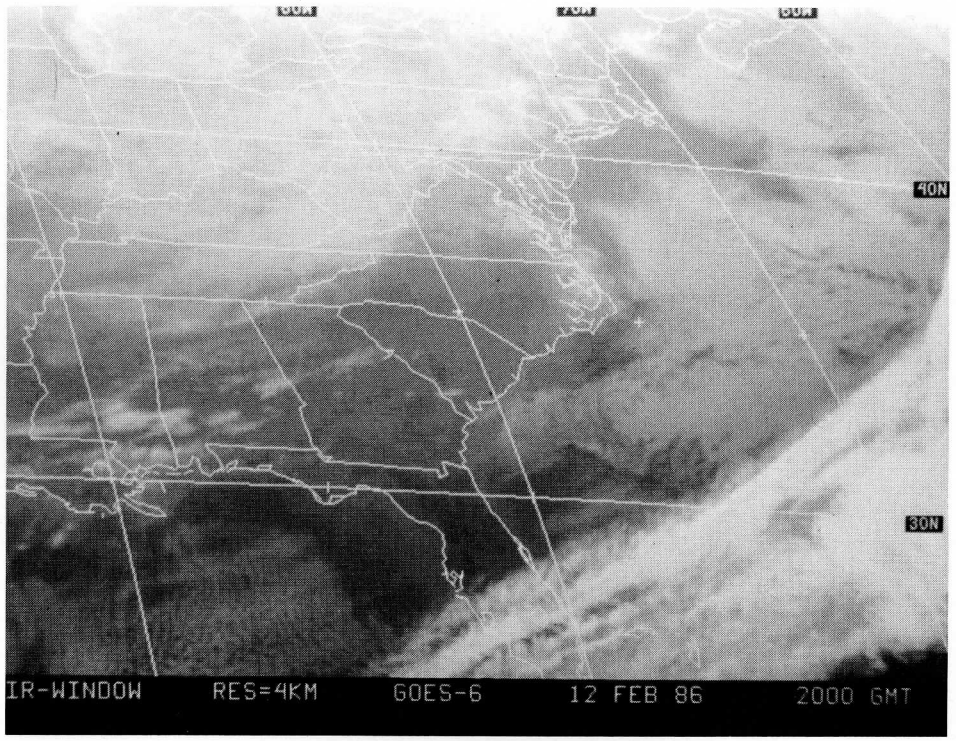
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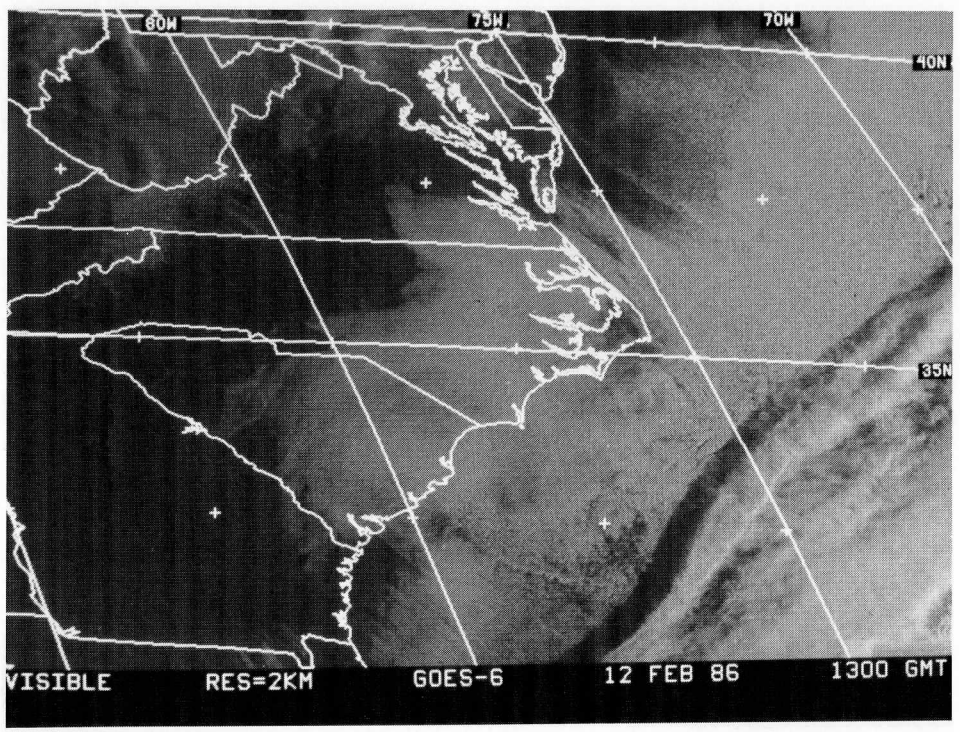
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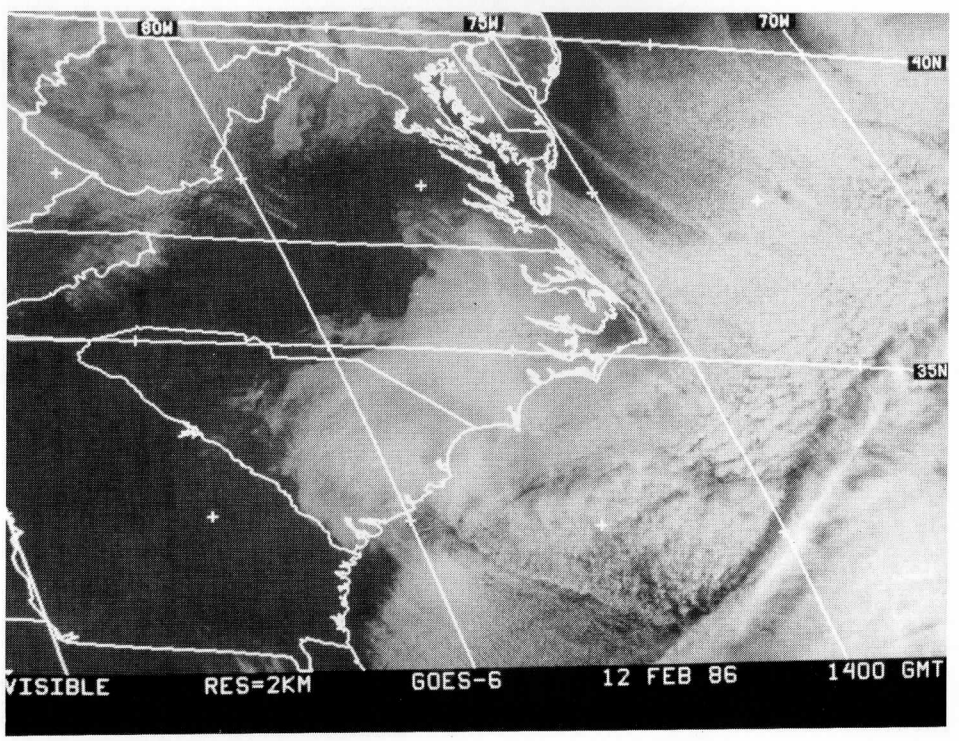
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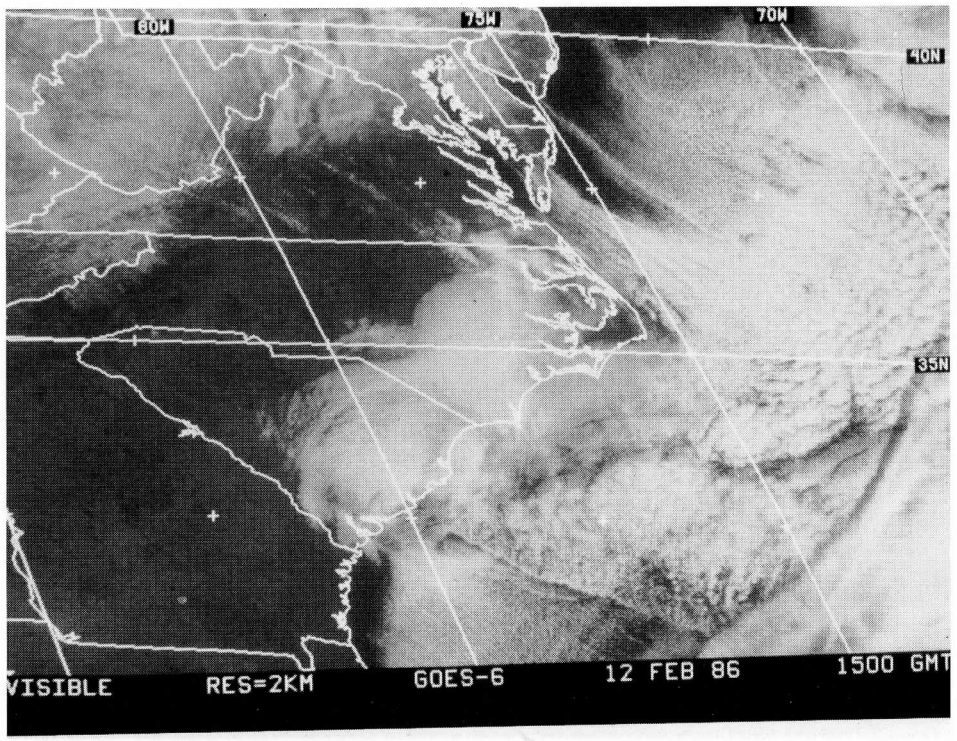
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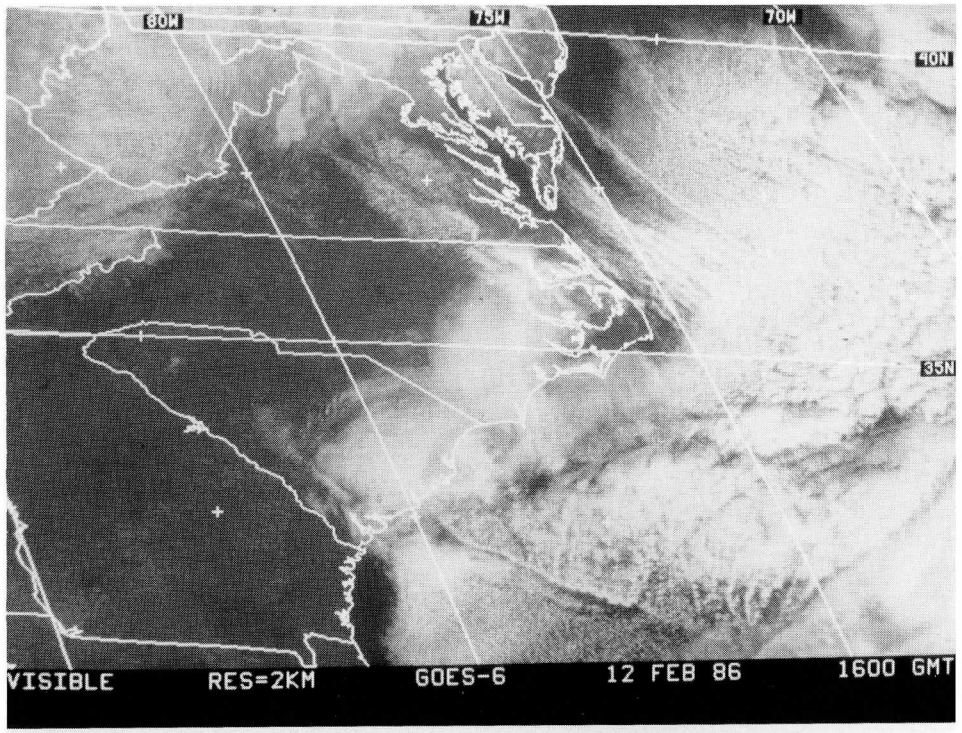
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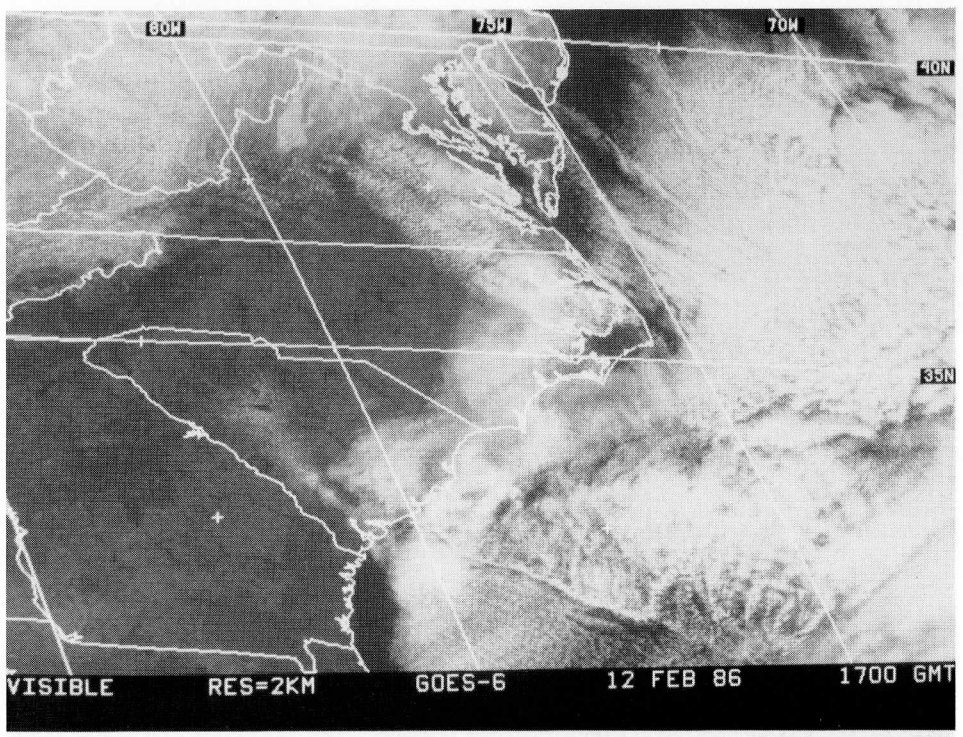
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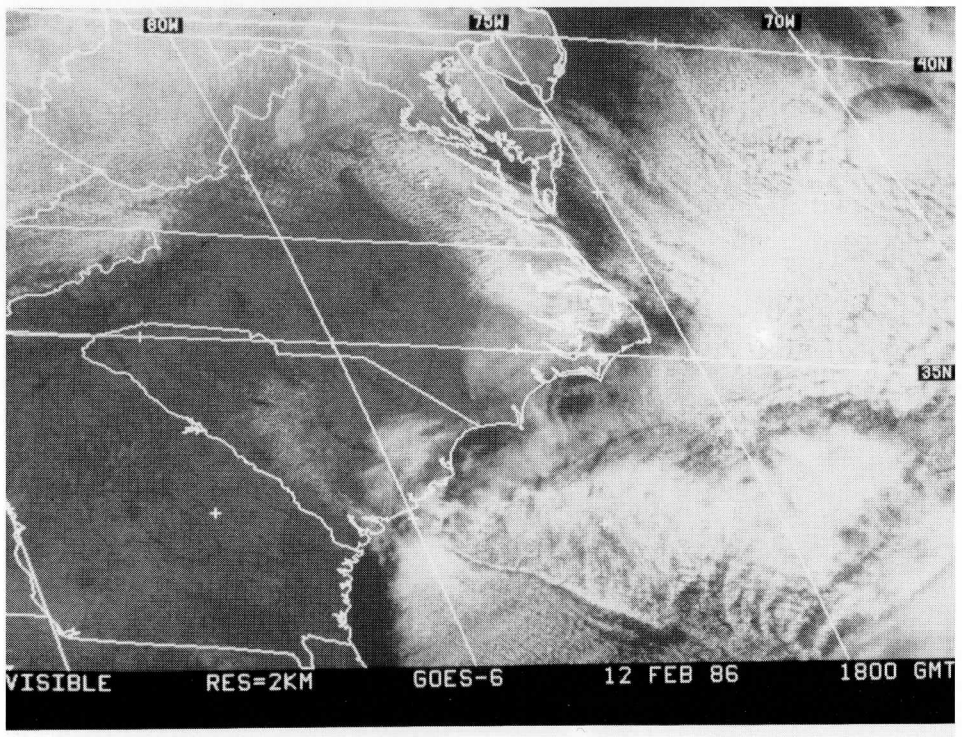
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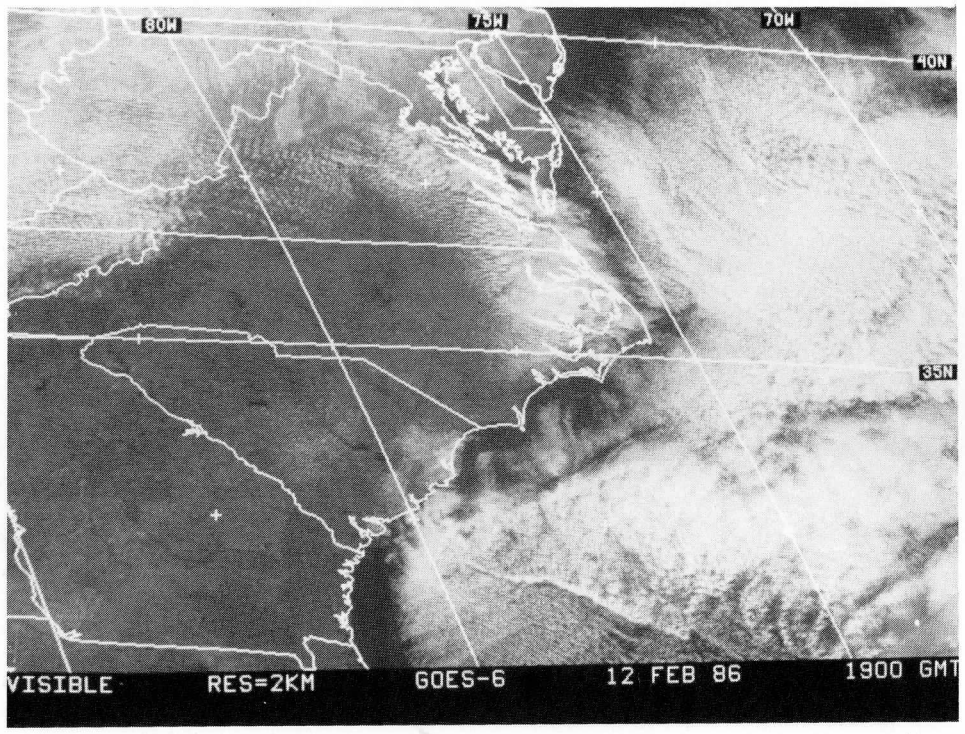
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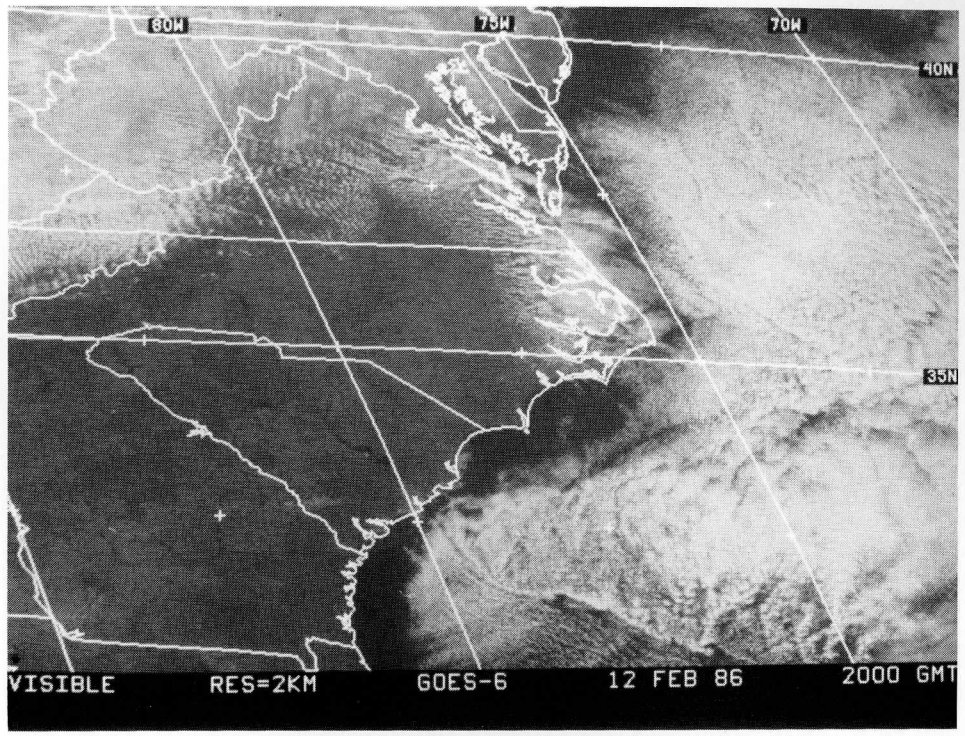
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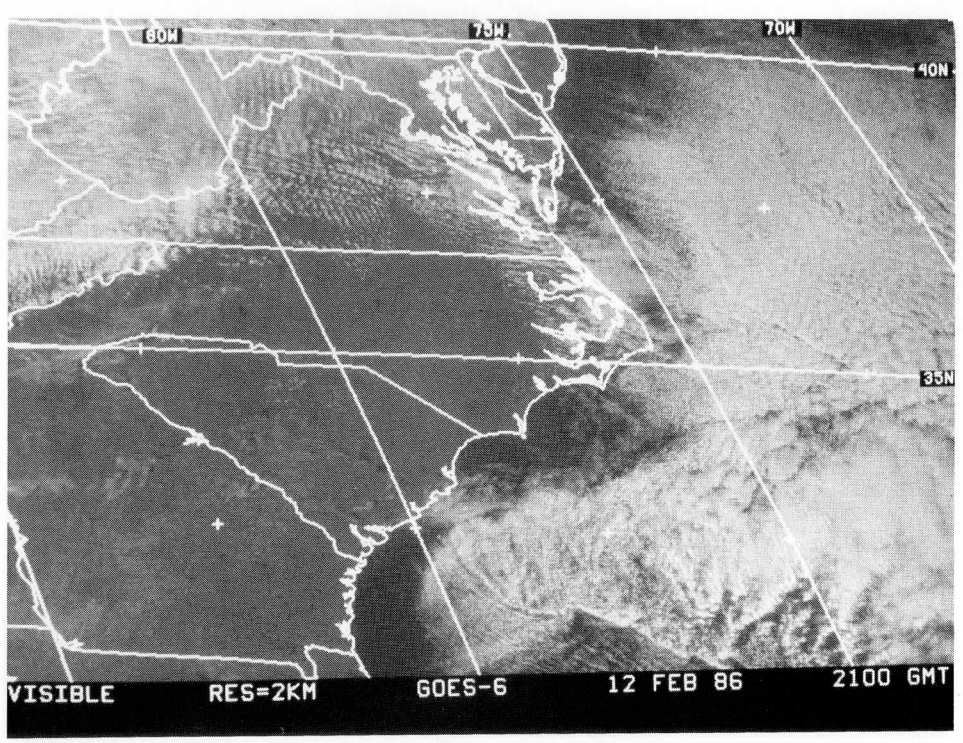
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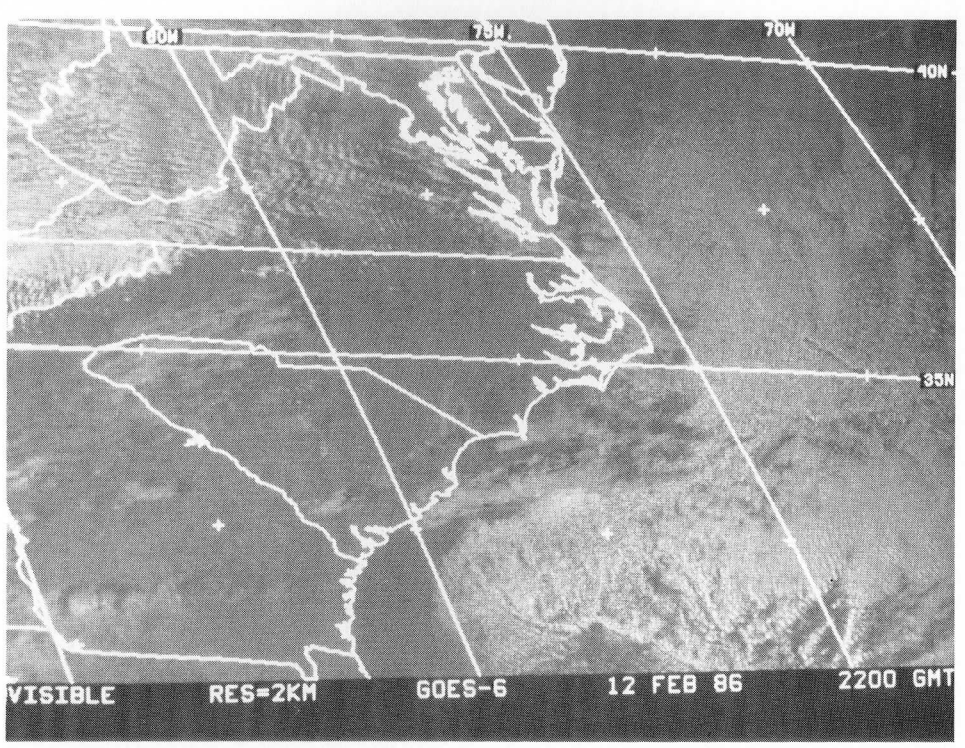
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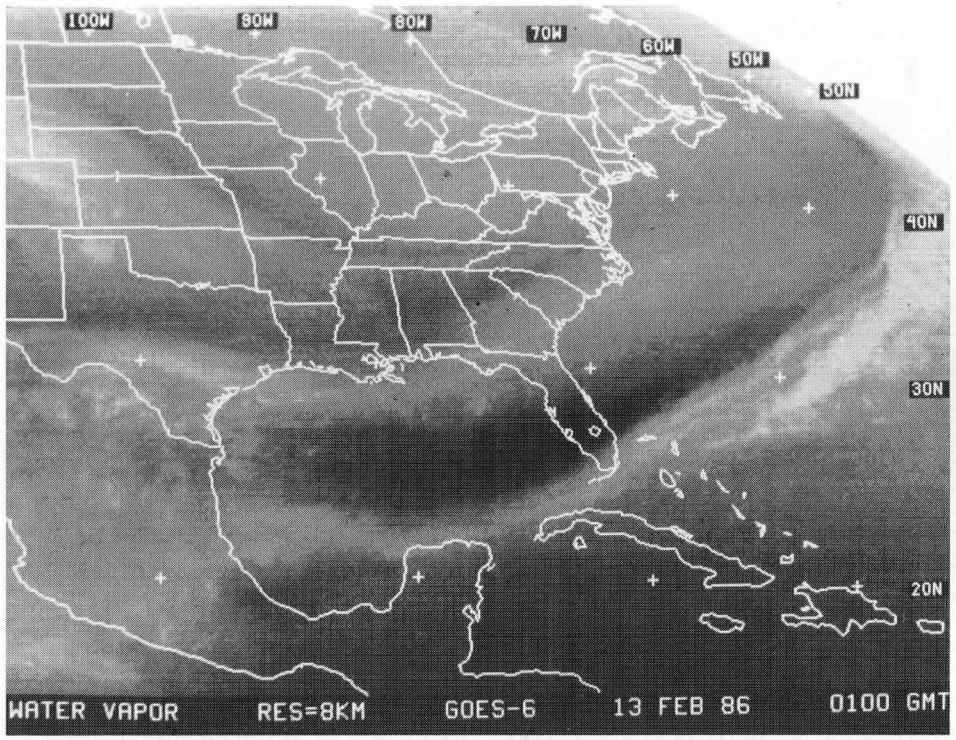
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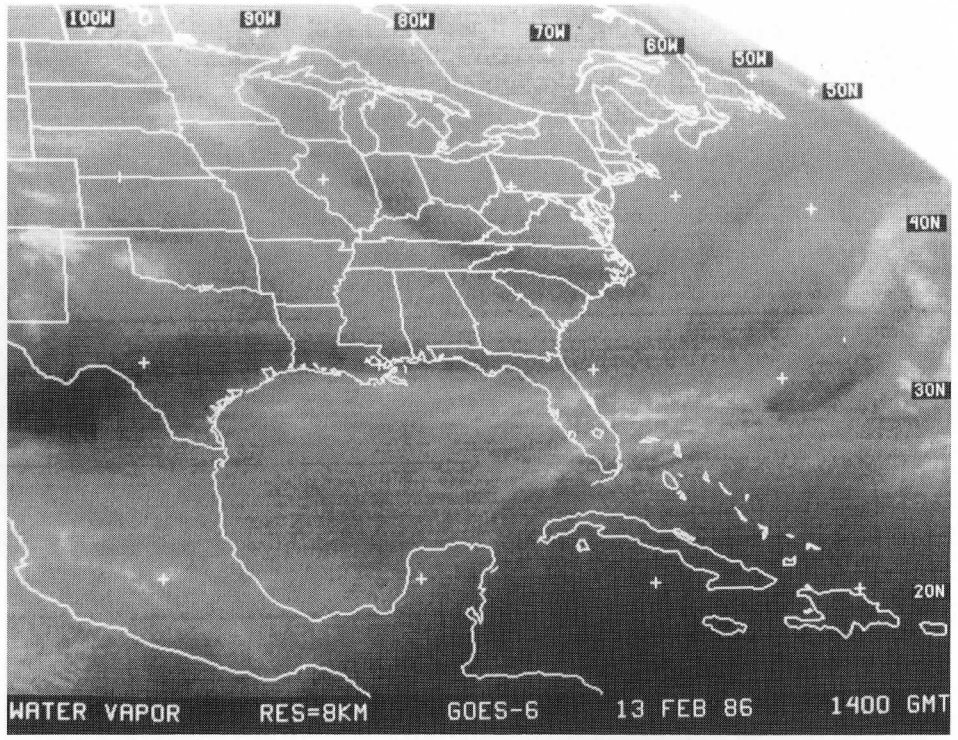
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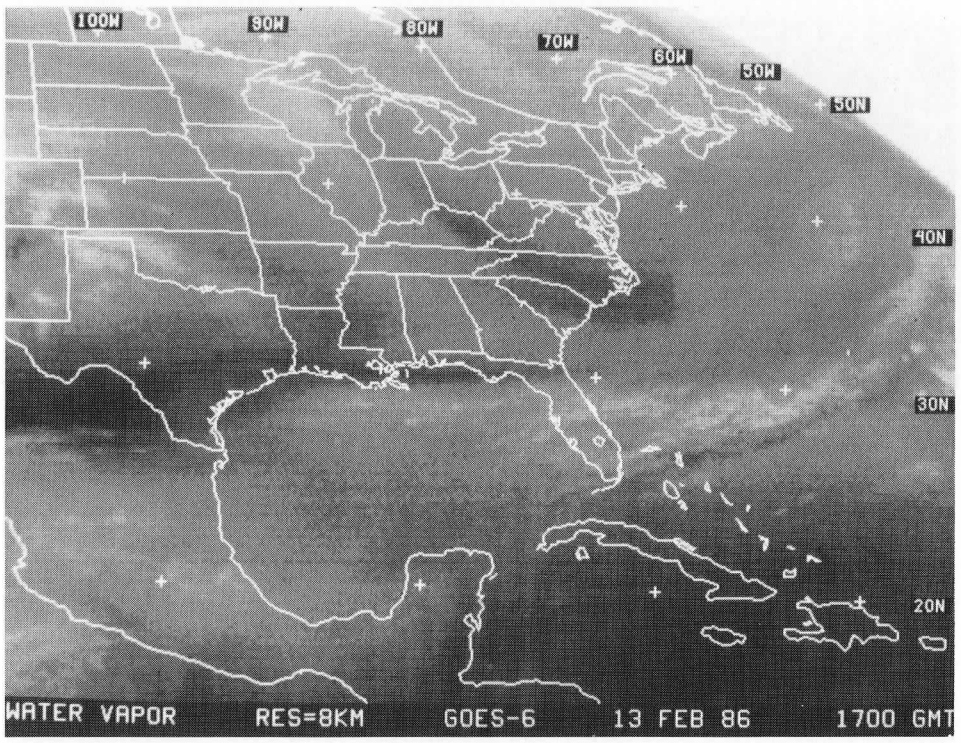
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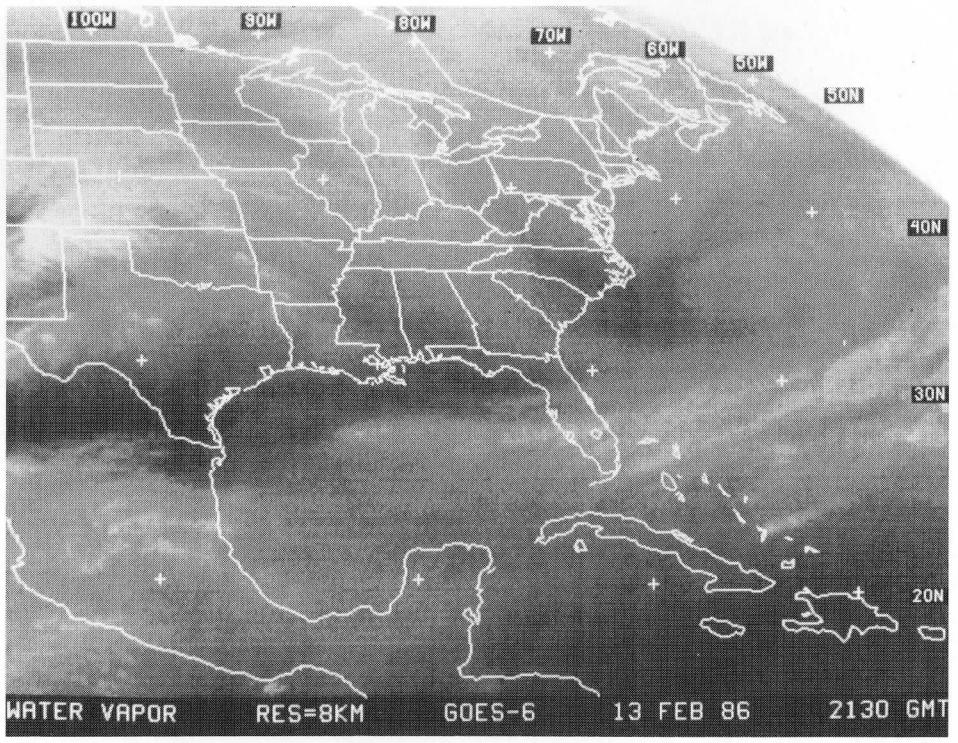
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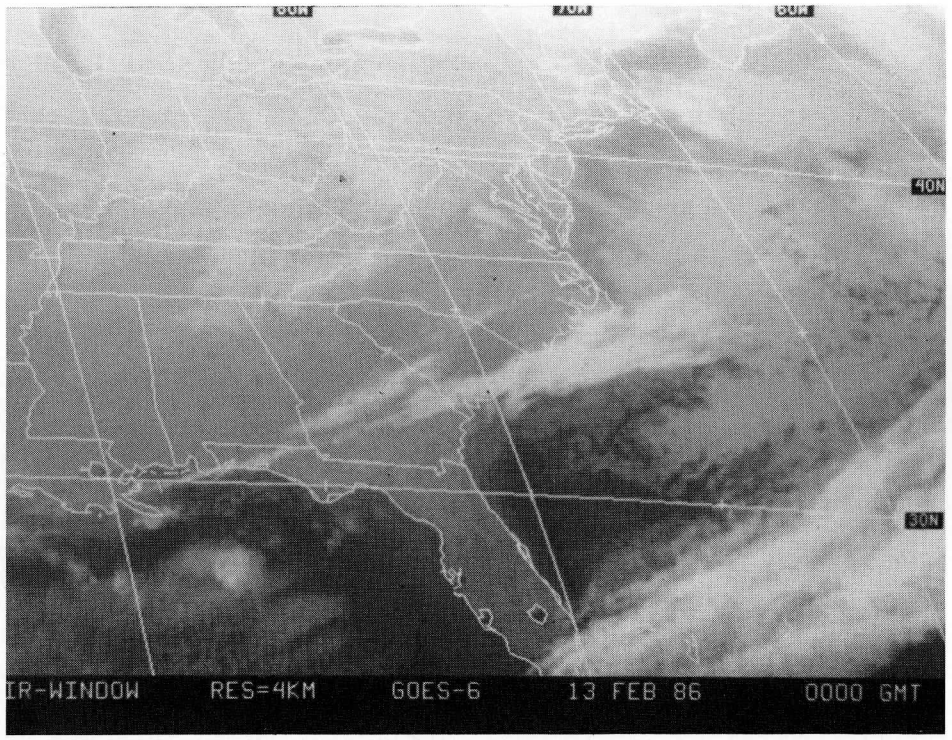
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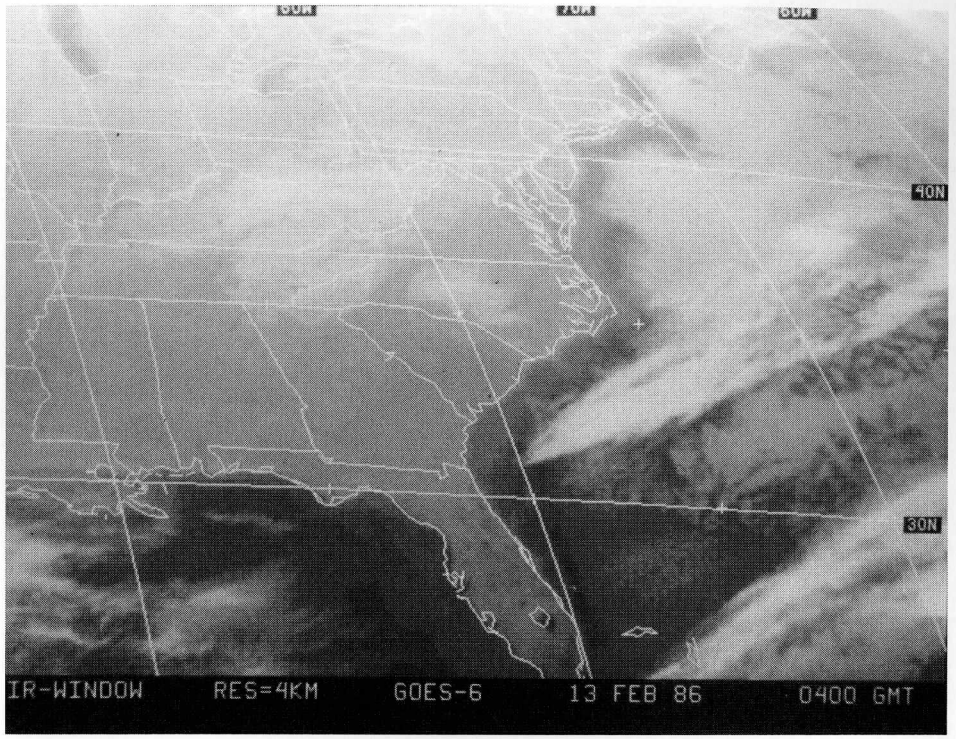
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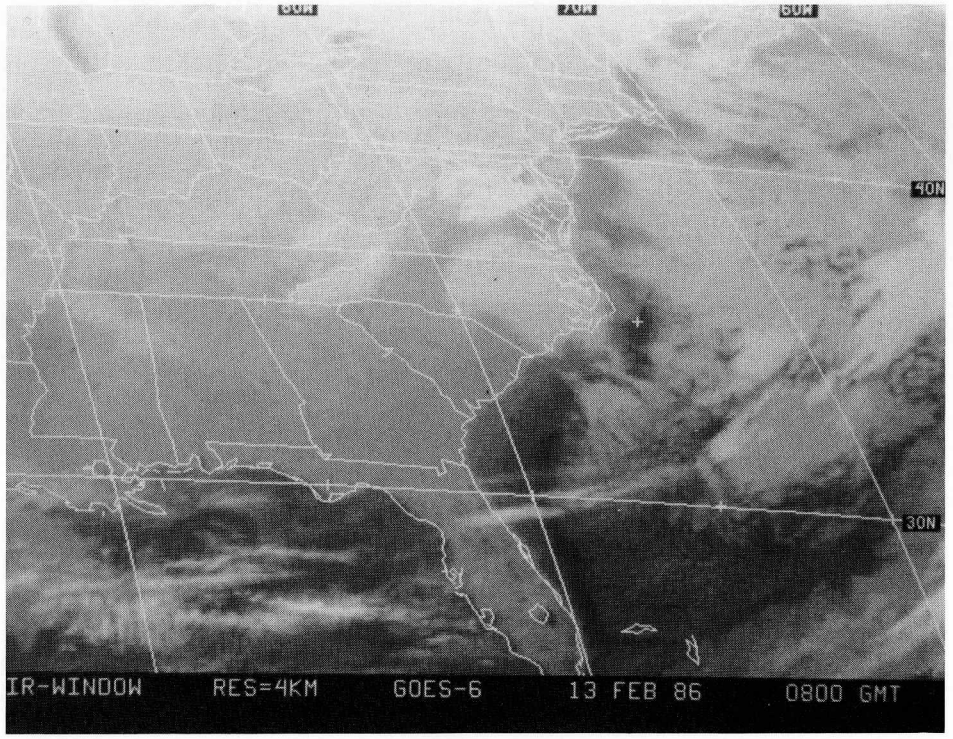
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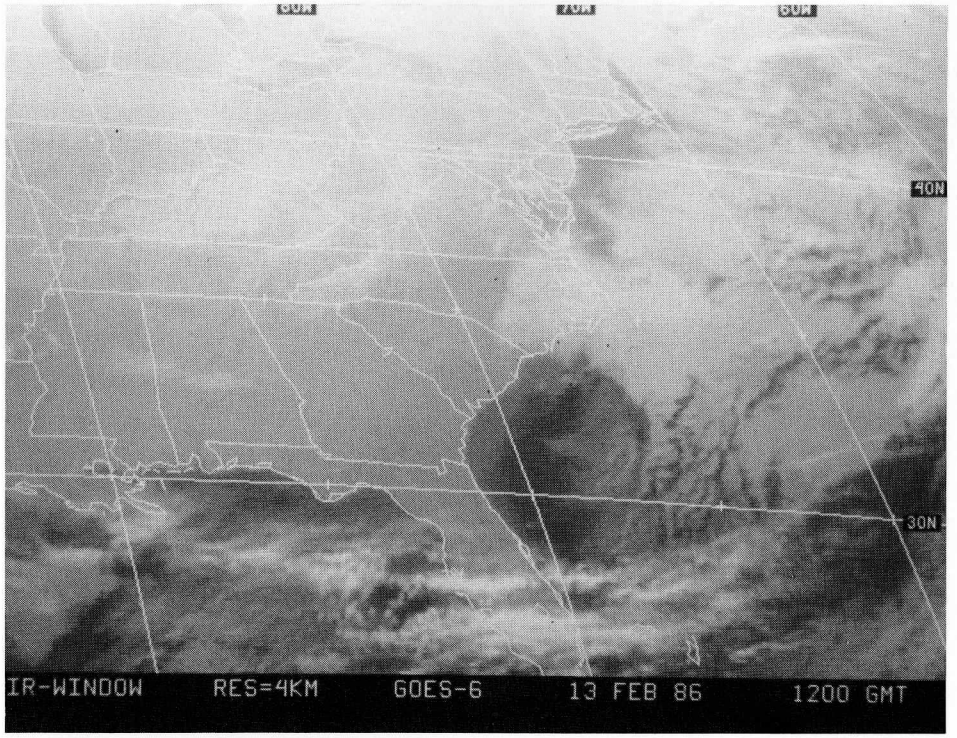
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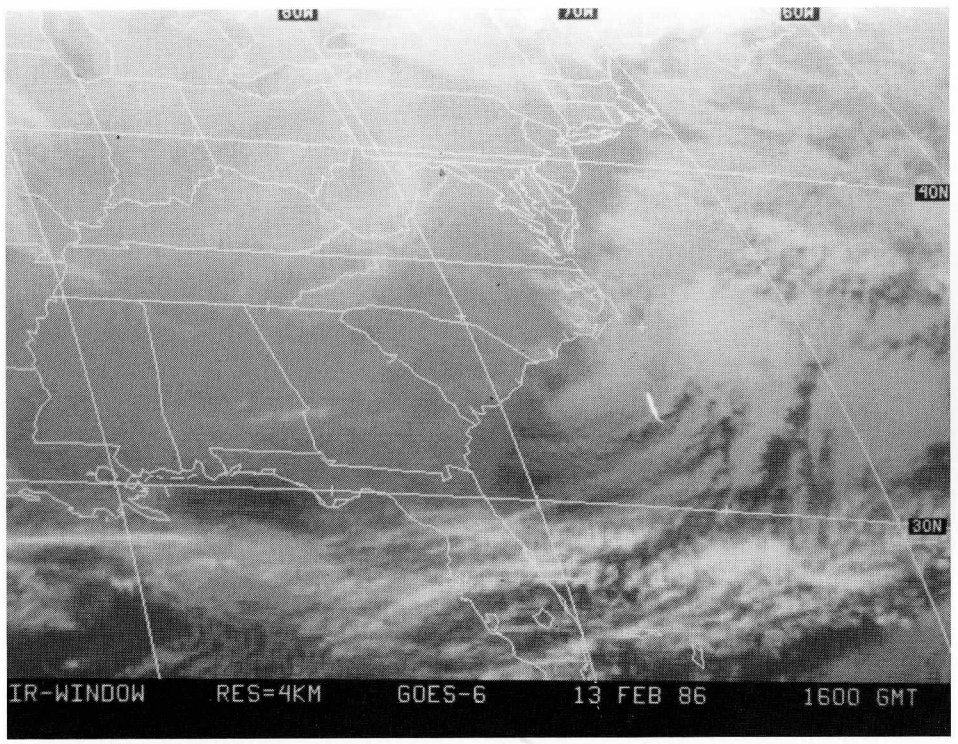
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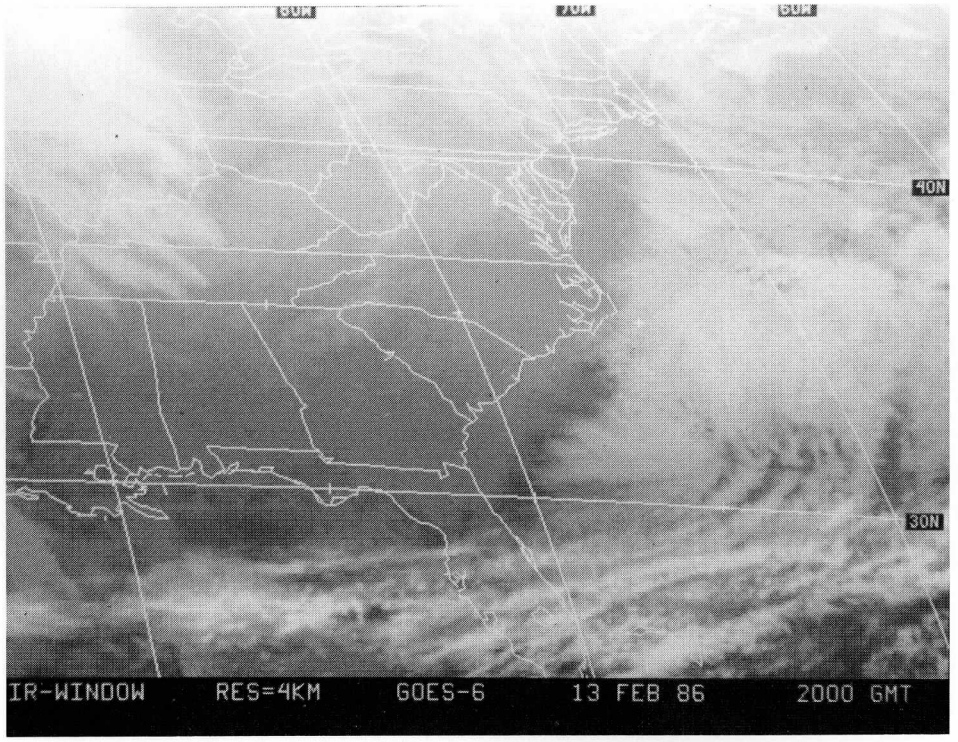
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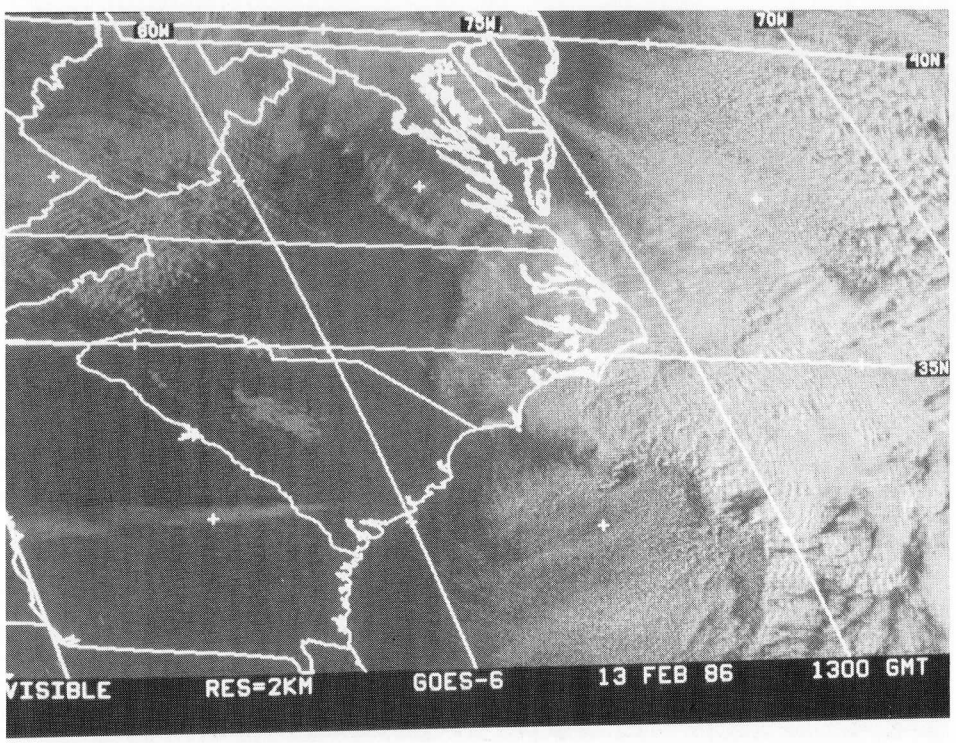
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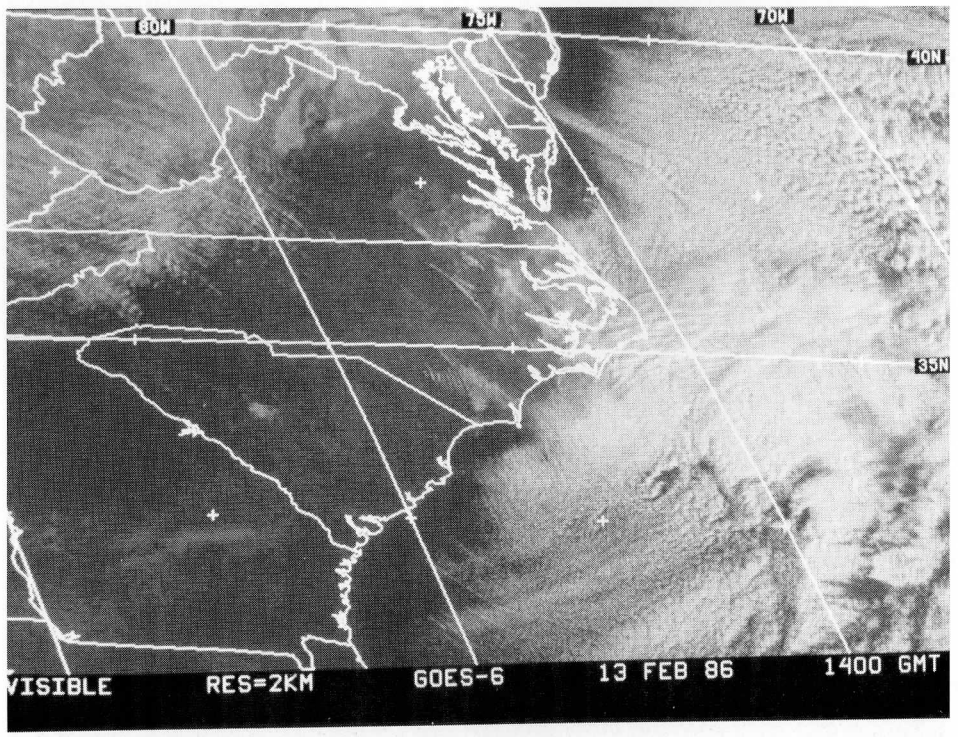
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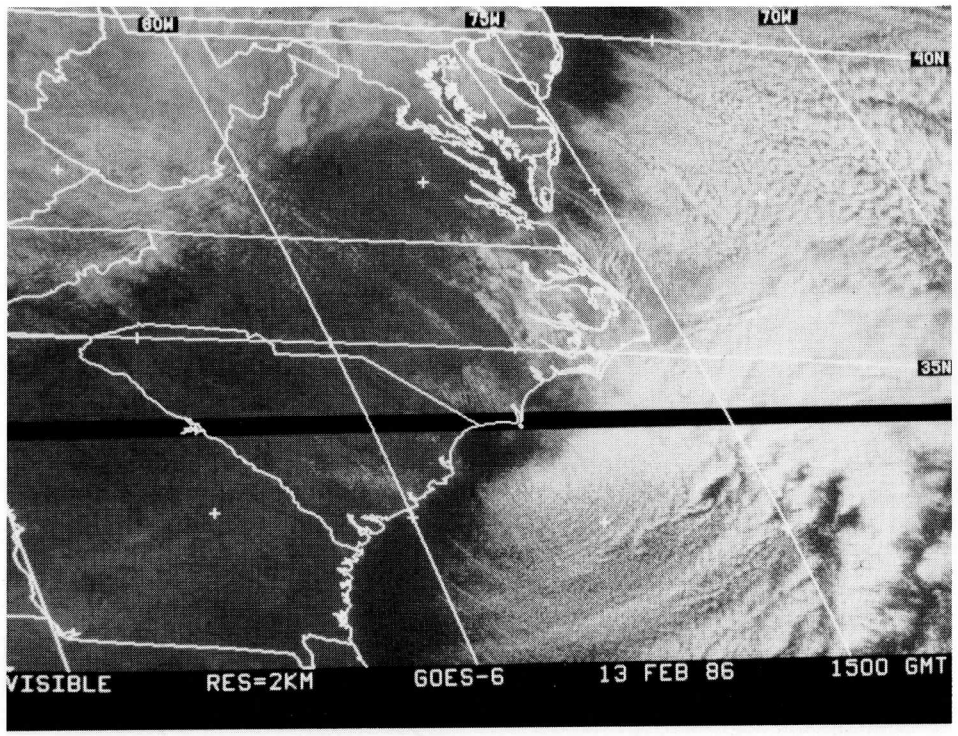
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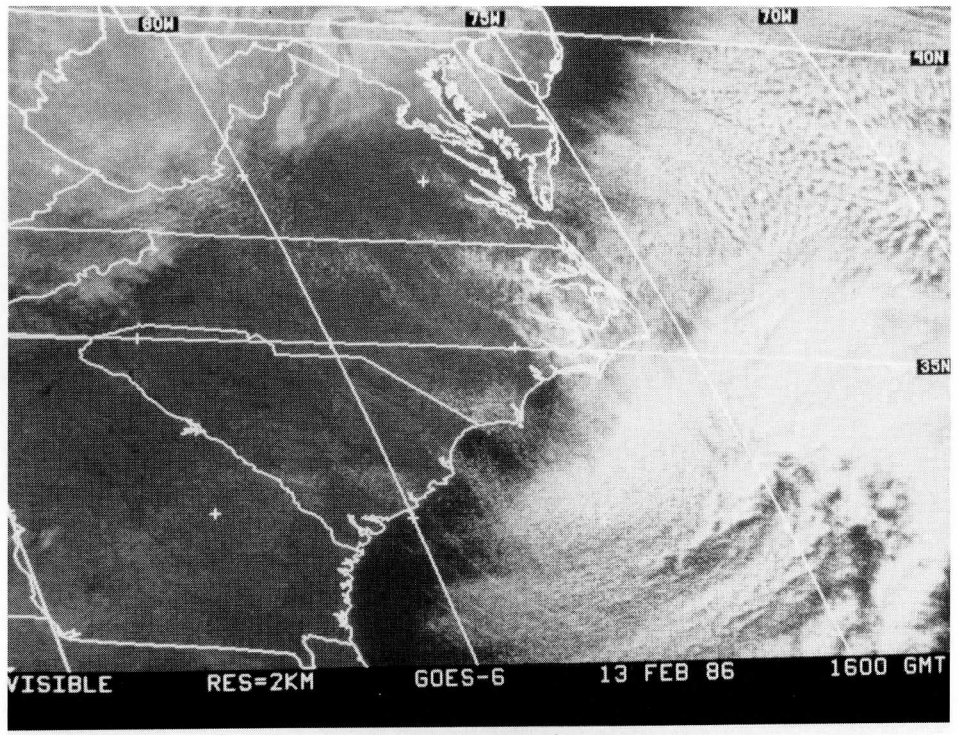
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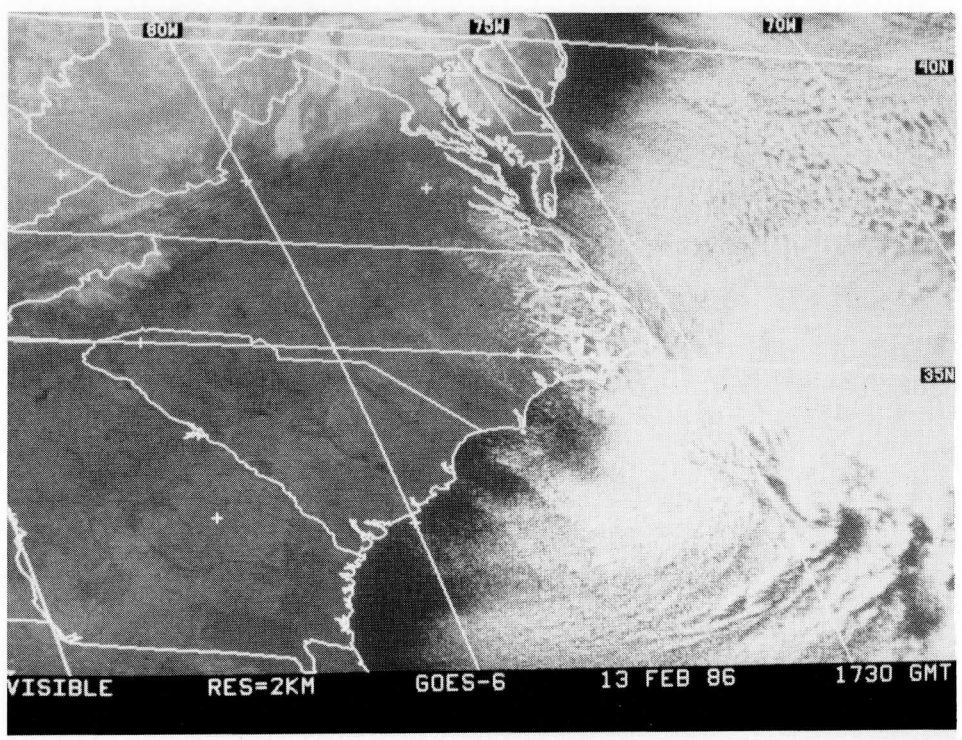
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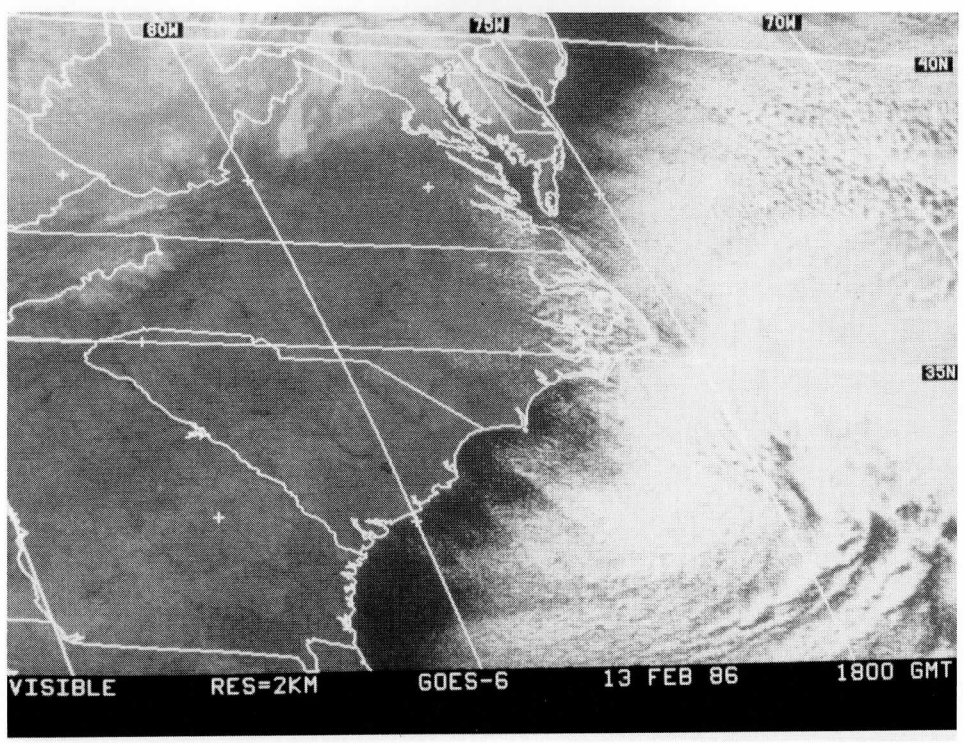
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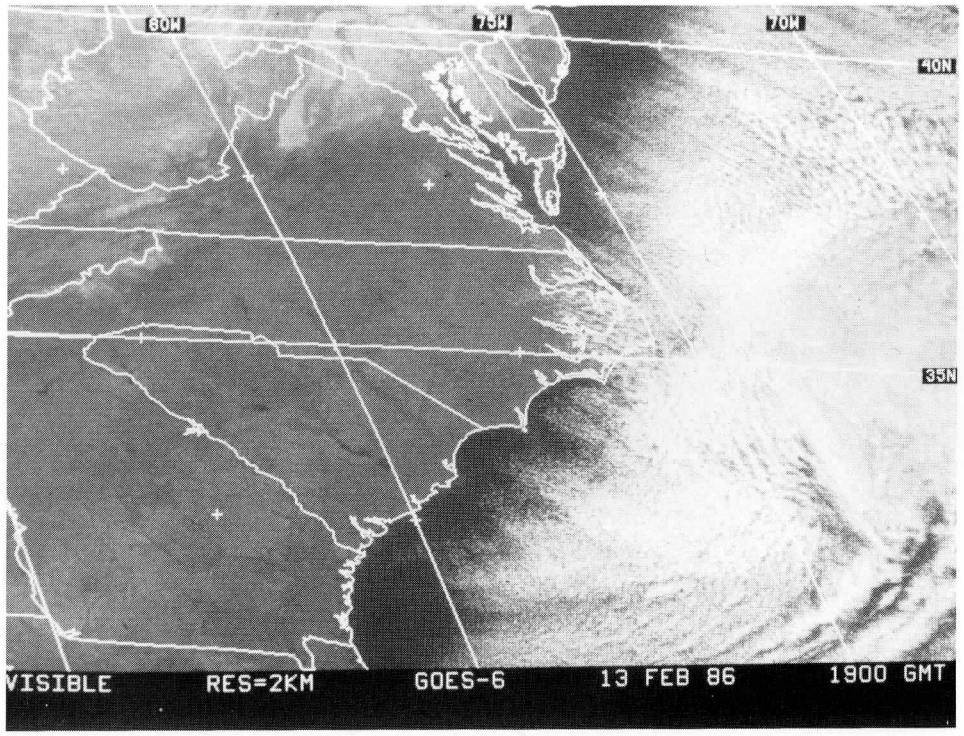
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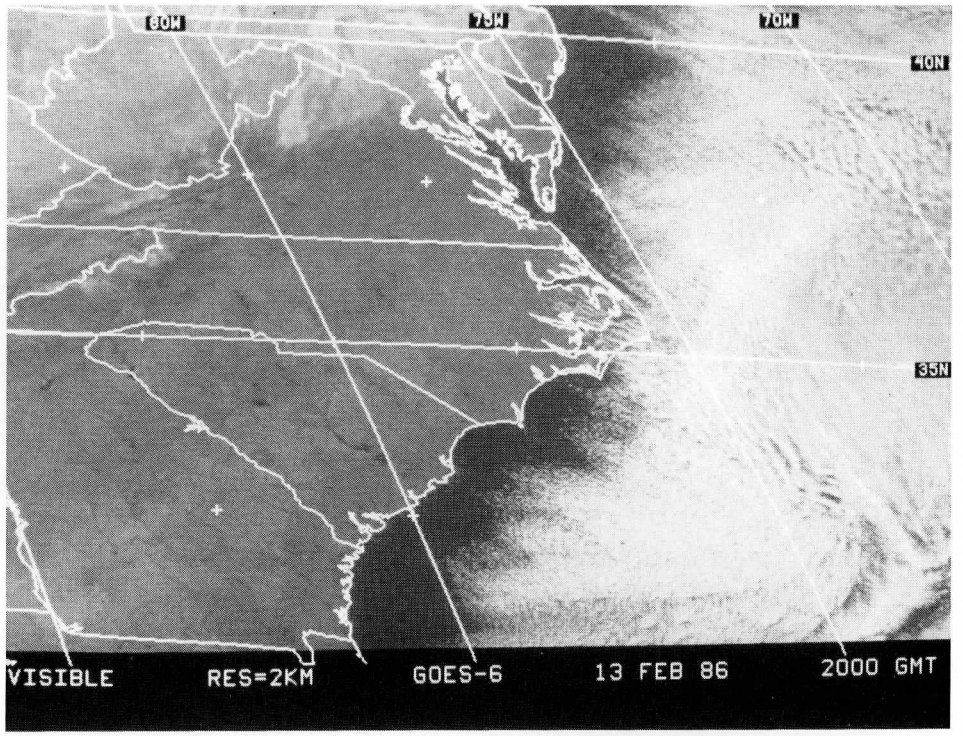
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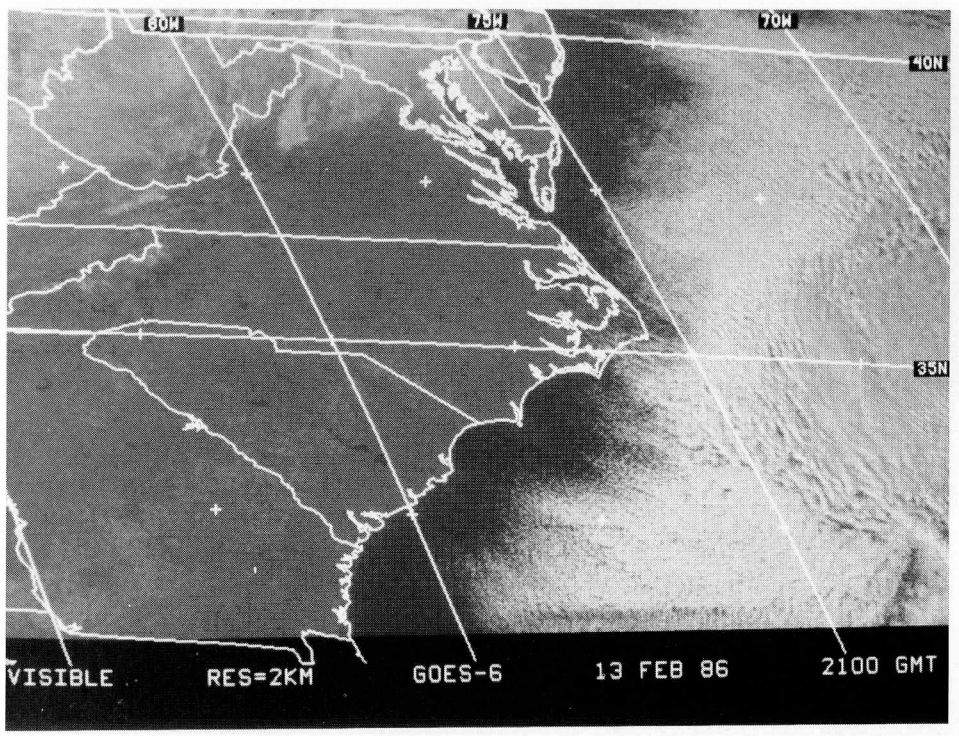
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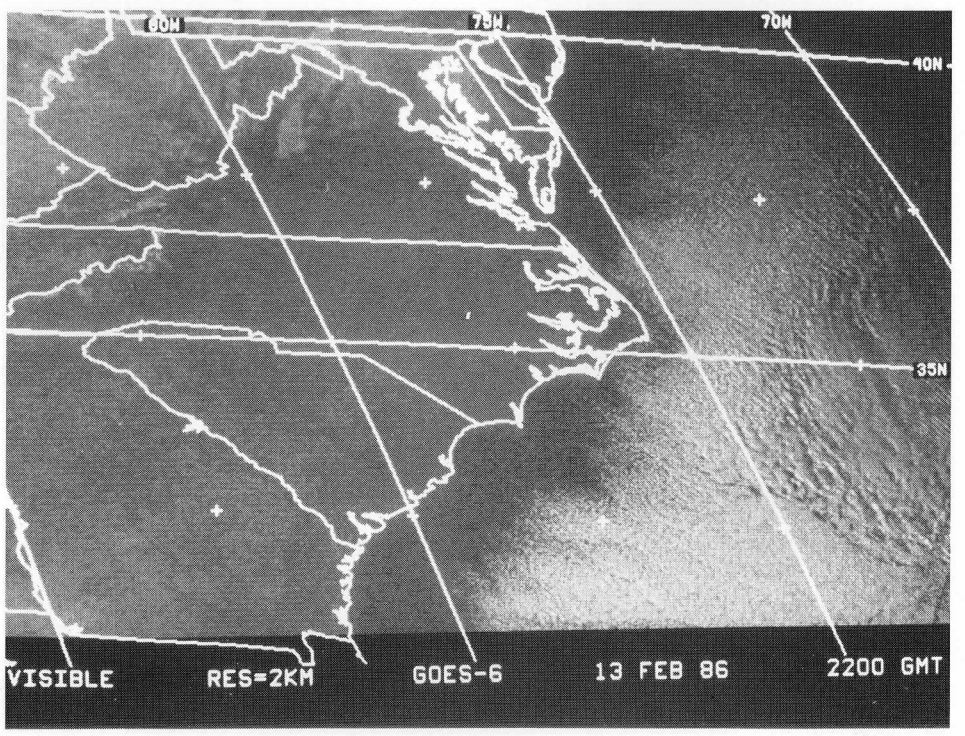
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END OF IOP

IOP #6 - Developing Wave / Offshore Cyclogenesis
February 14 - February 15

Satellite Synopsis

Water Vapor

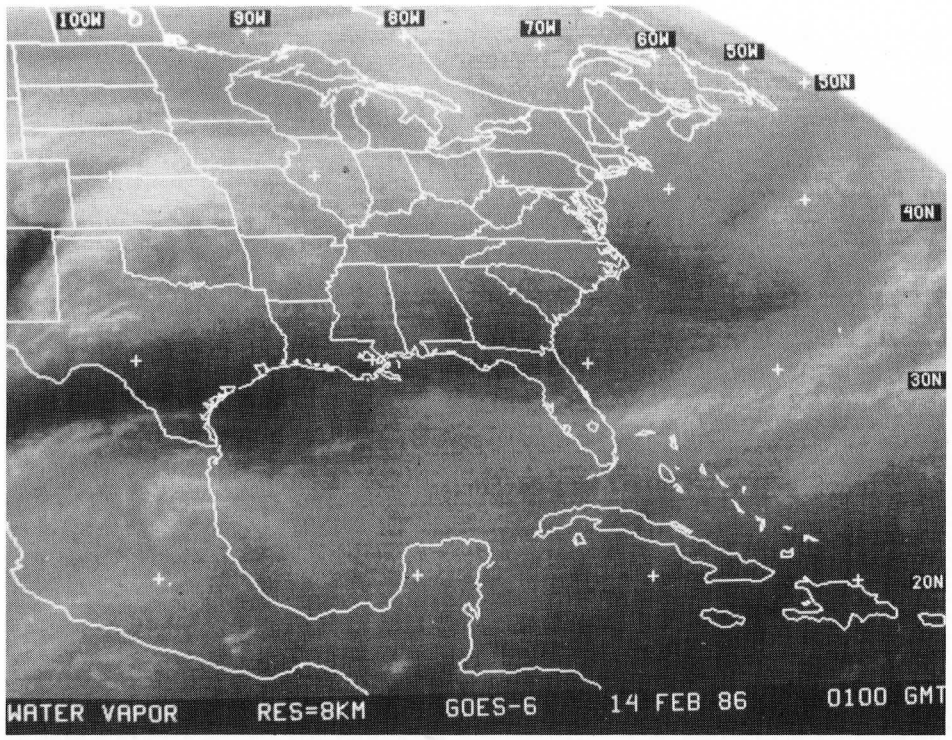
- 14th, circulation in northwest Missouri around 09 GMT moves through Kentucky into West Virginia, then northeast into New England. Circulation looks pretty strong mid-day on the 14th.
- 14th, weak wave passes over Florida.
- 15th, strong subsidence region develops over North Carolina, moves offshore with the digging trough.

IR

- Solid stratus deck offshore.
- Closed-cell cumulus offshore.
- Circulation evident in Kentucky late on the 14th.

Visible

- 14th, patchy, structured cloud patterns offshore.
- 15th, striking wave clouds in Virginias and North Carolina.
- 15th, cloud streets and convergence lines offshore.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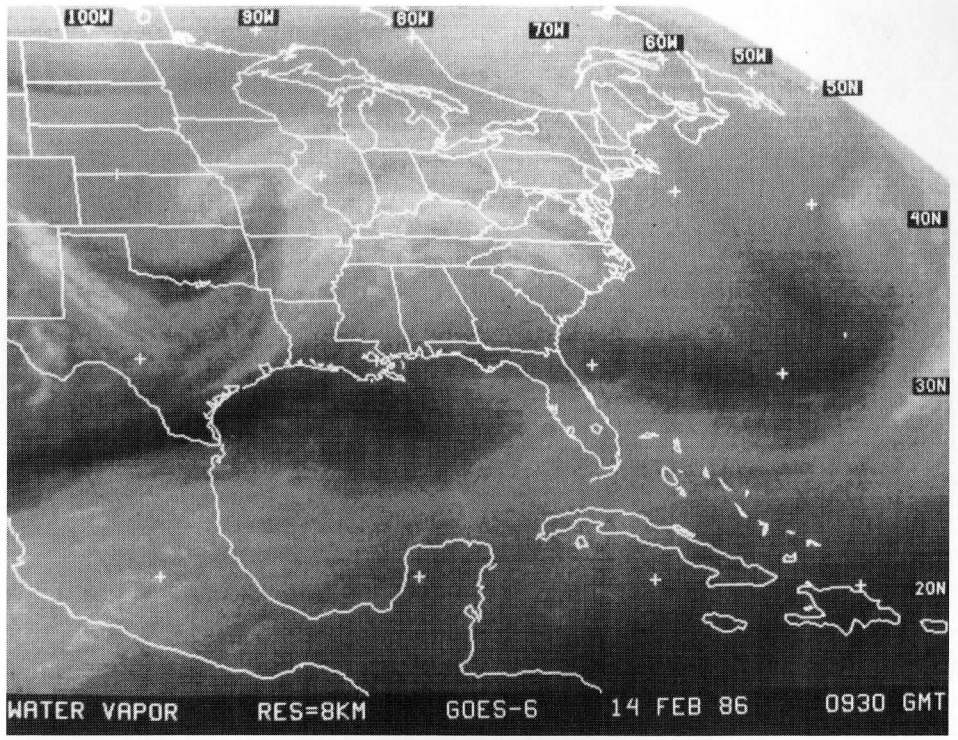
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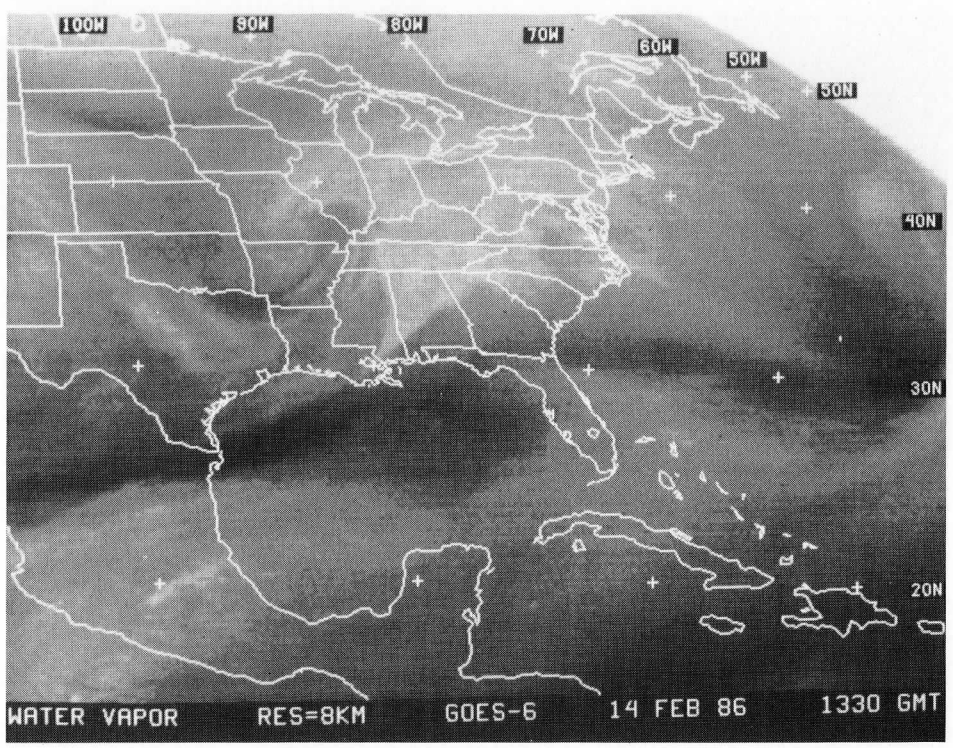
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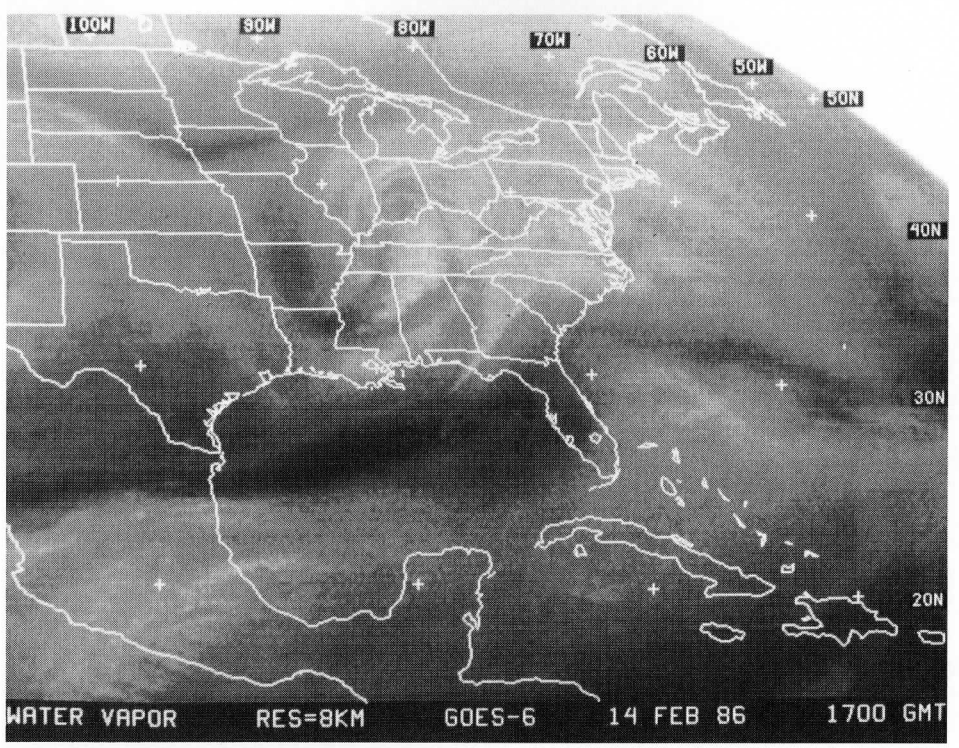
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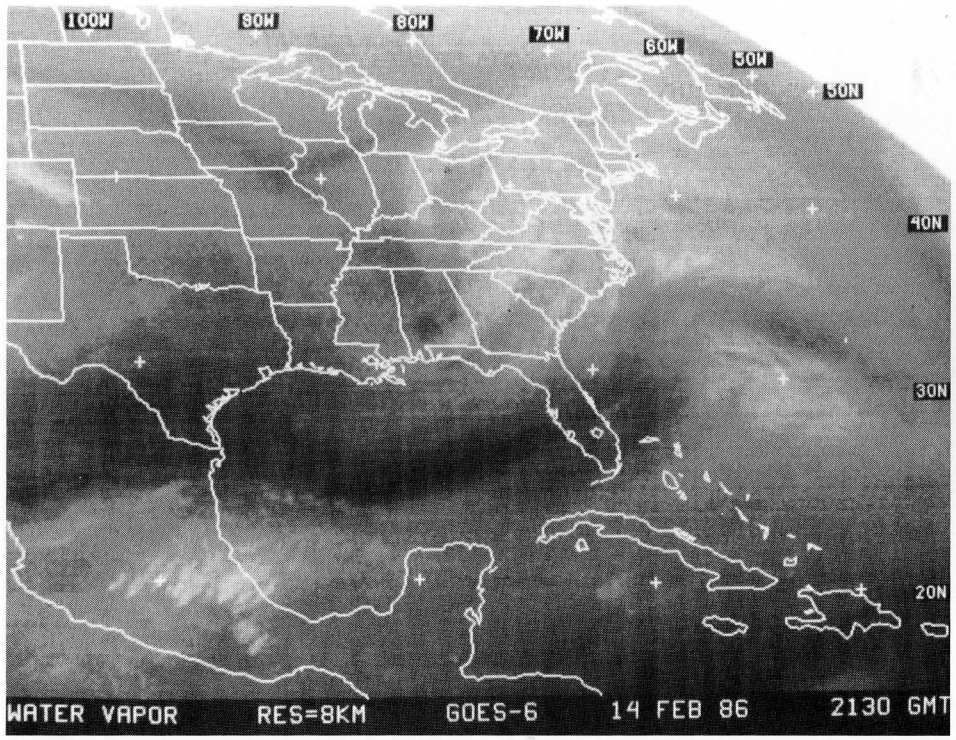
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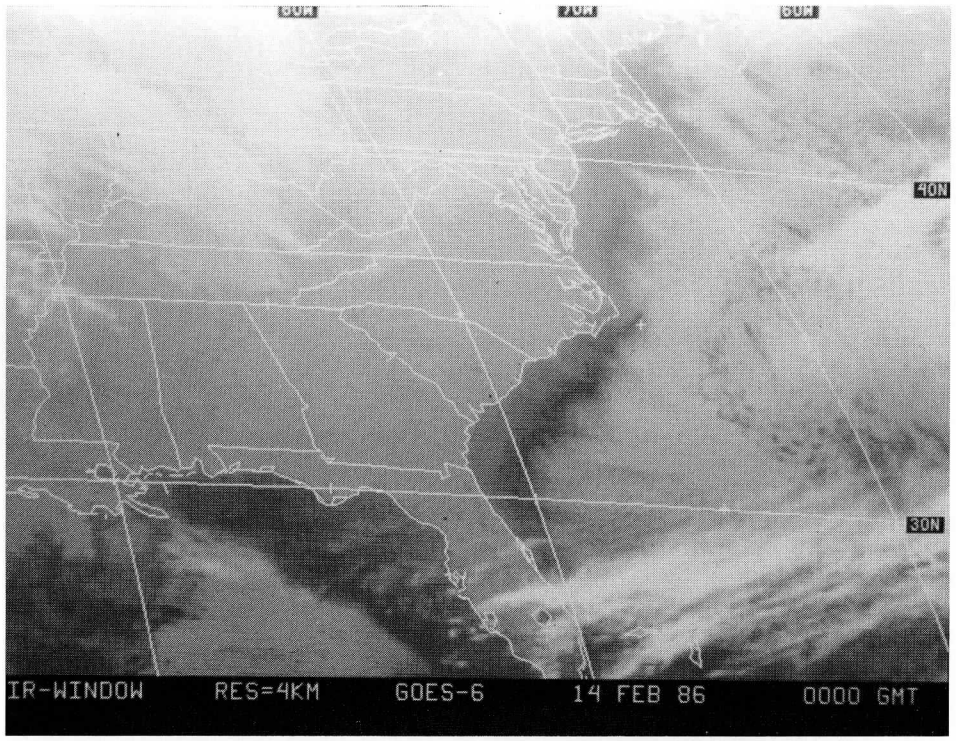
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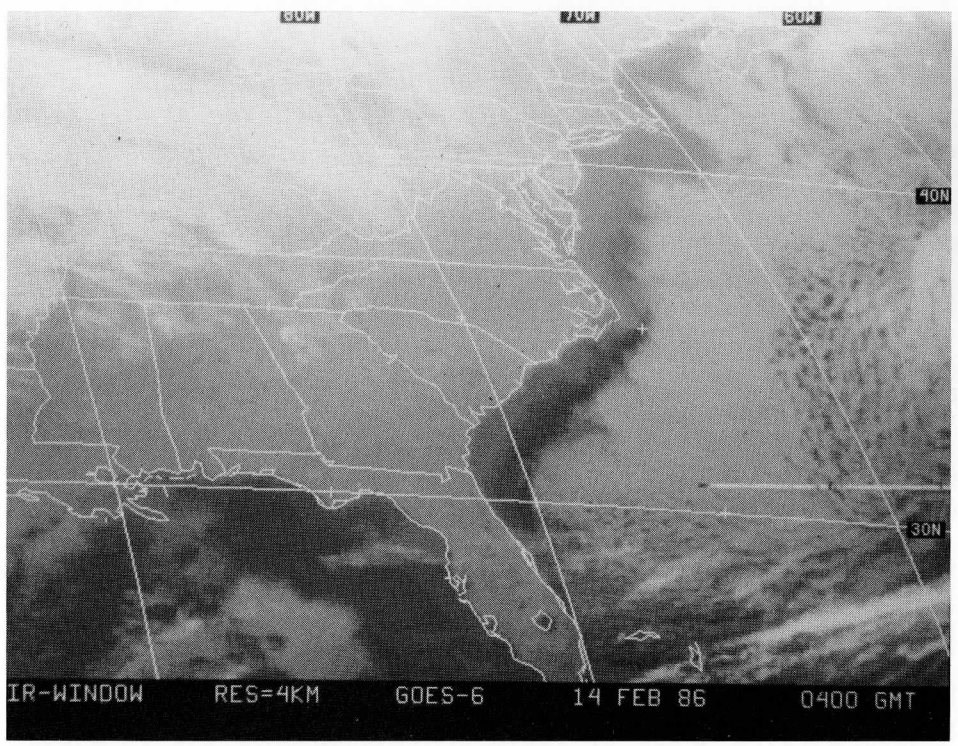
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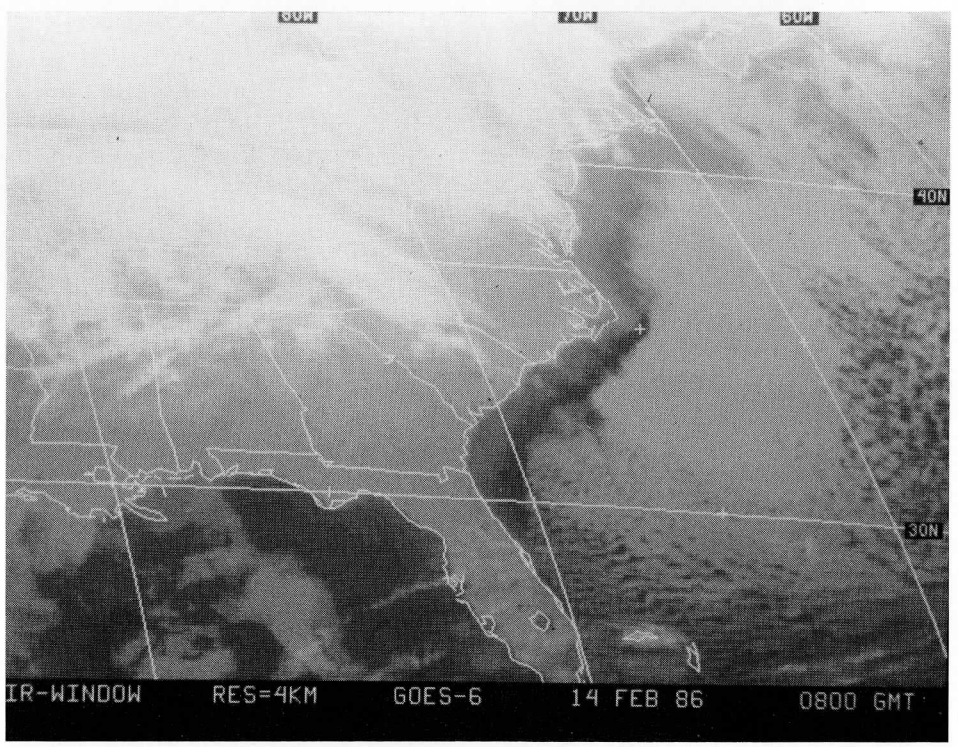
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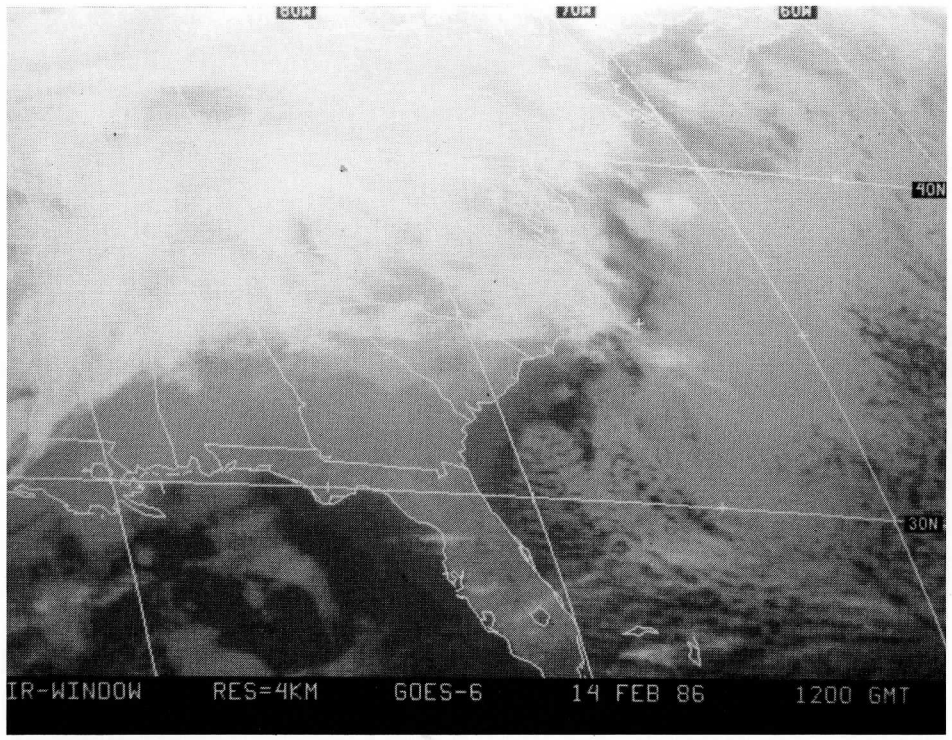
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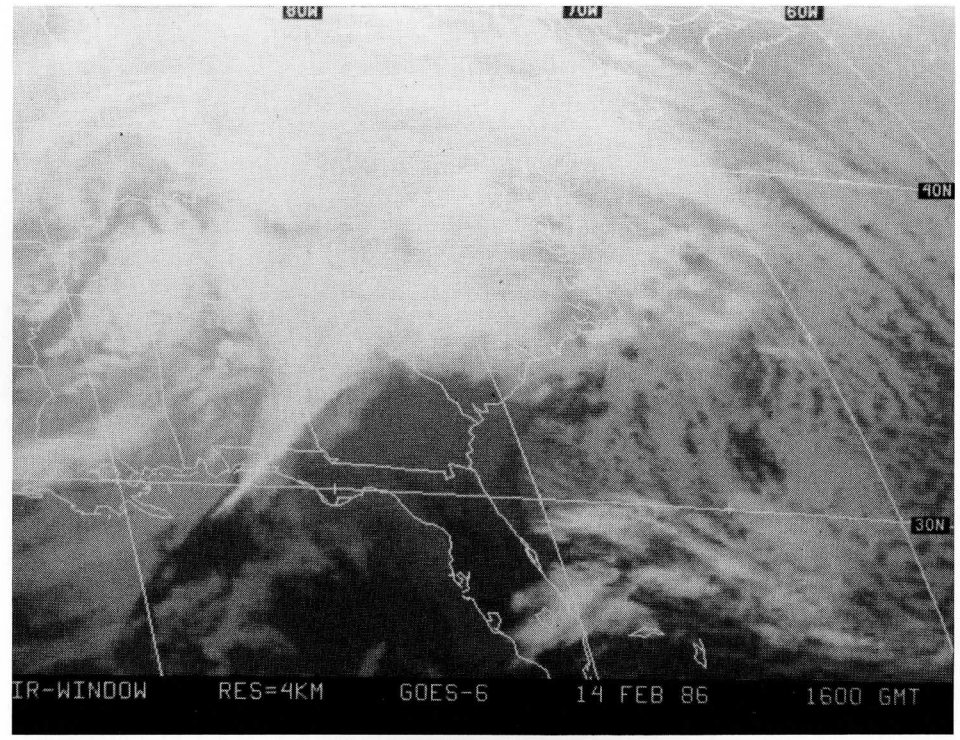
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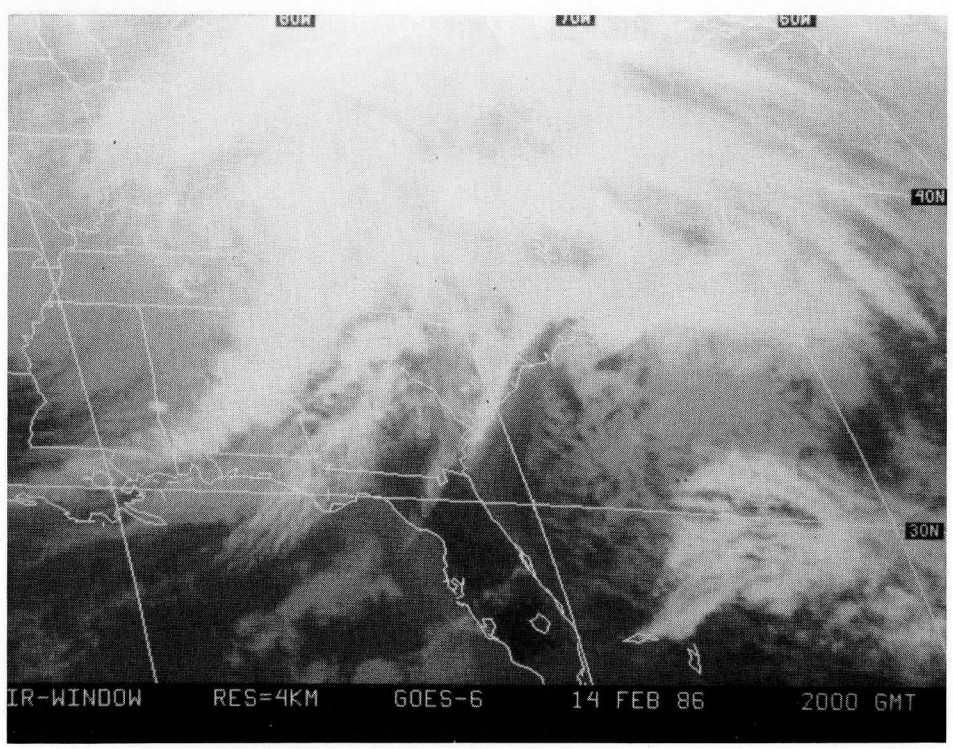
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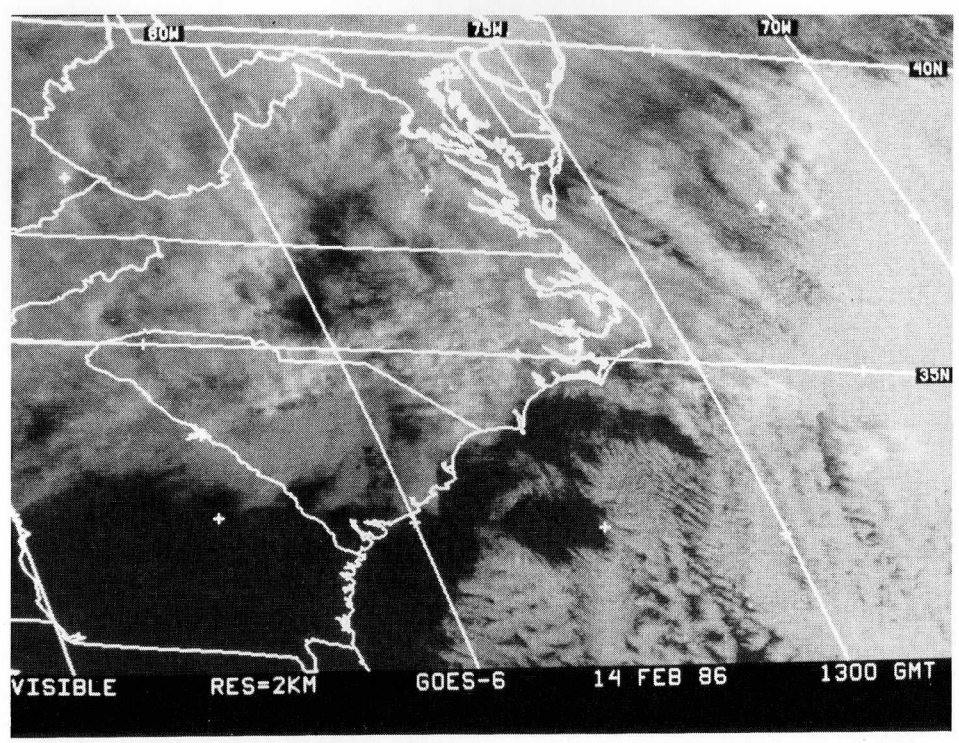
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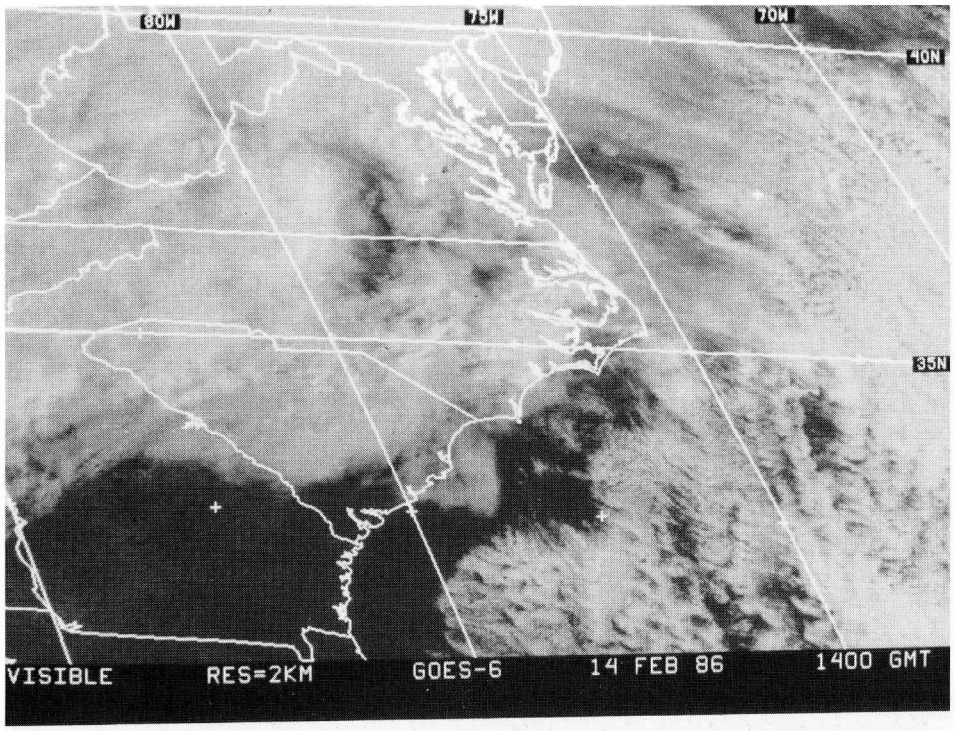
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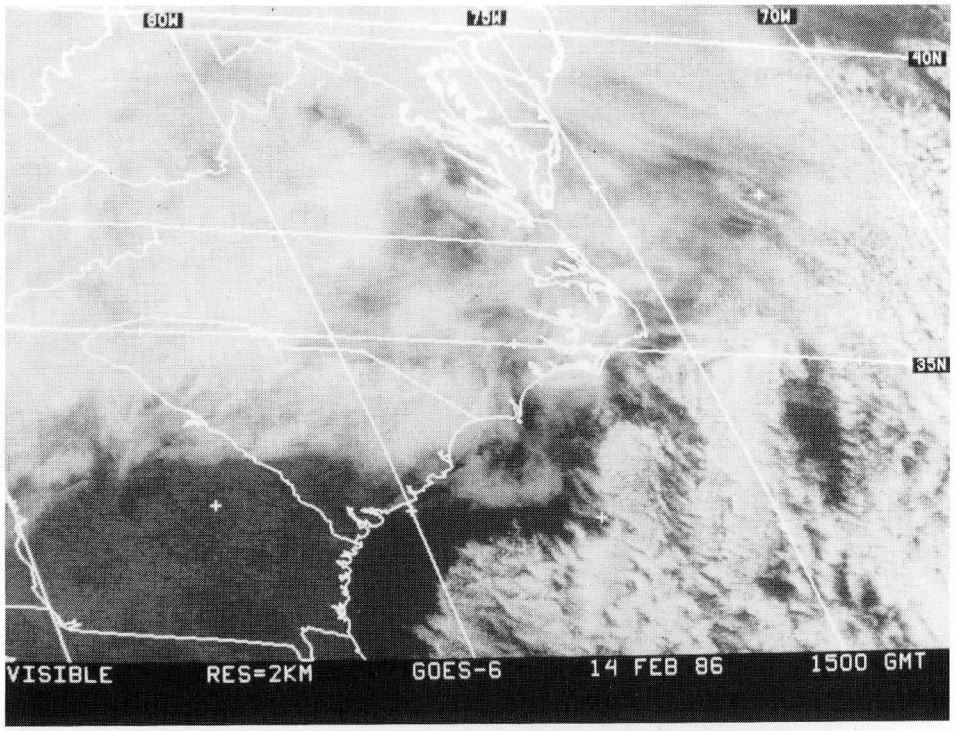
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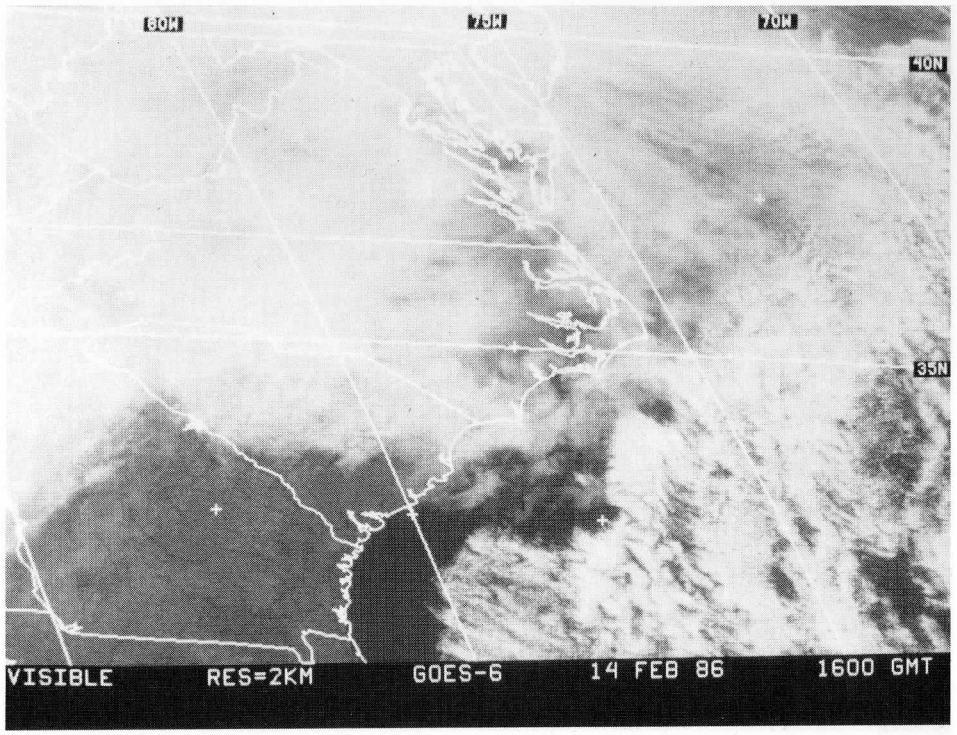
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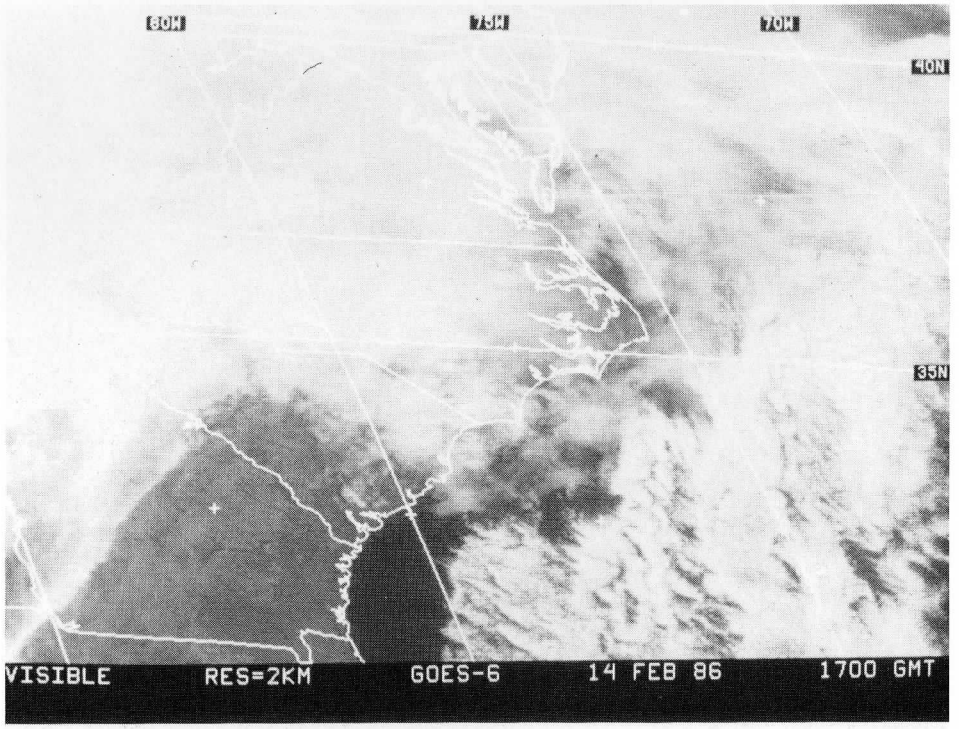
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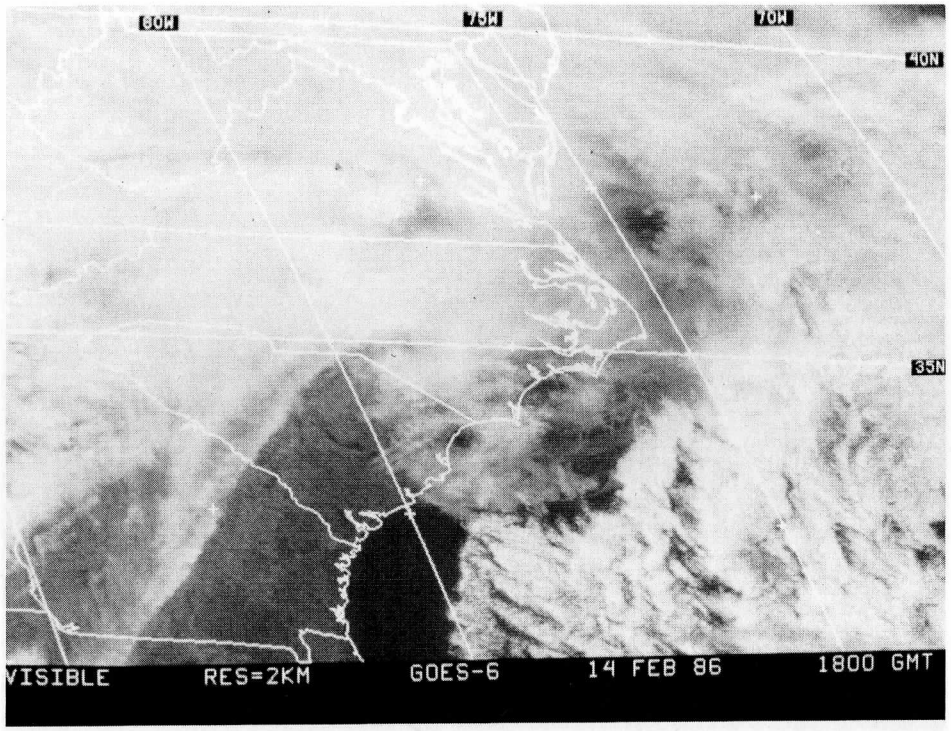
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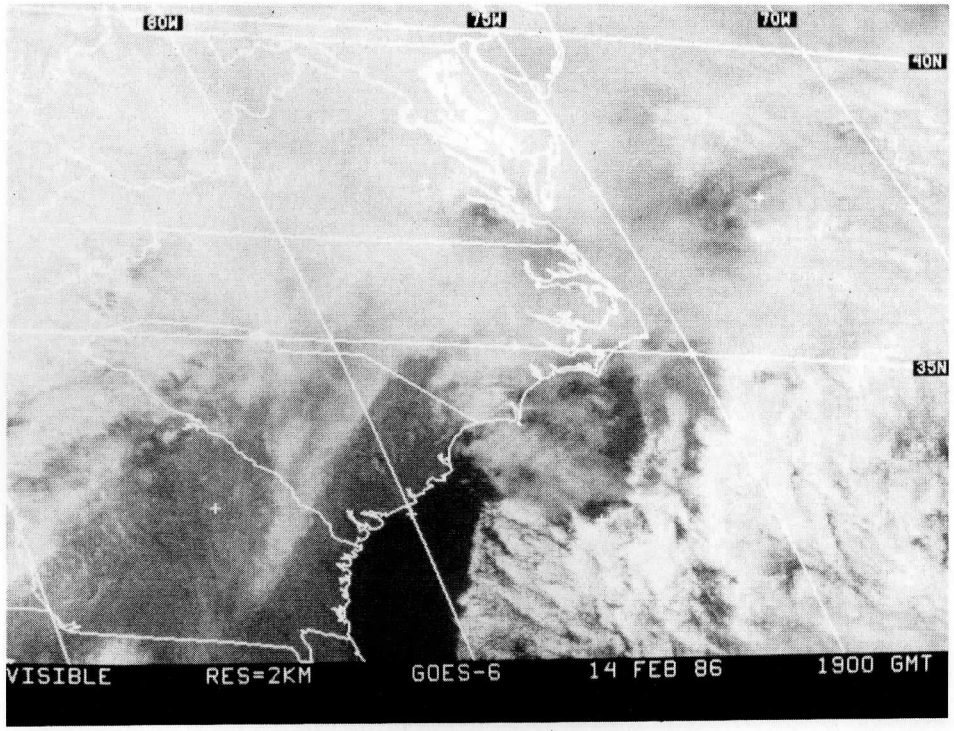
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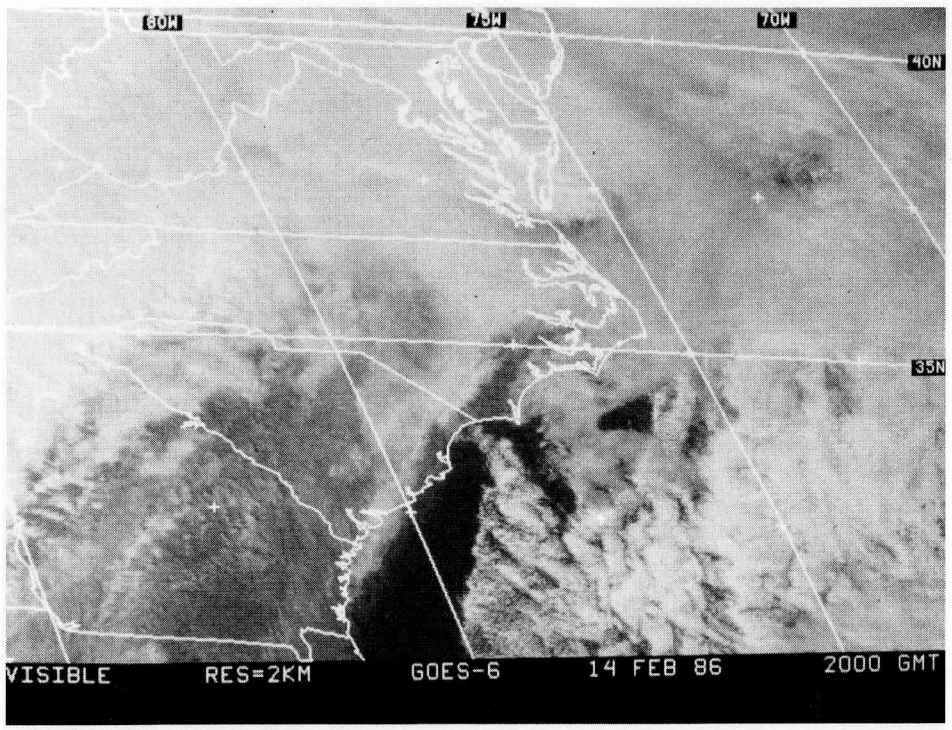
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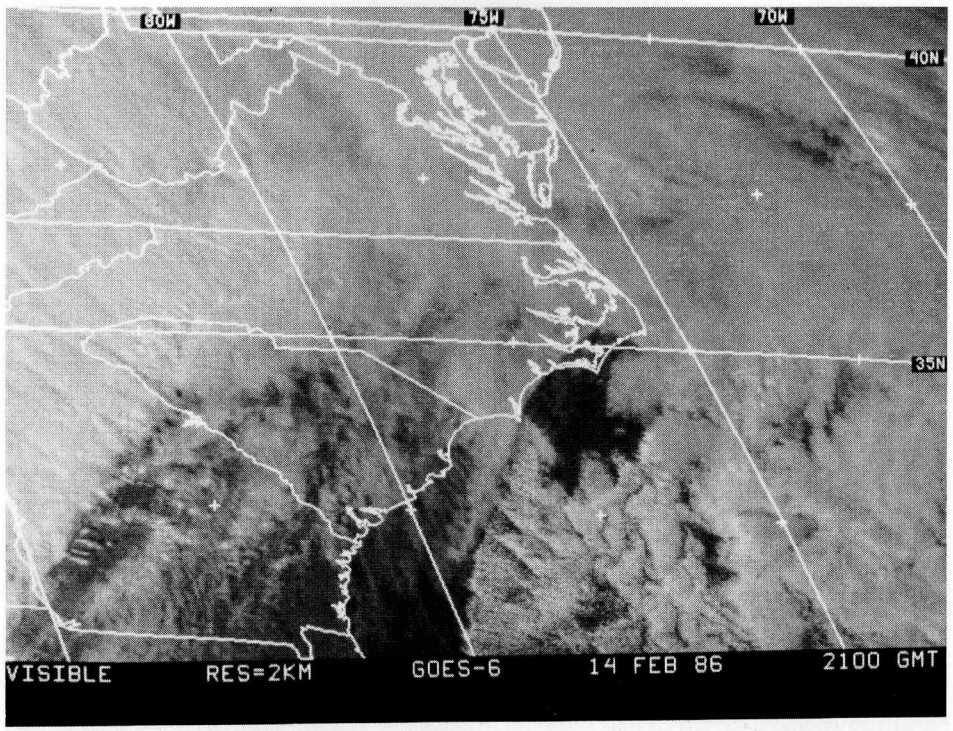
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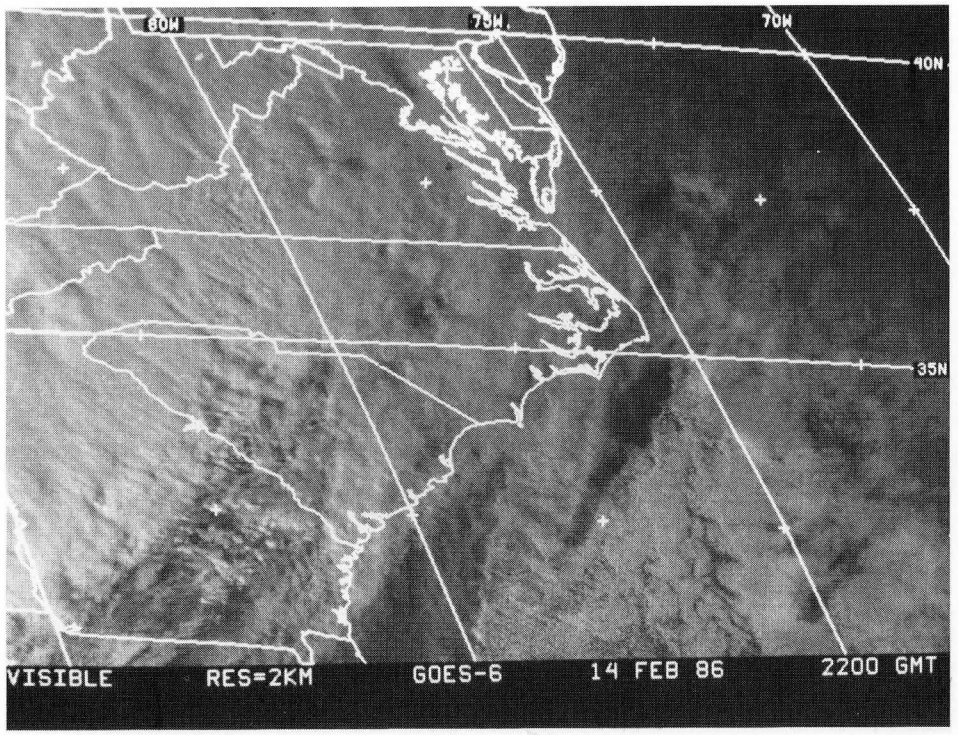
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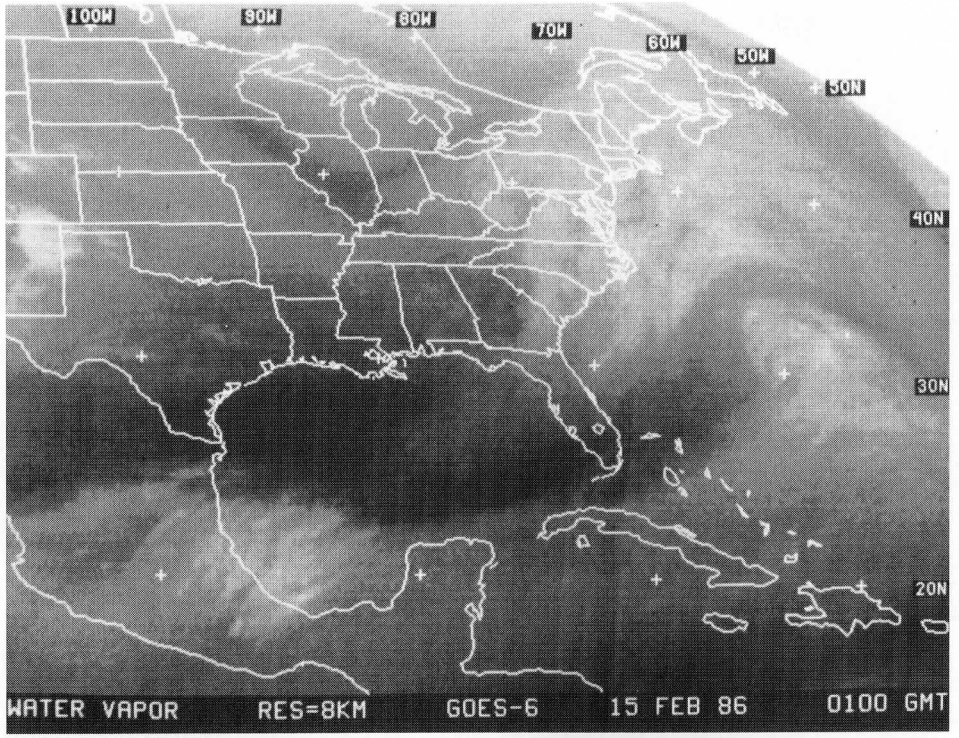
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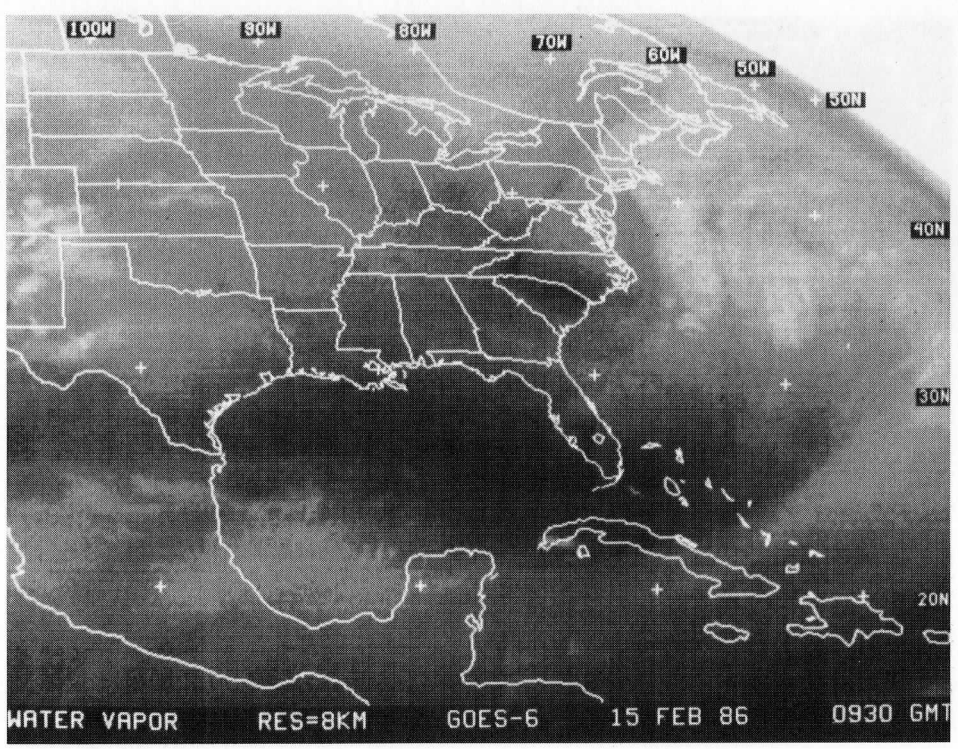
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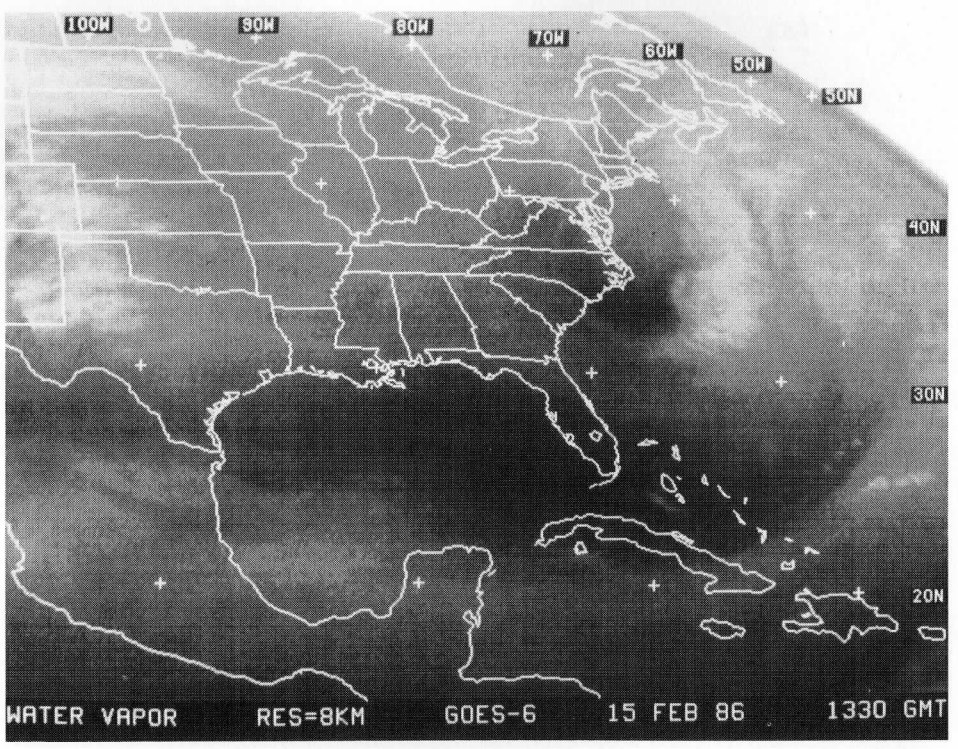
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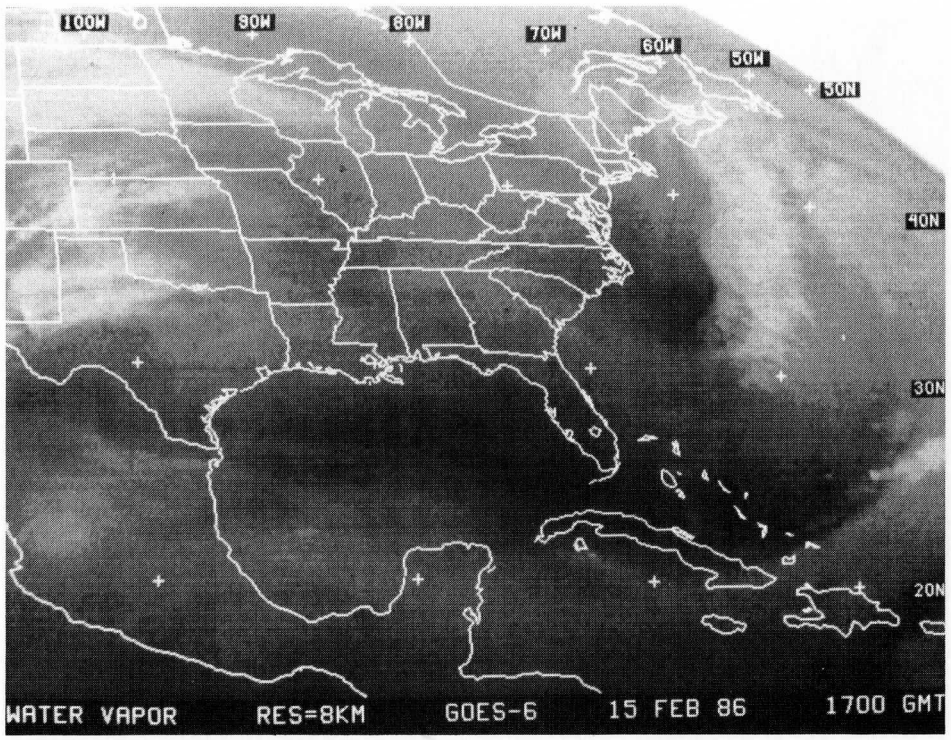
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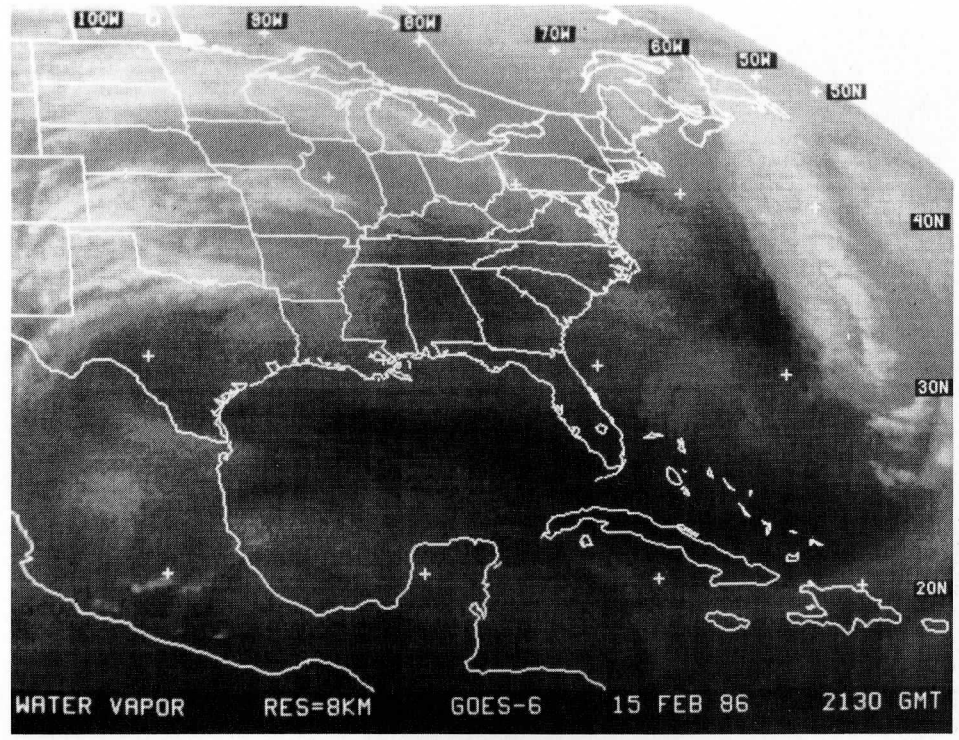
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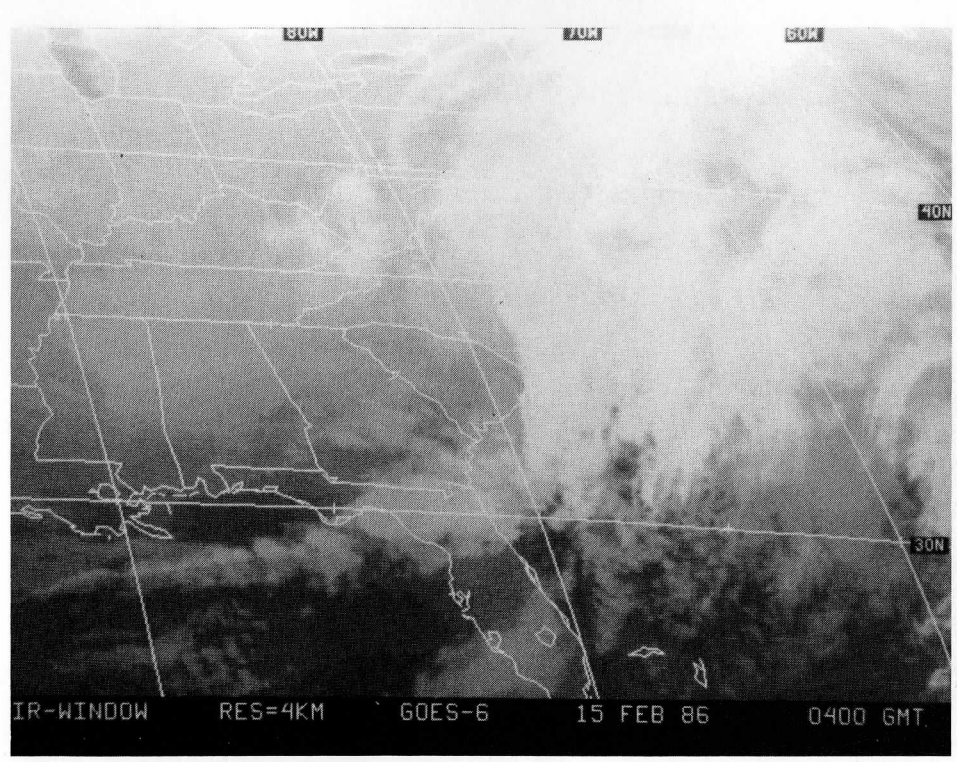
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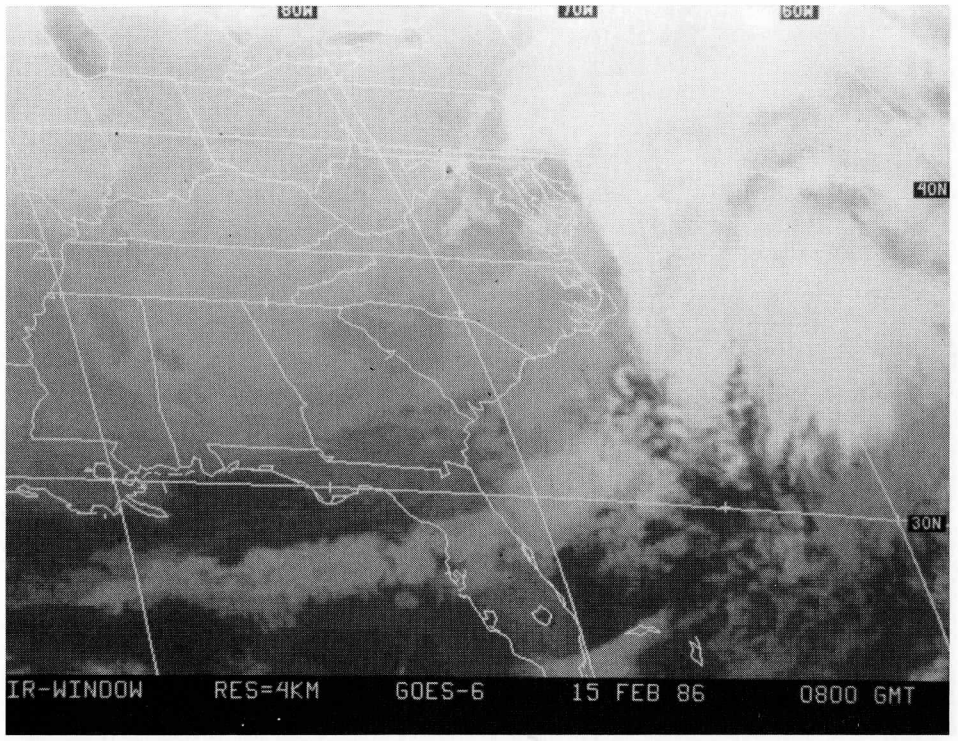
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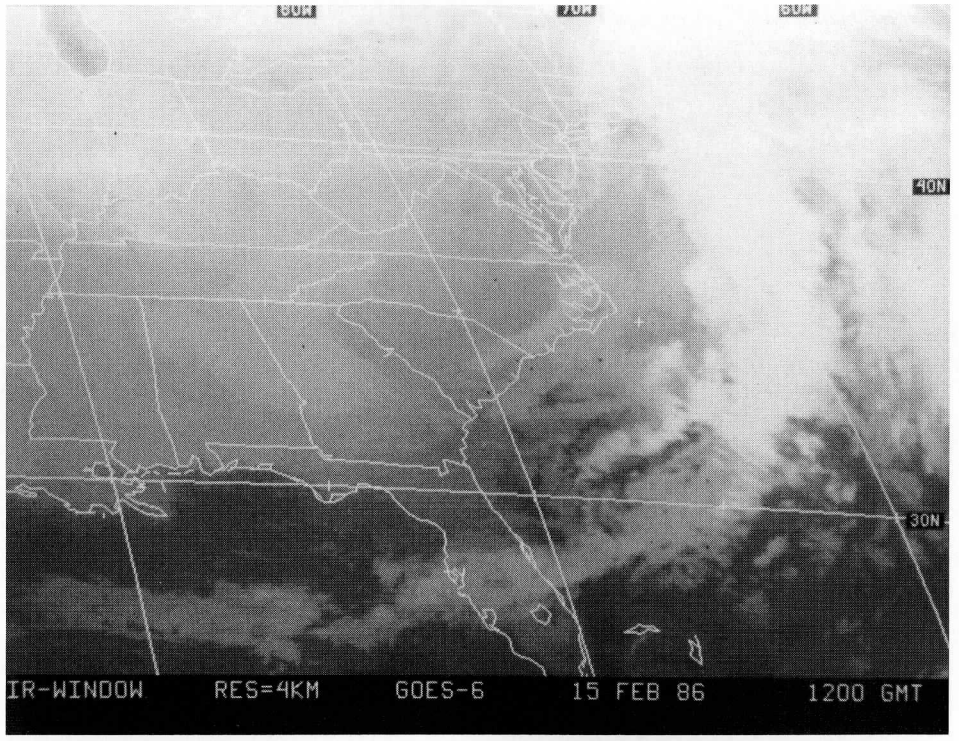
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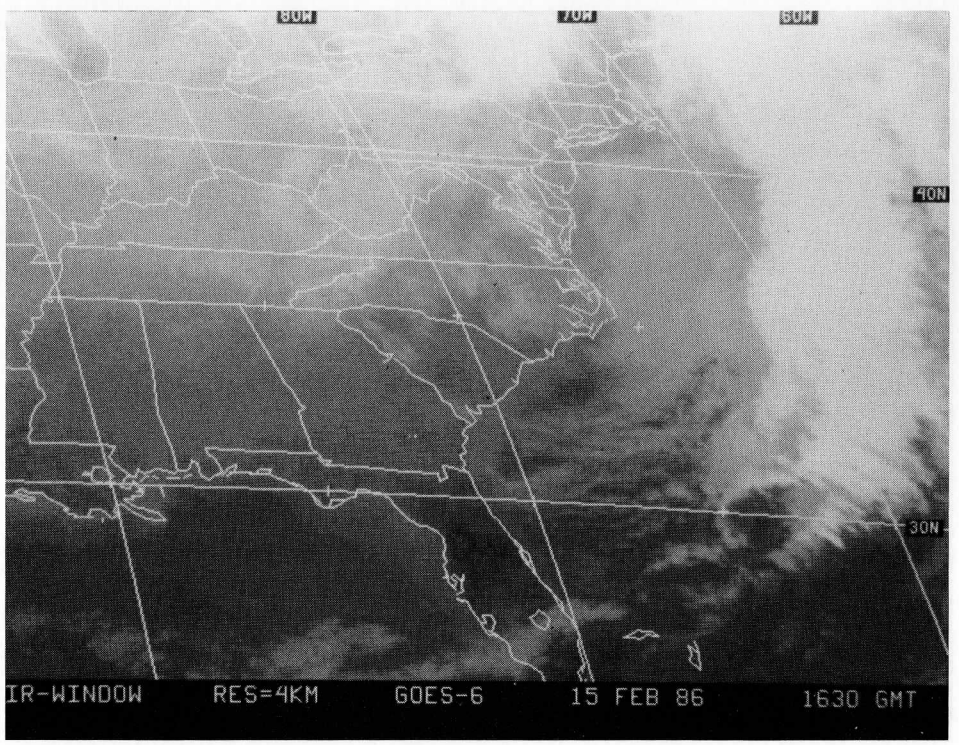
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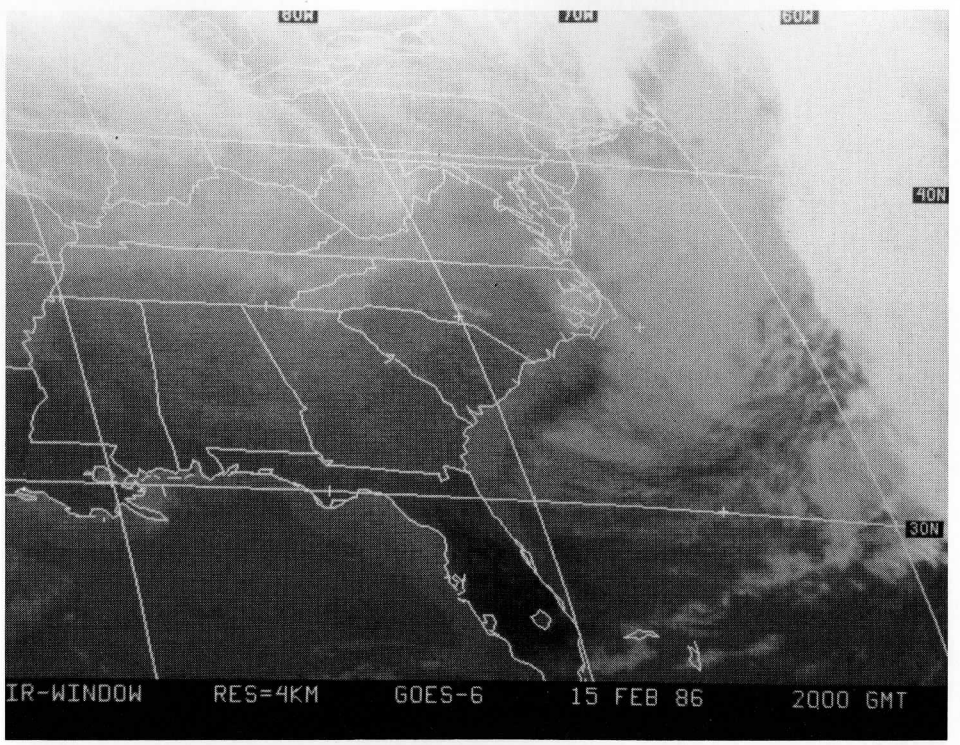
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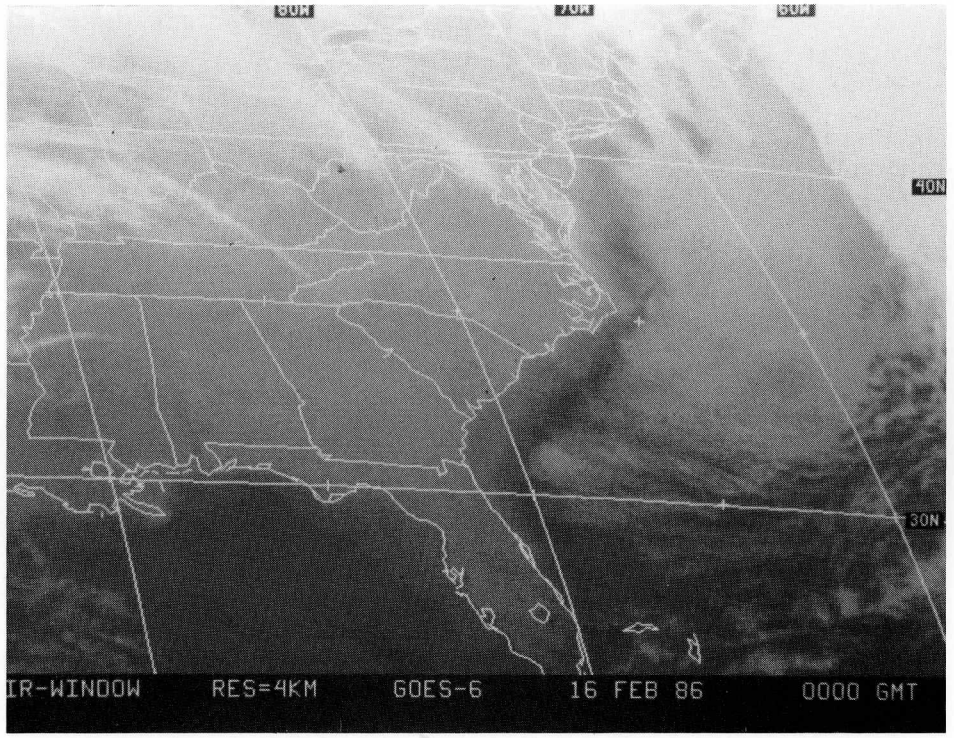
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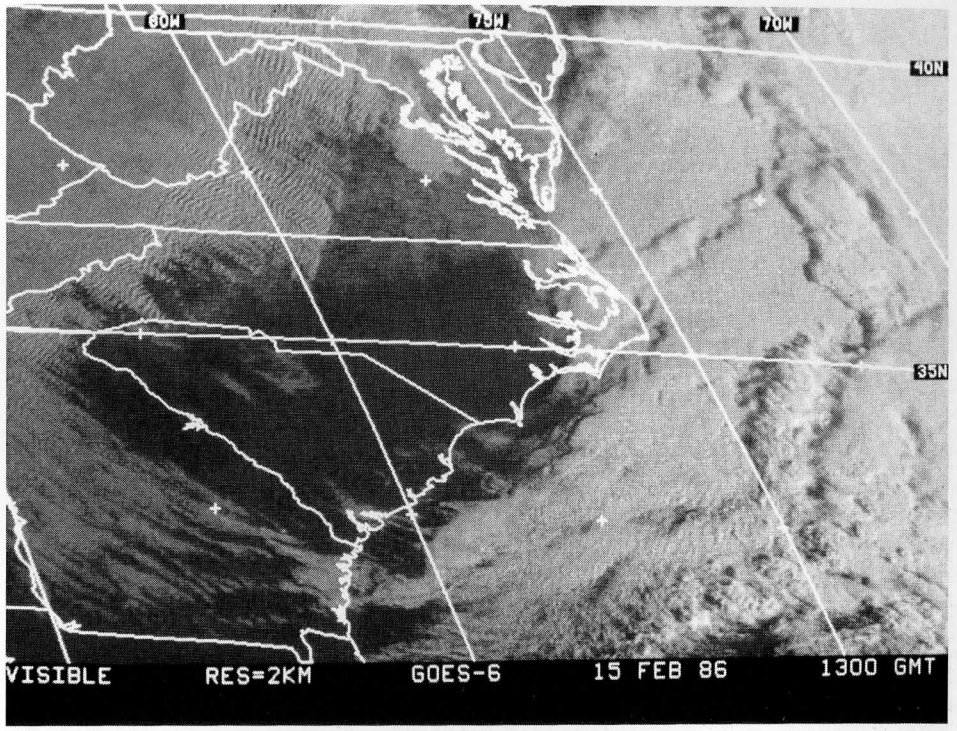
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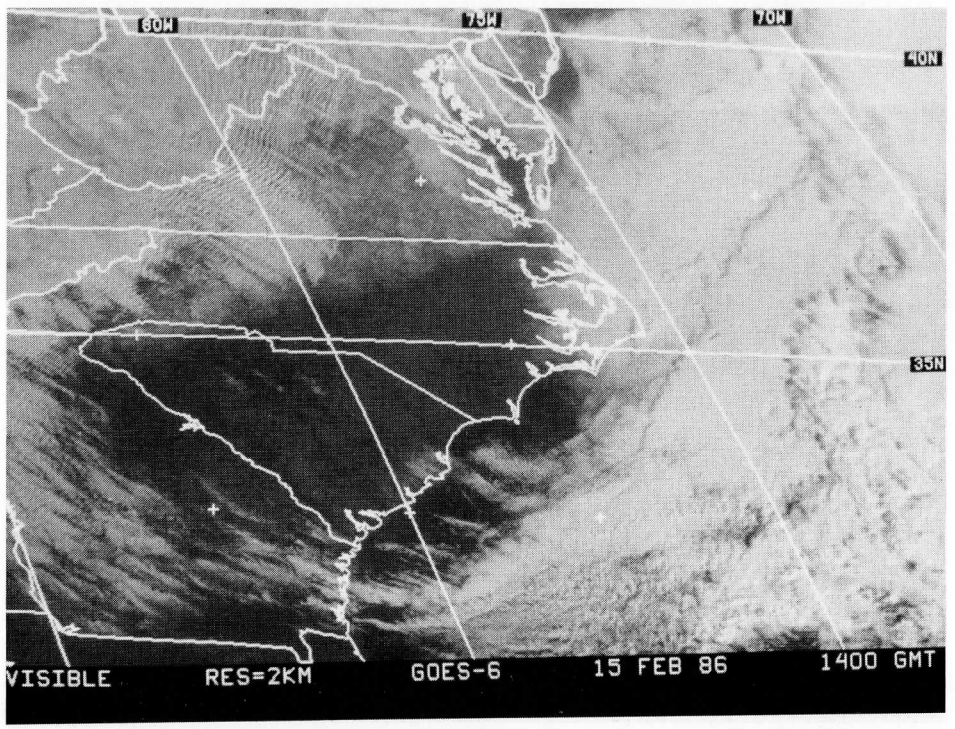
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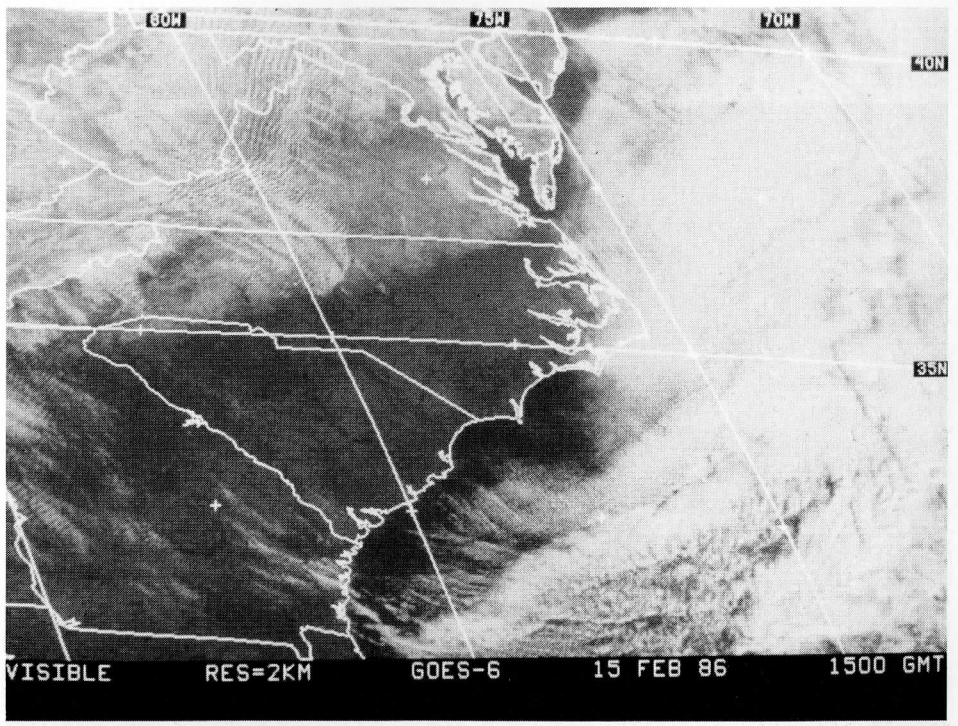
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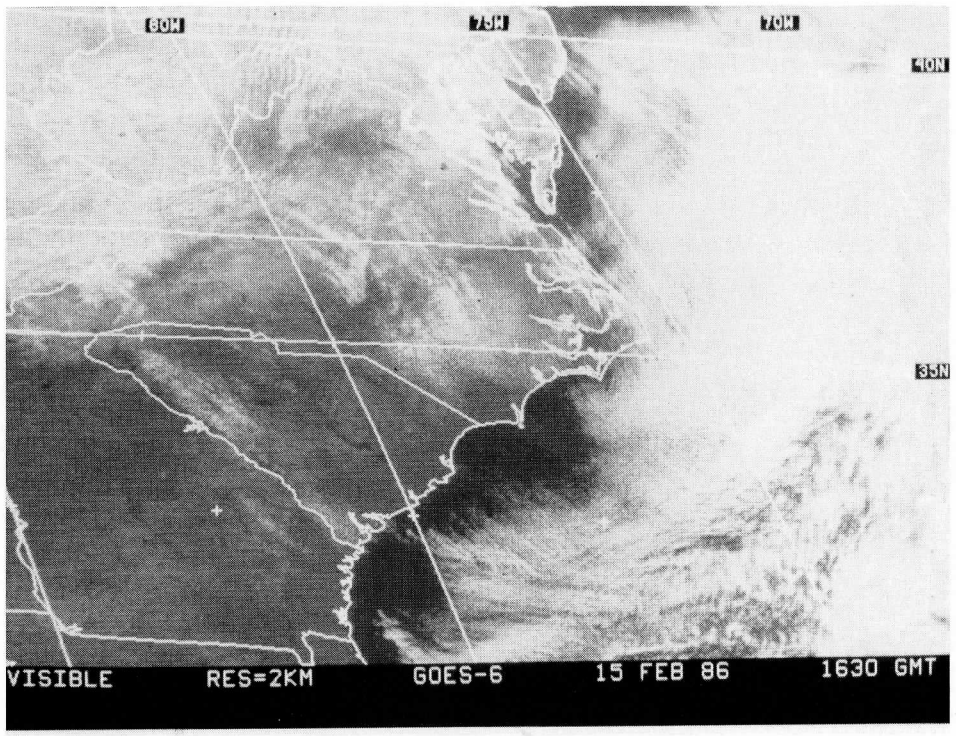
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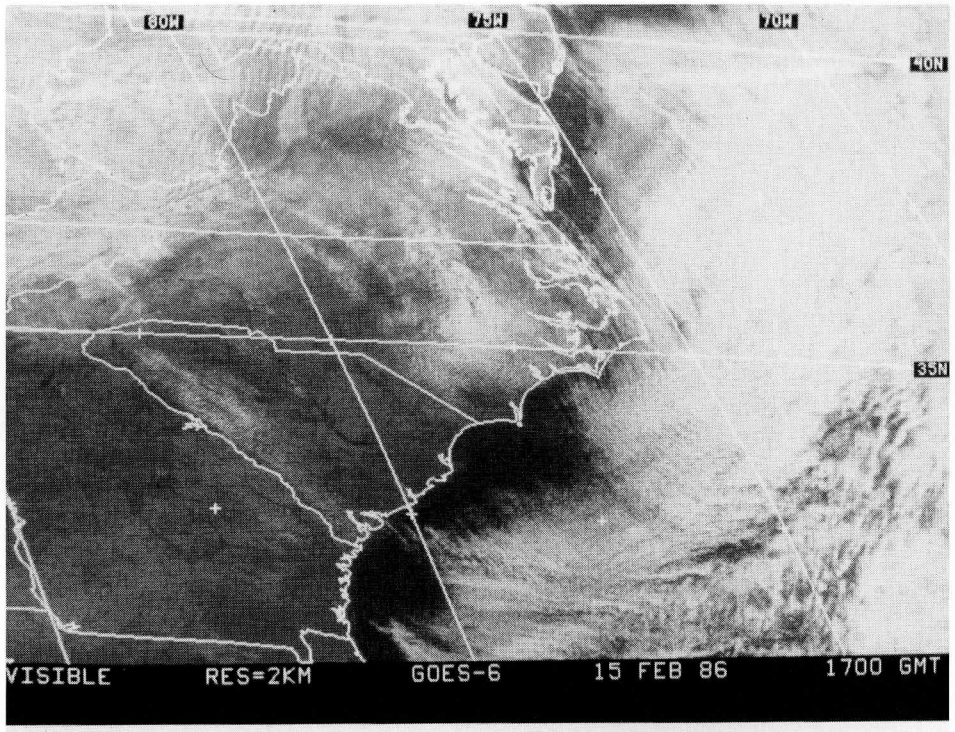
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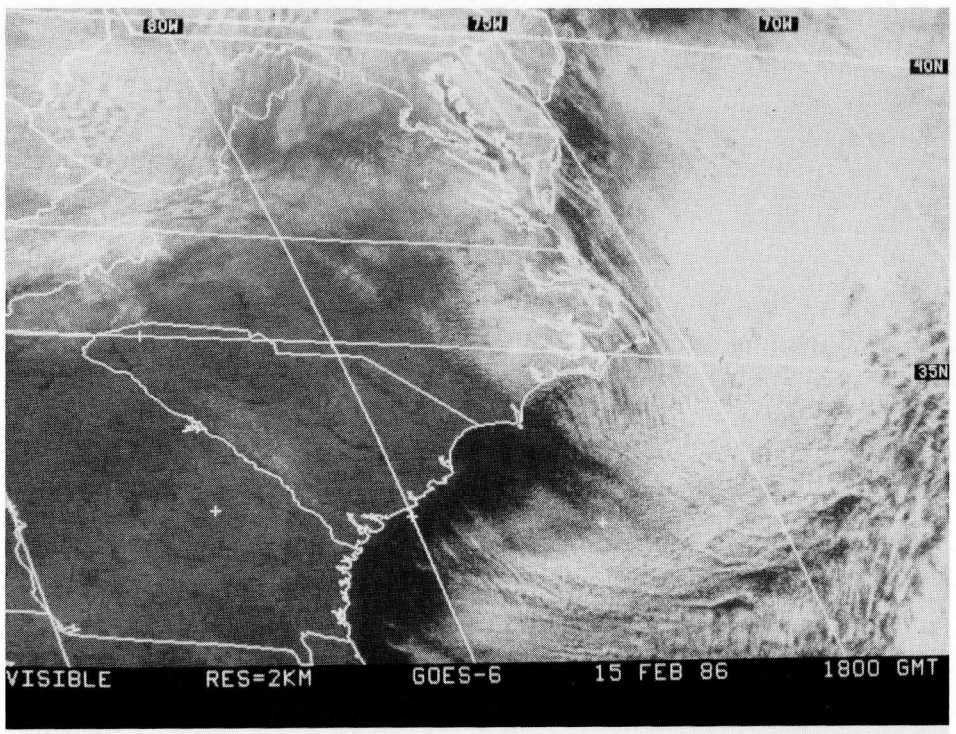
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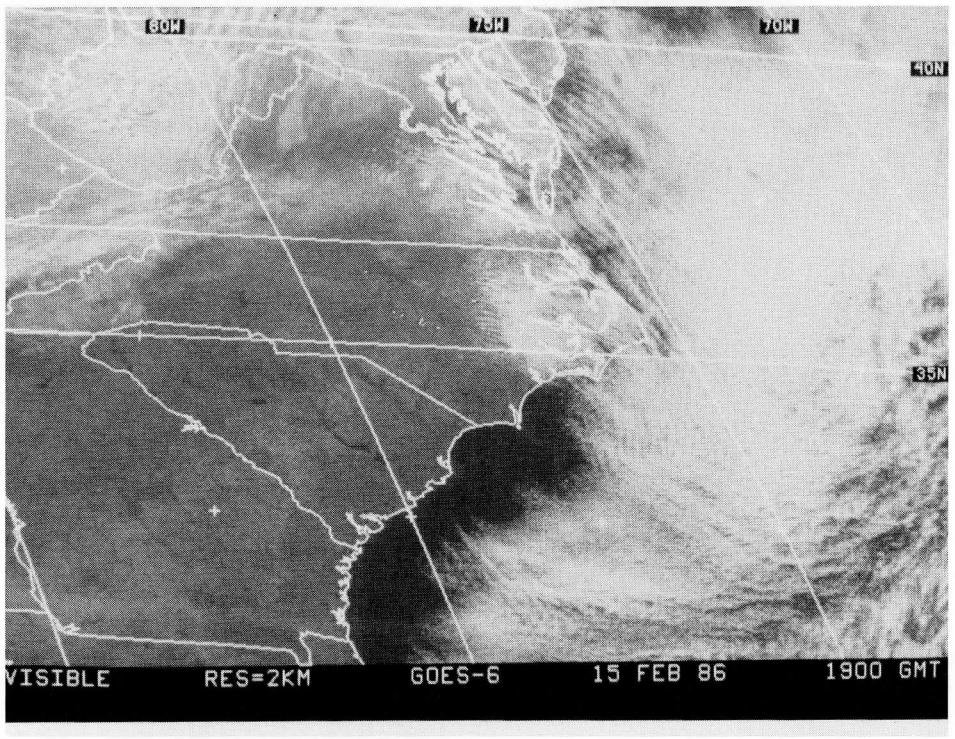
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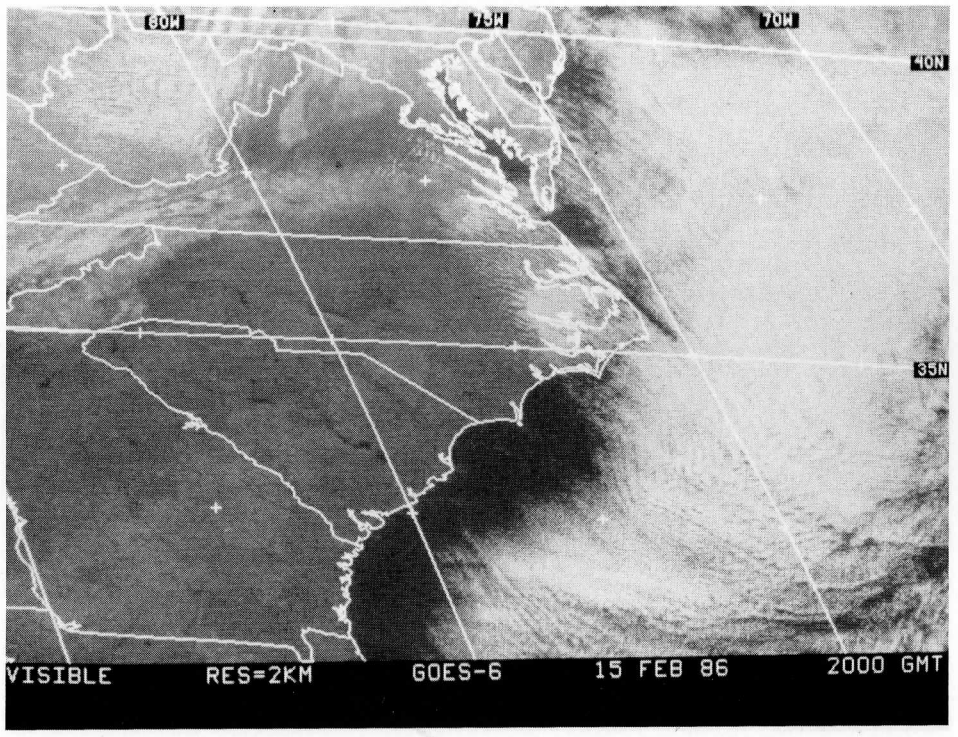
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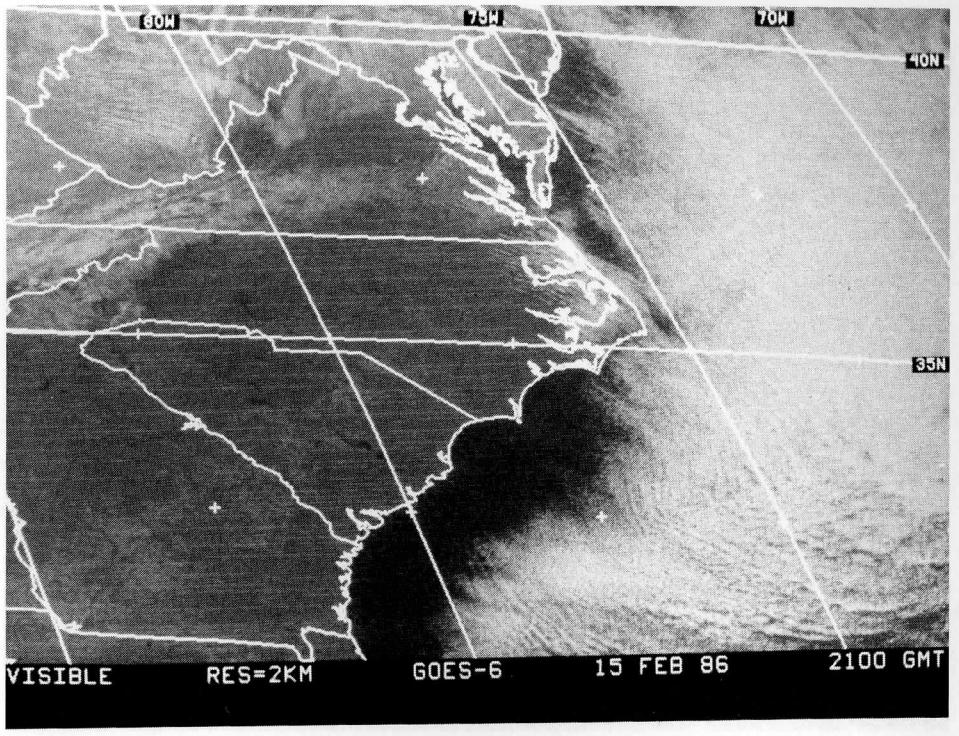
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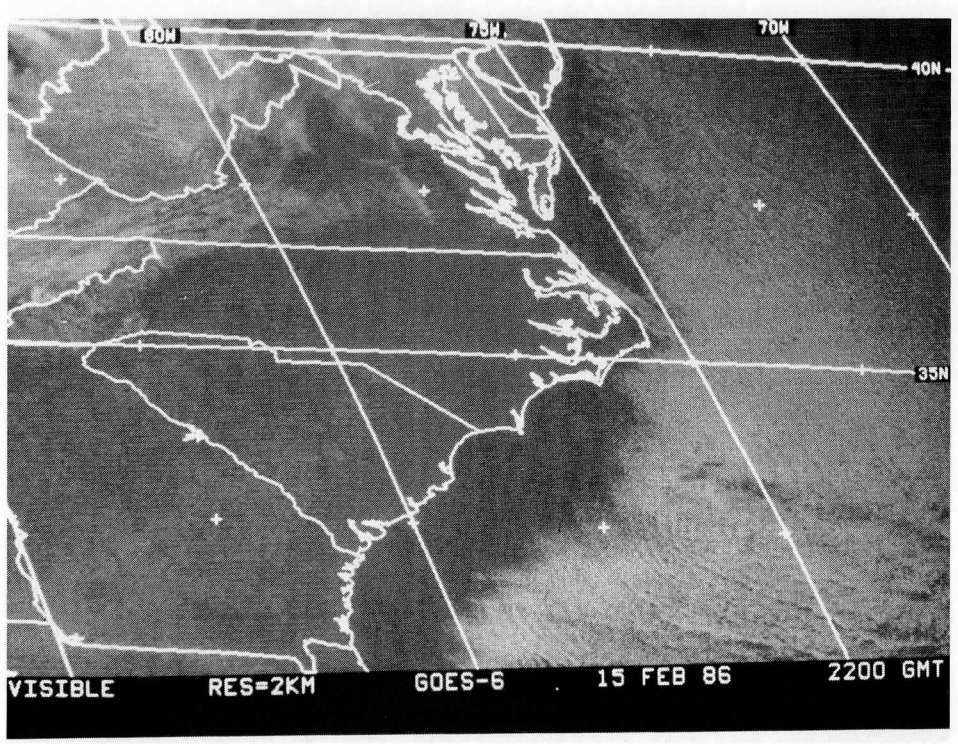
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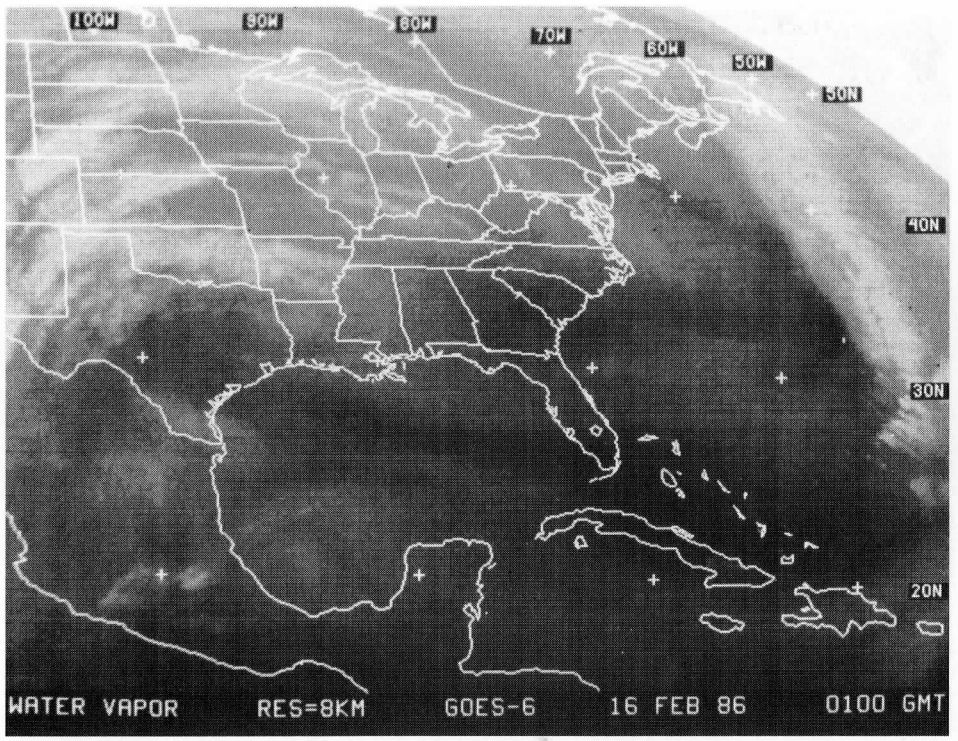
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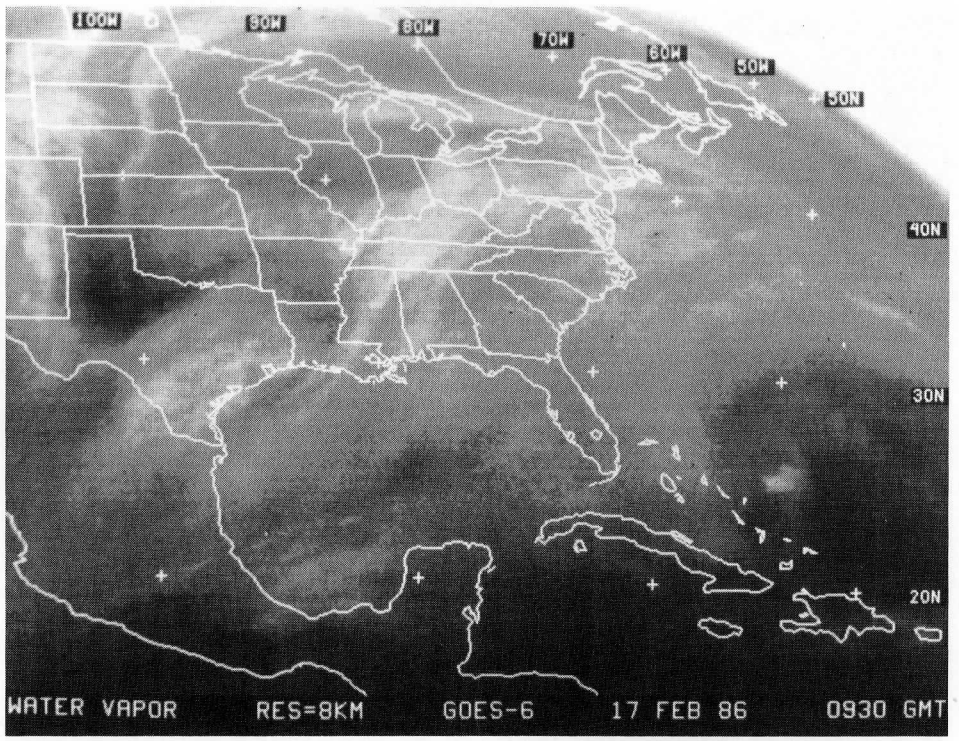
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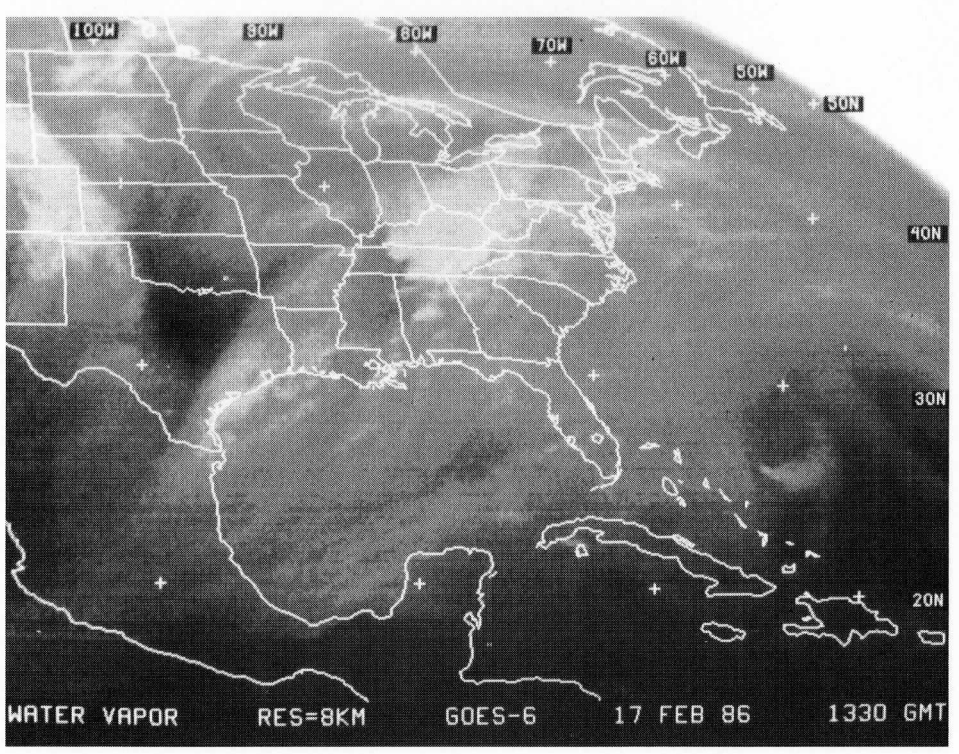
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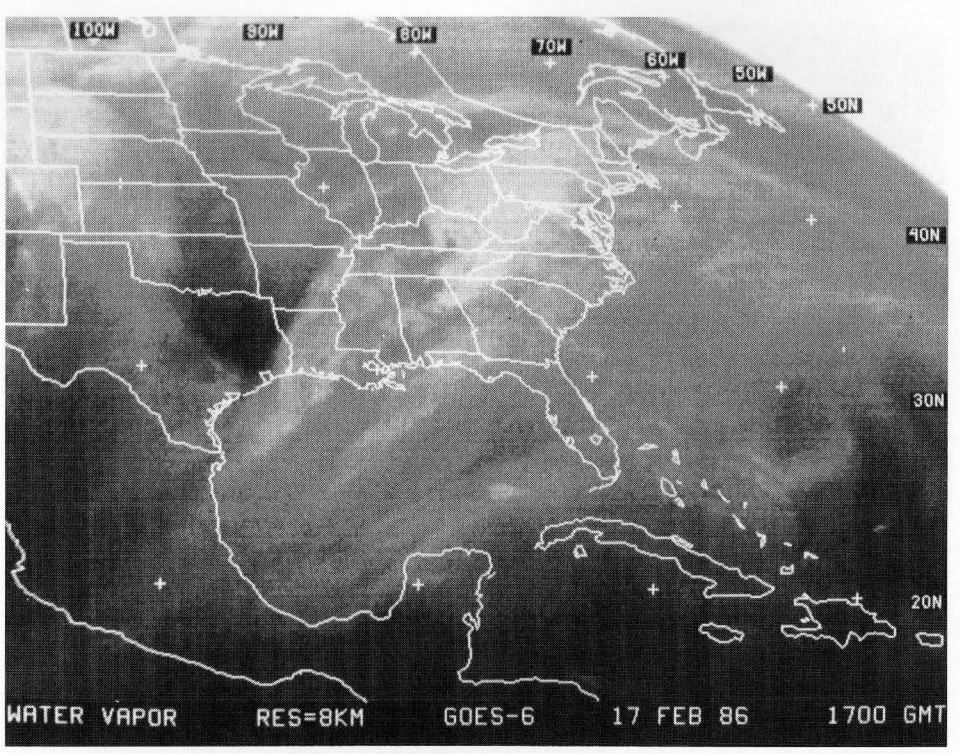
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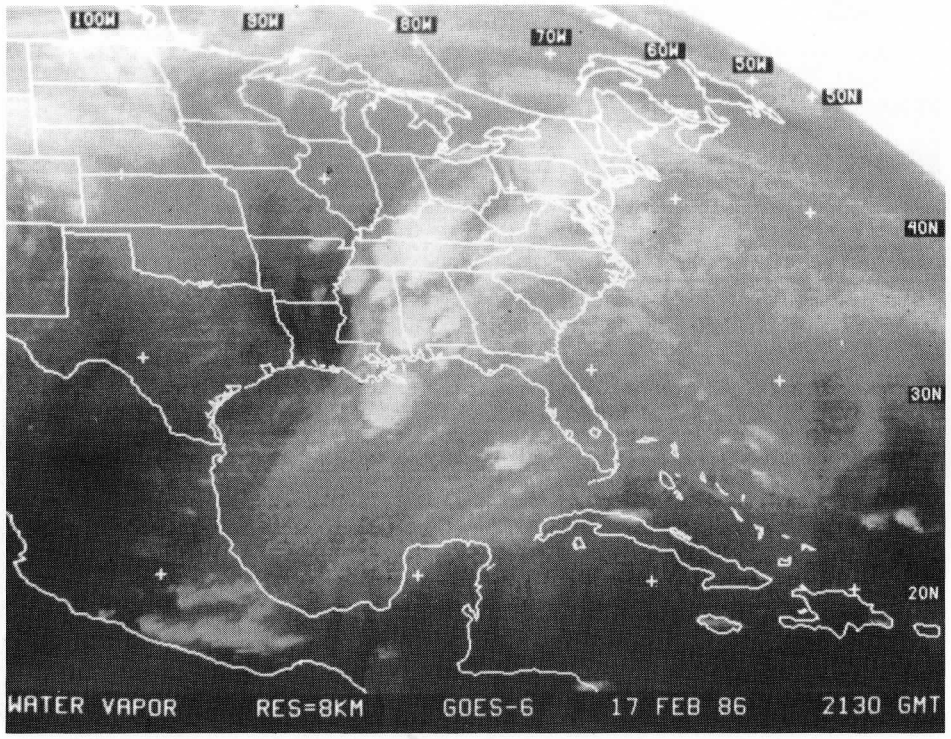
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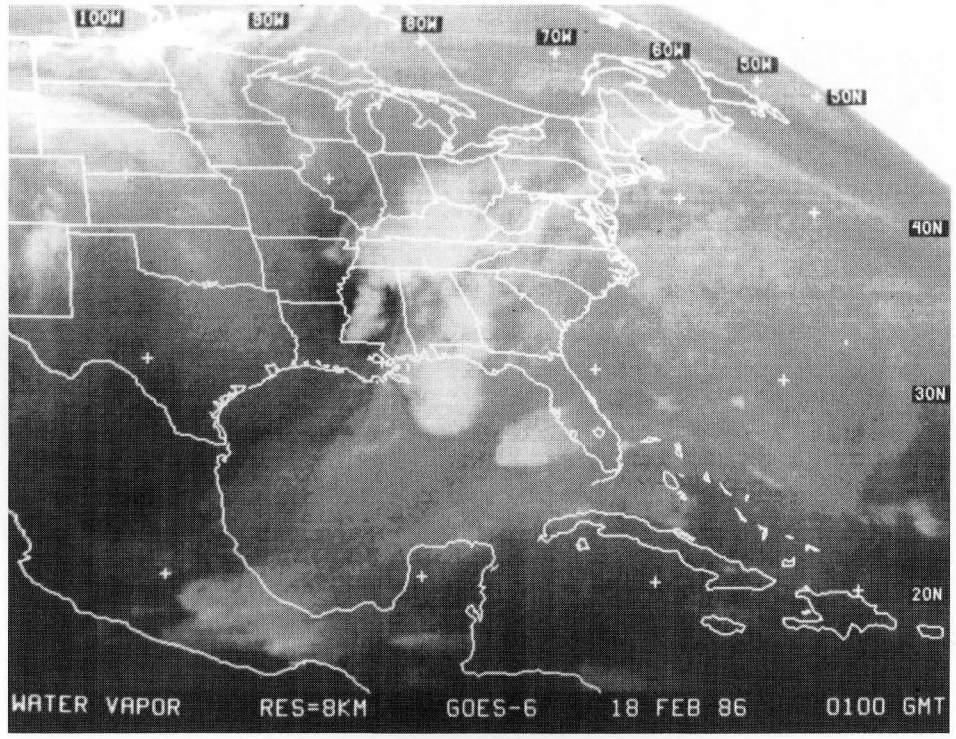
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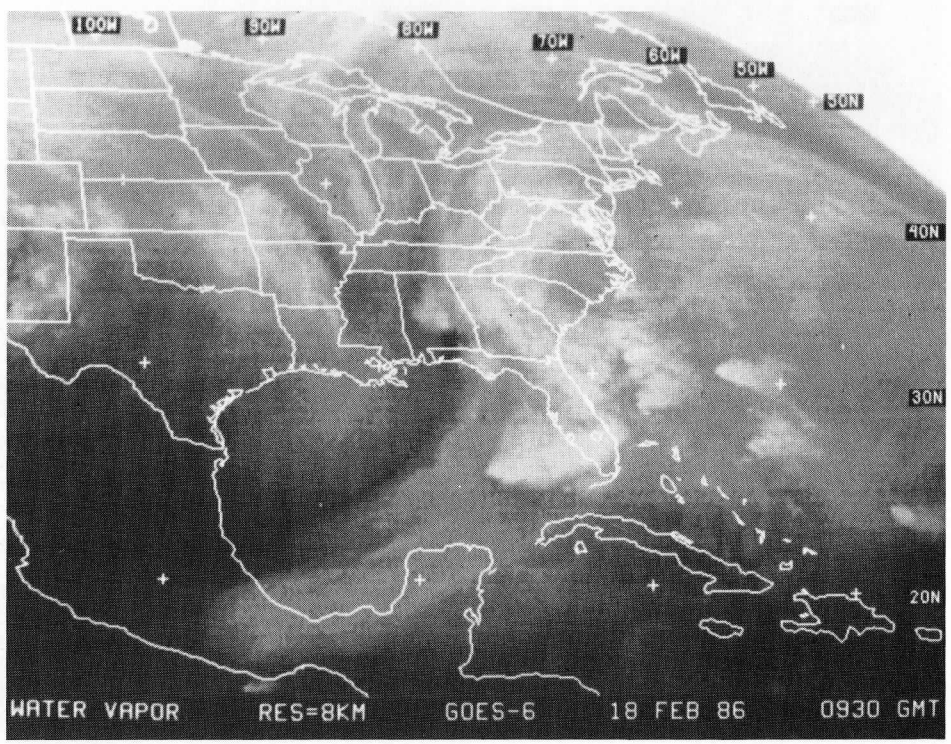
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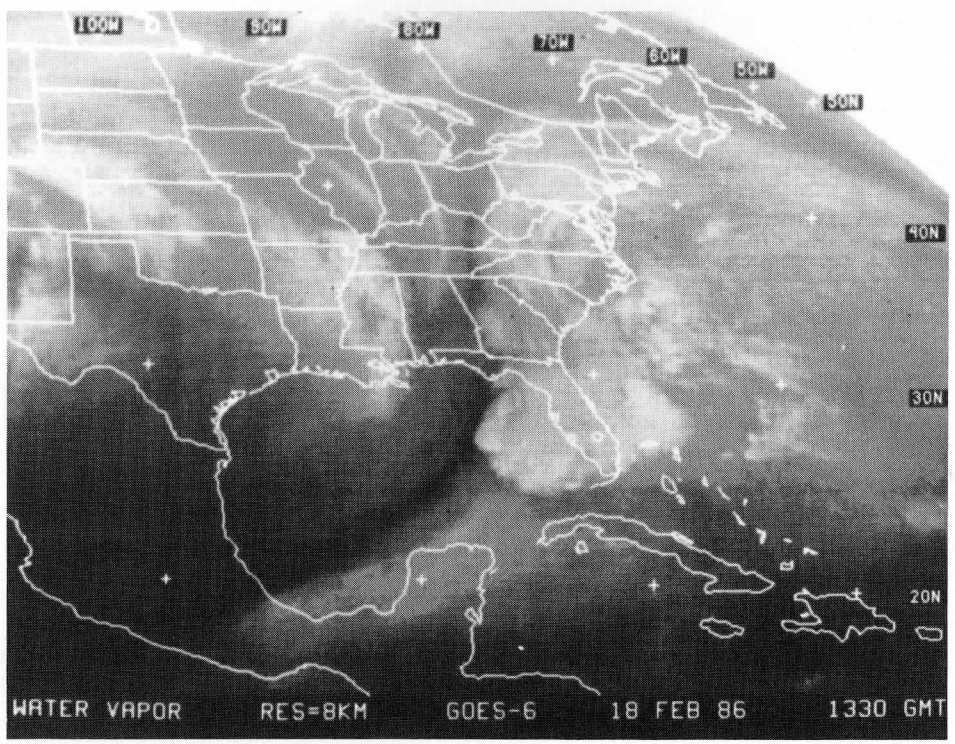
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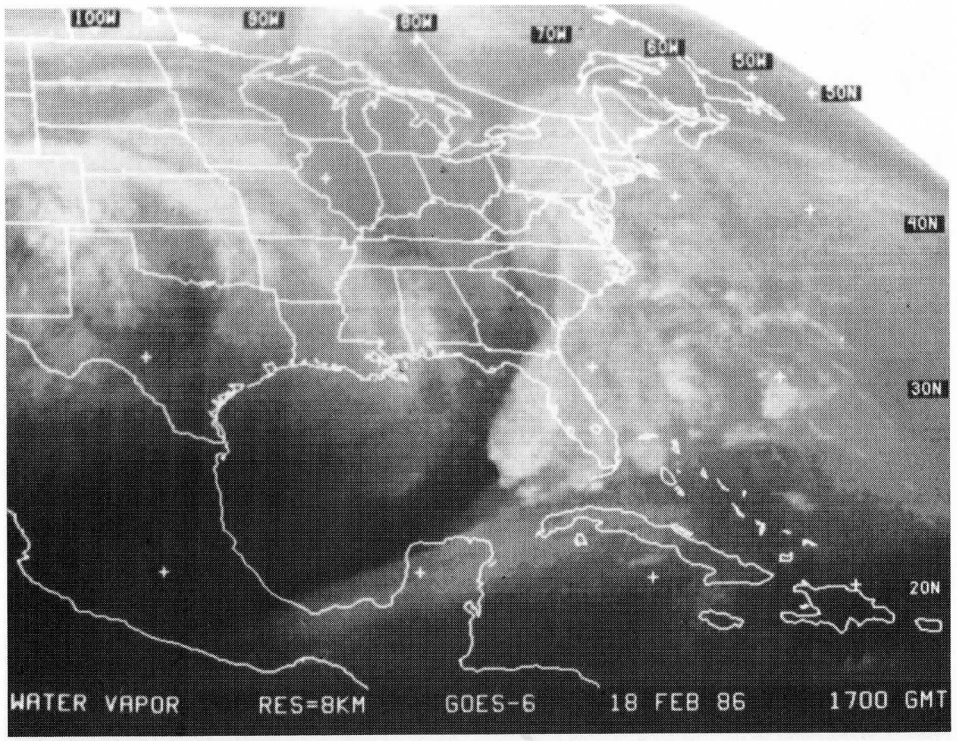
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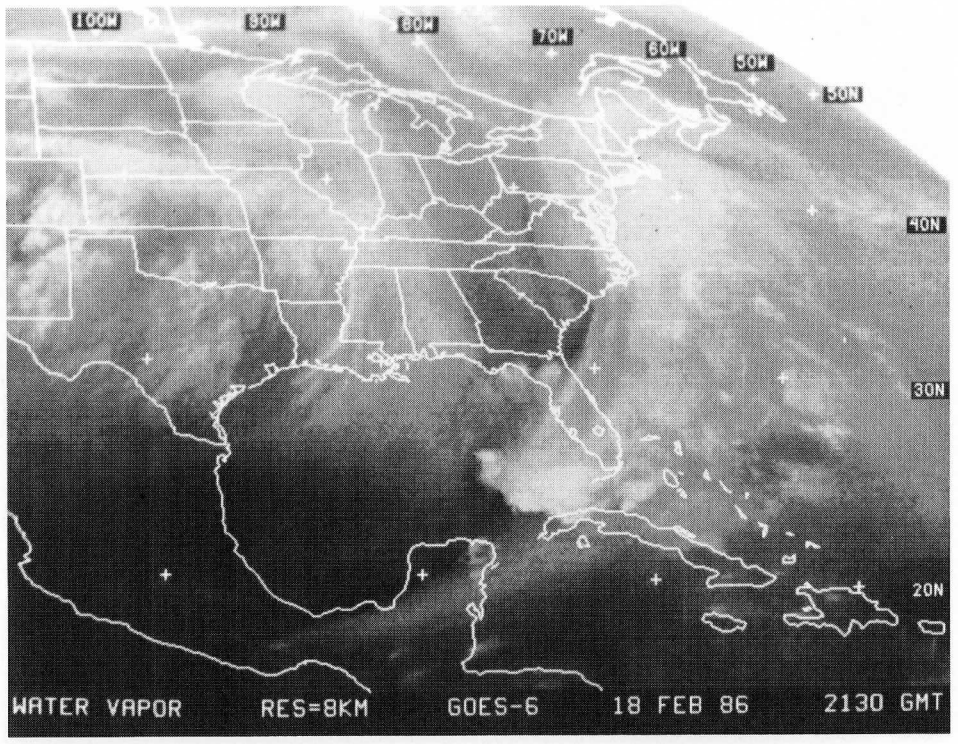
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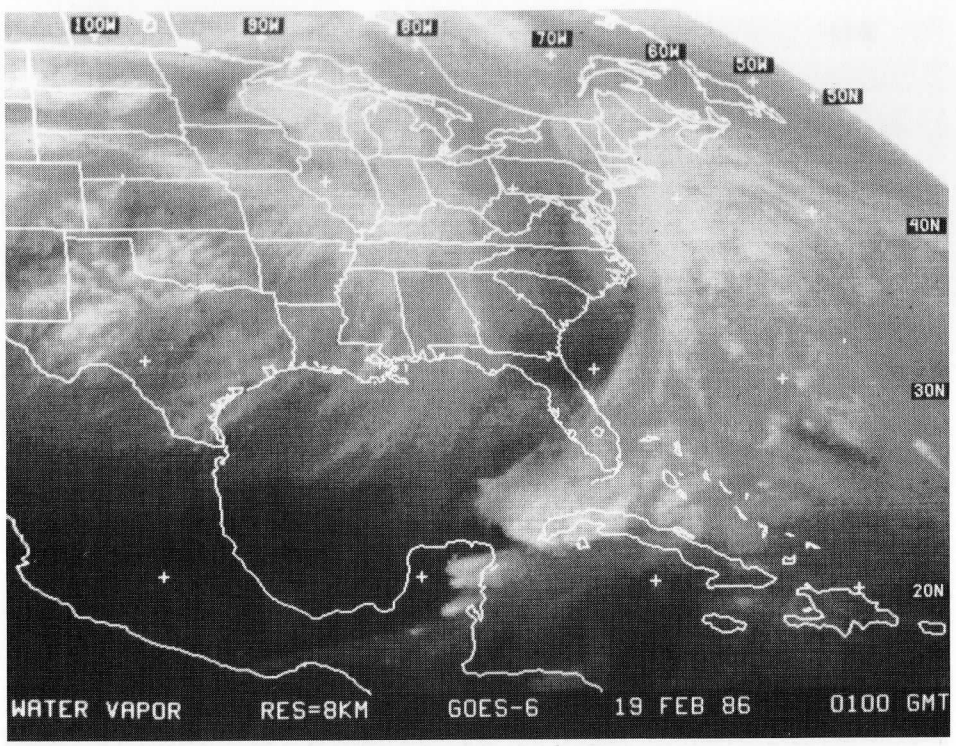
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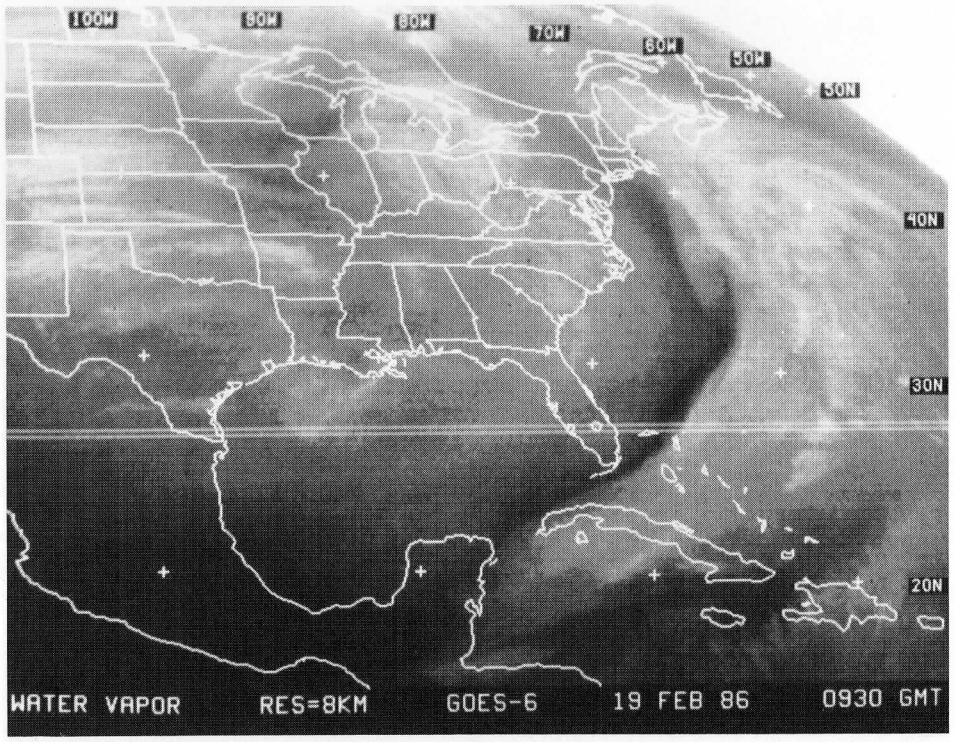
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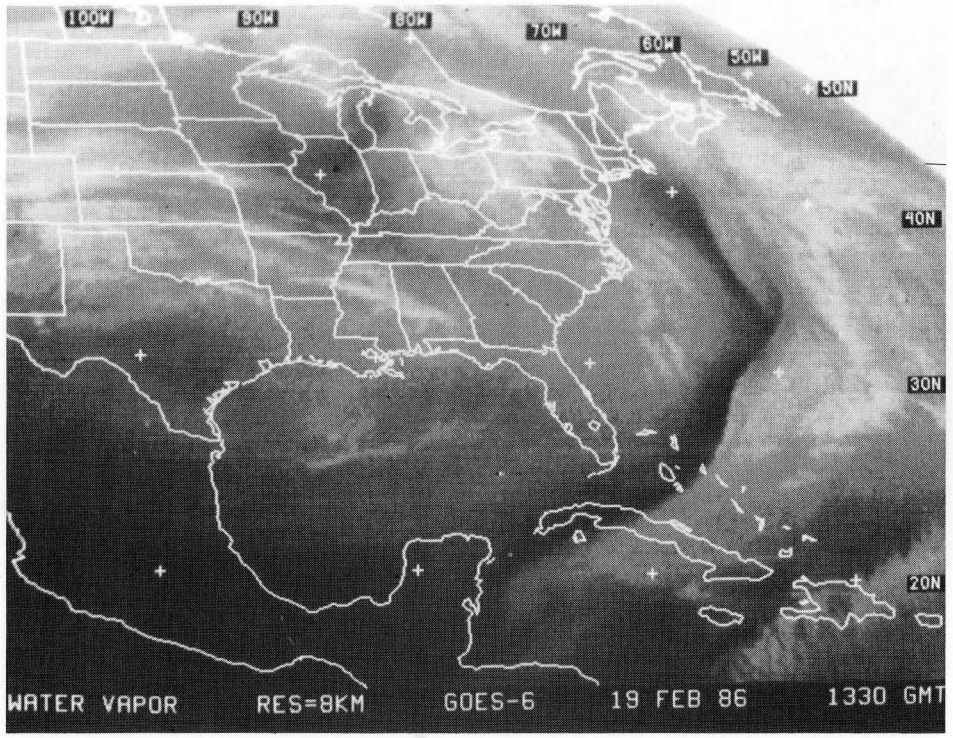
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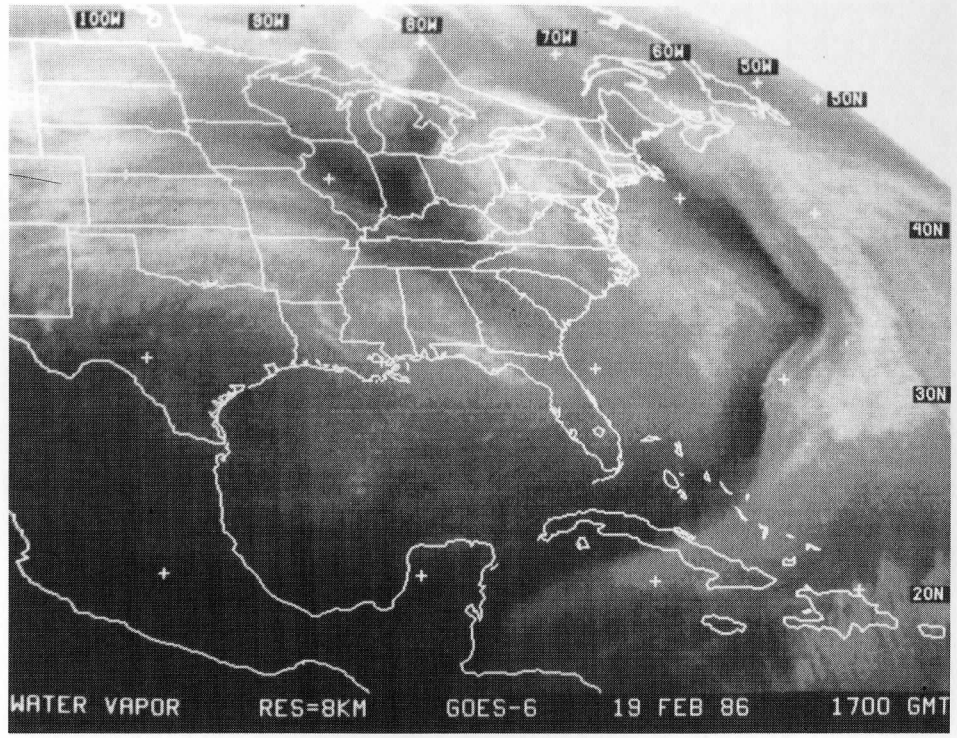
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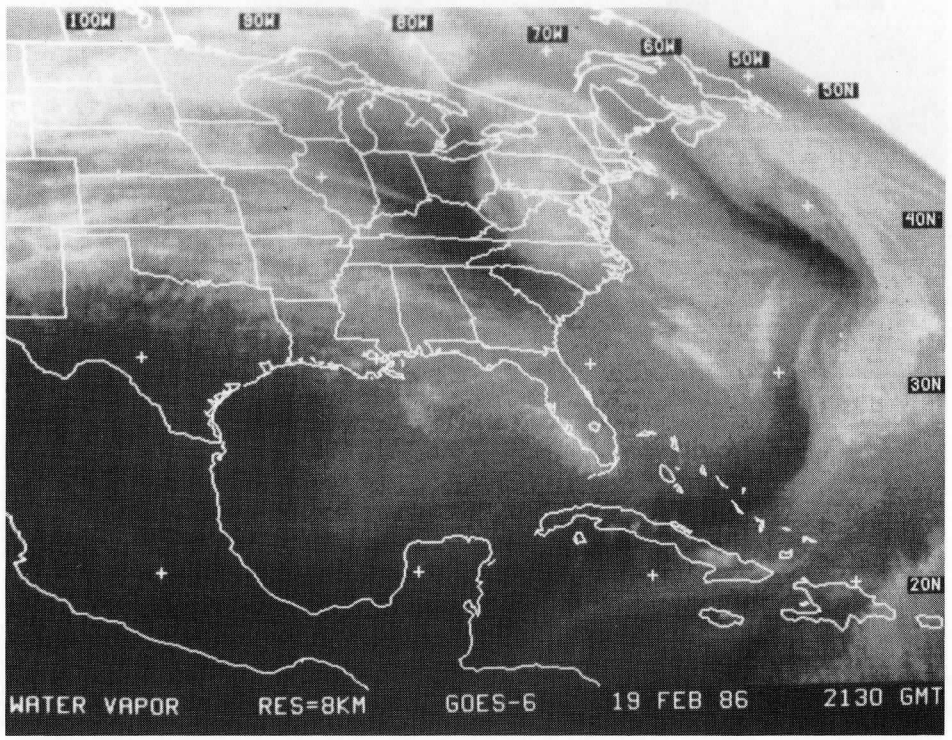
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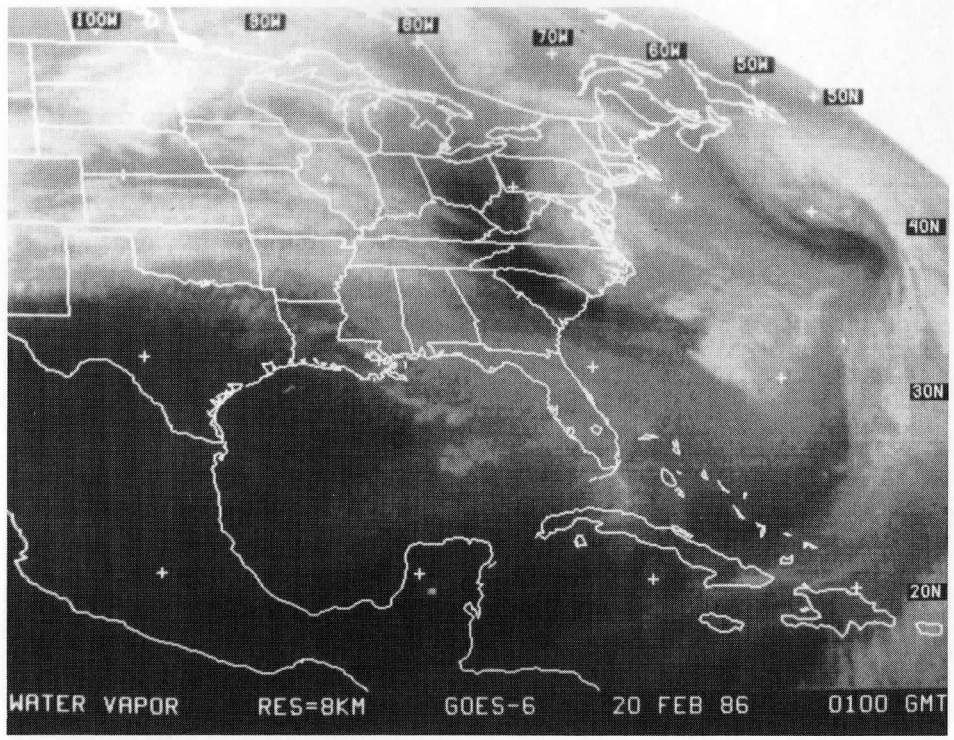
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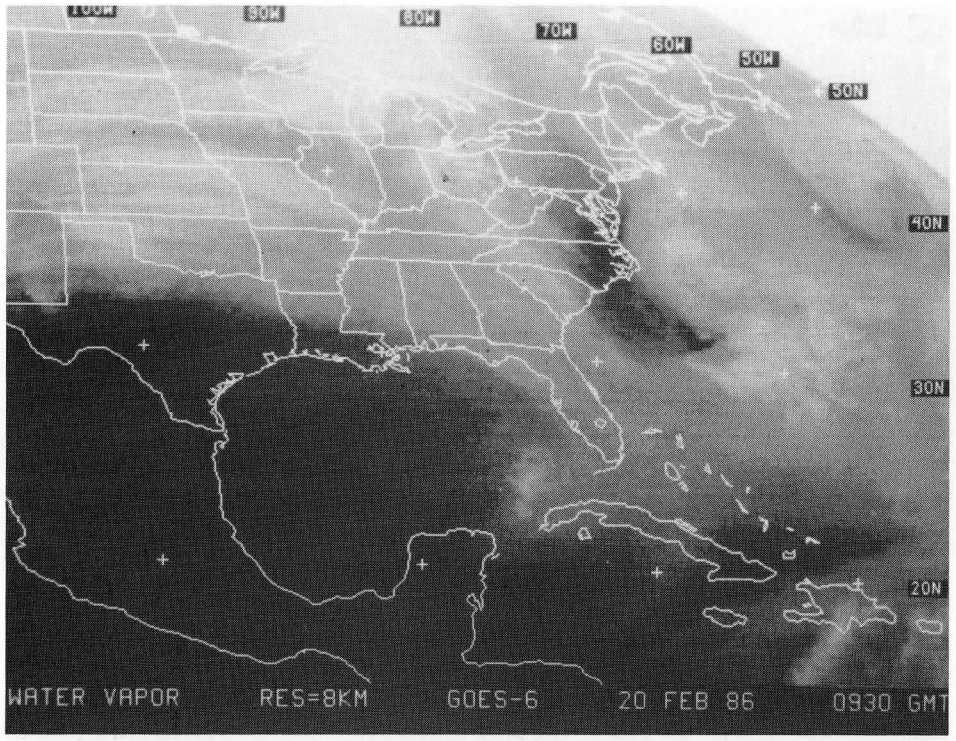
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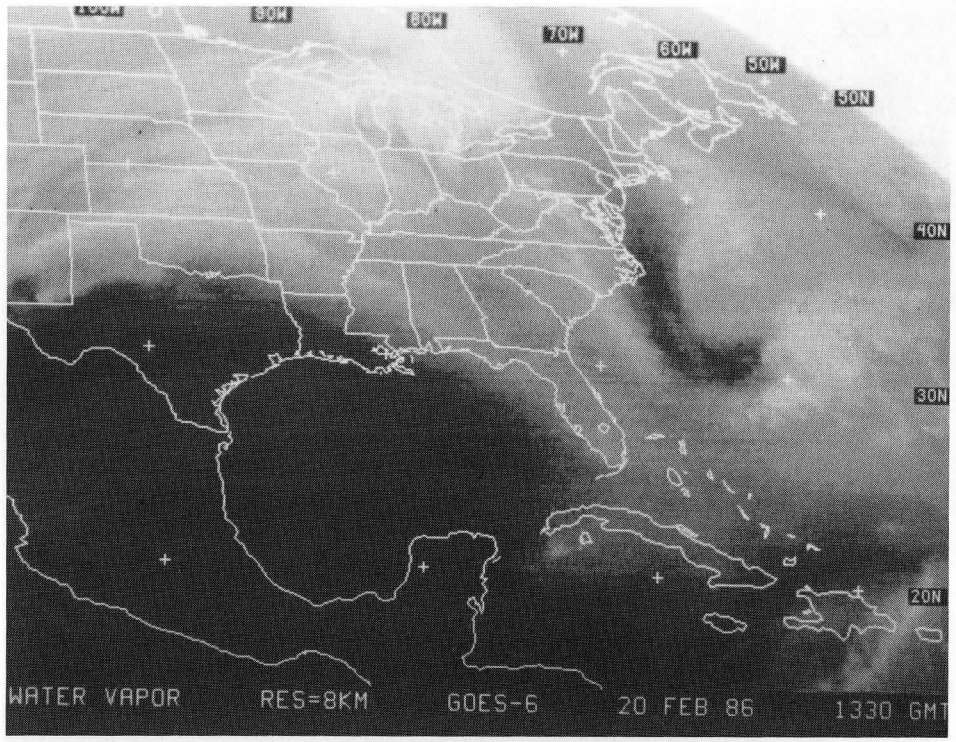
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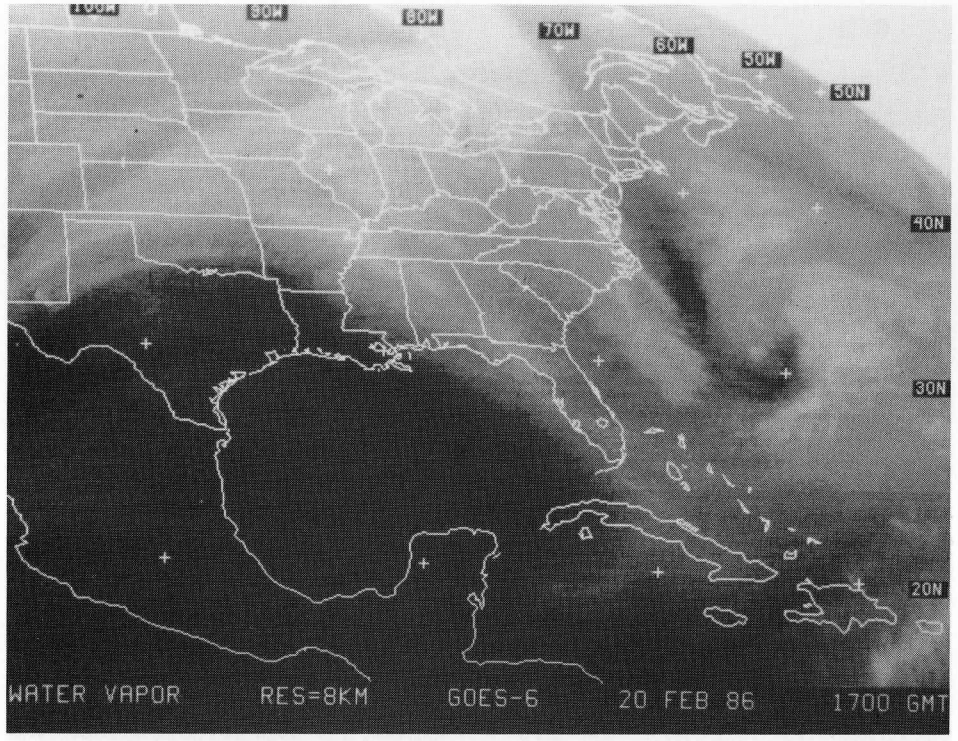
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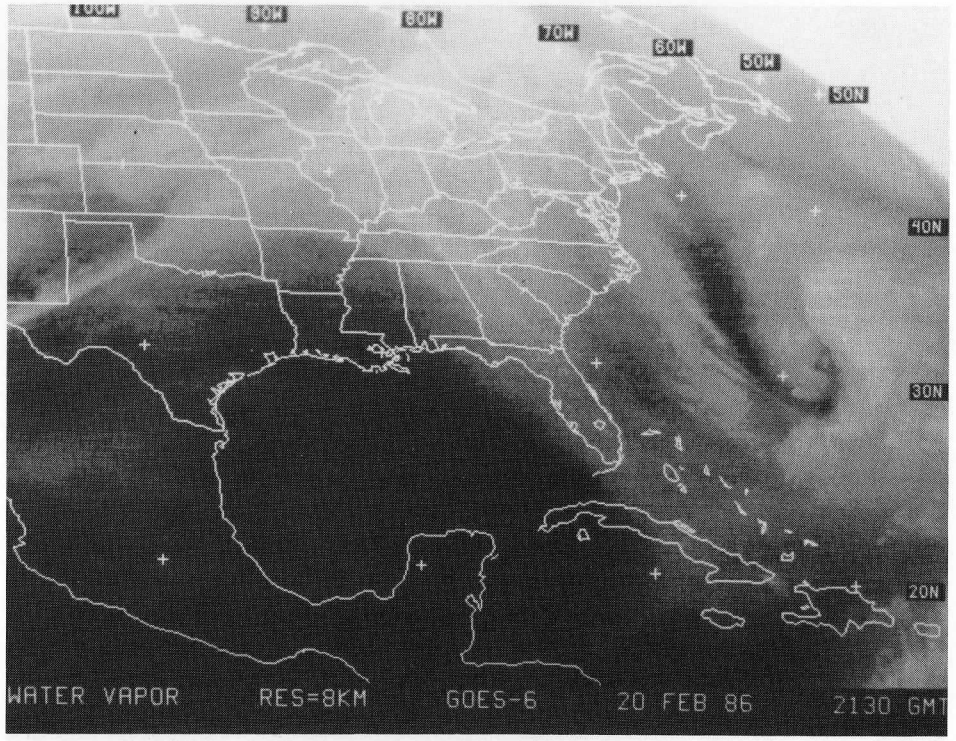
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WATER VAPOR RES=8KM GOES-6 20 FEB 86 2130 GMT

IOP #7 - Wave Passage Through Virginia
February 21 - February 22

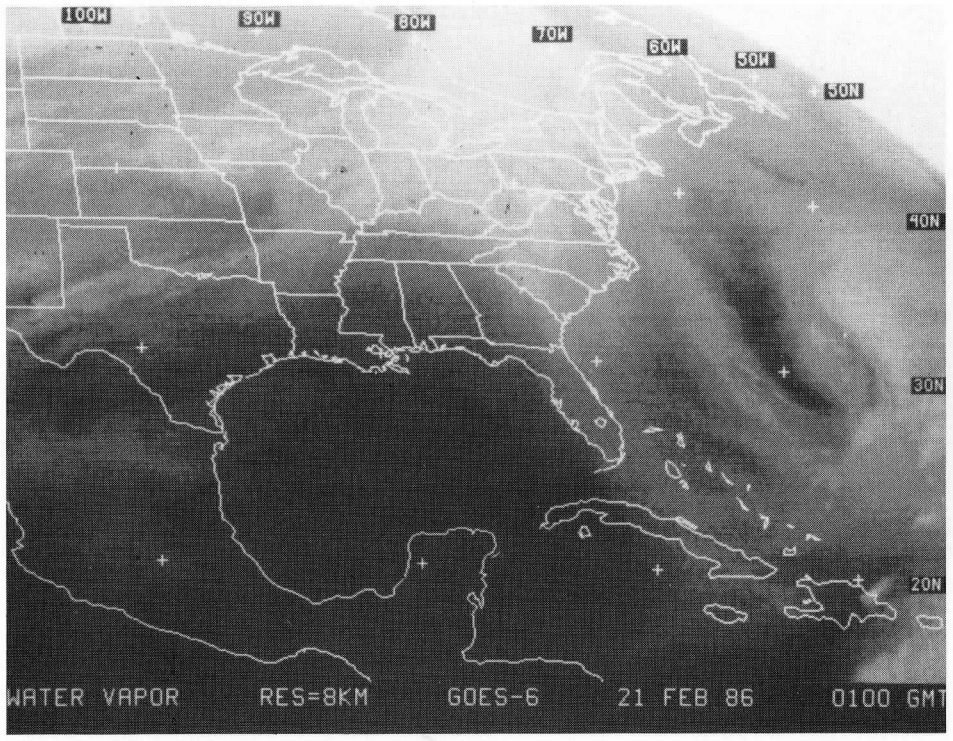
Satellite Synopsis

Water Vapor

- 21st, strong system well offshore near 30N, 60W.
- Very dry in the Gulf and Caribbean.

Visible

- 21st, some Gulf Stream light rain showers, and some dramatic wave clouds form late in the Virginias.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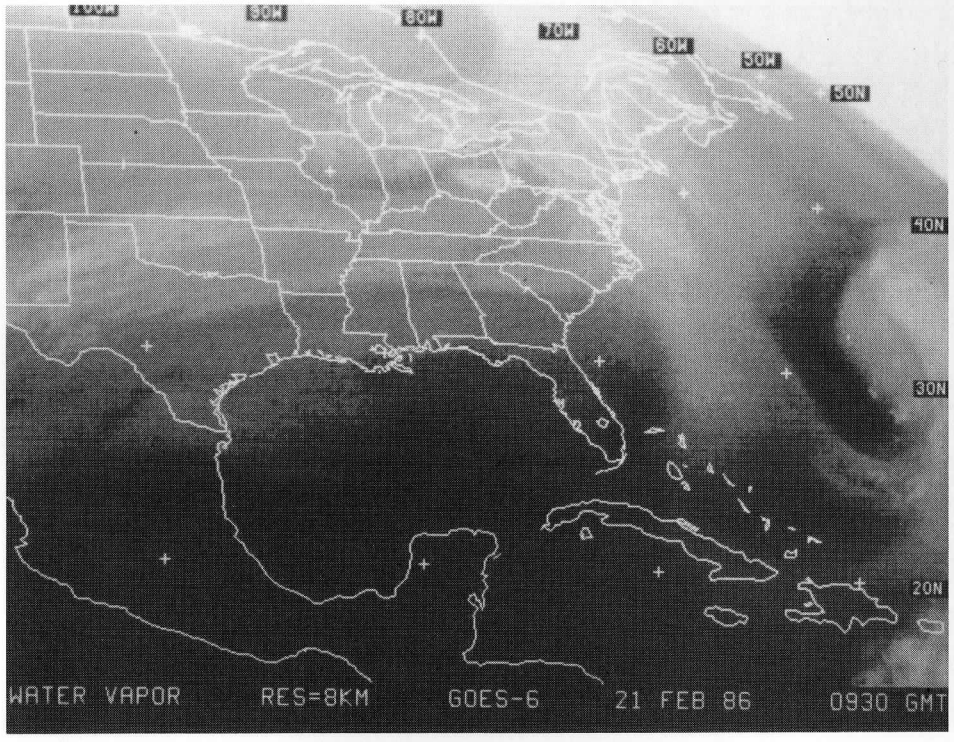
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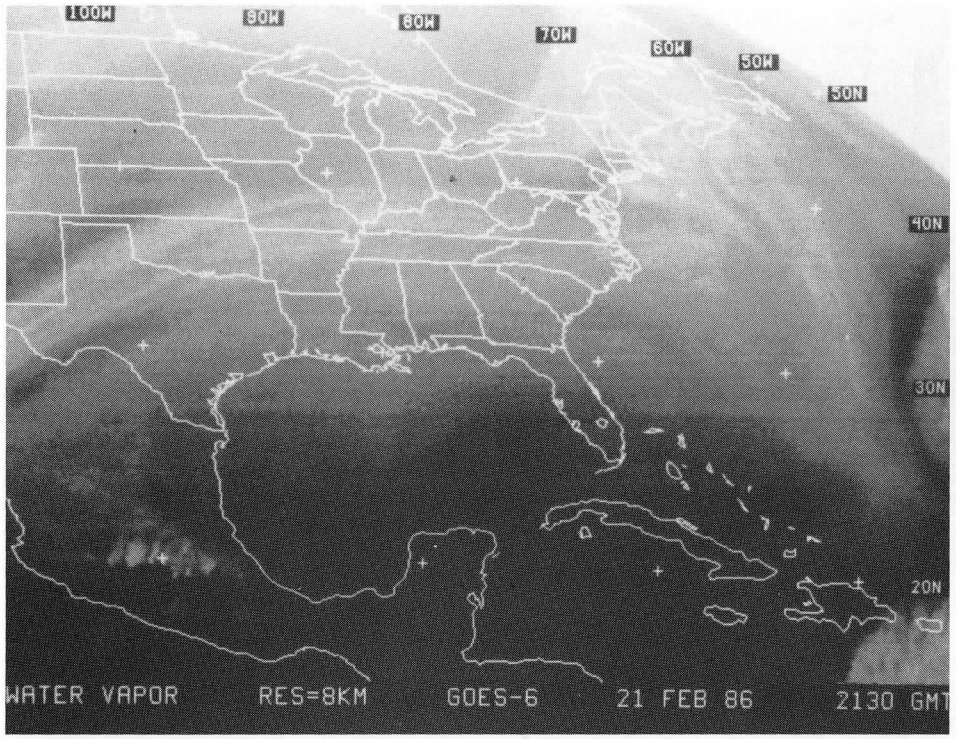
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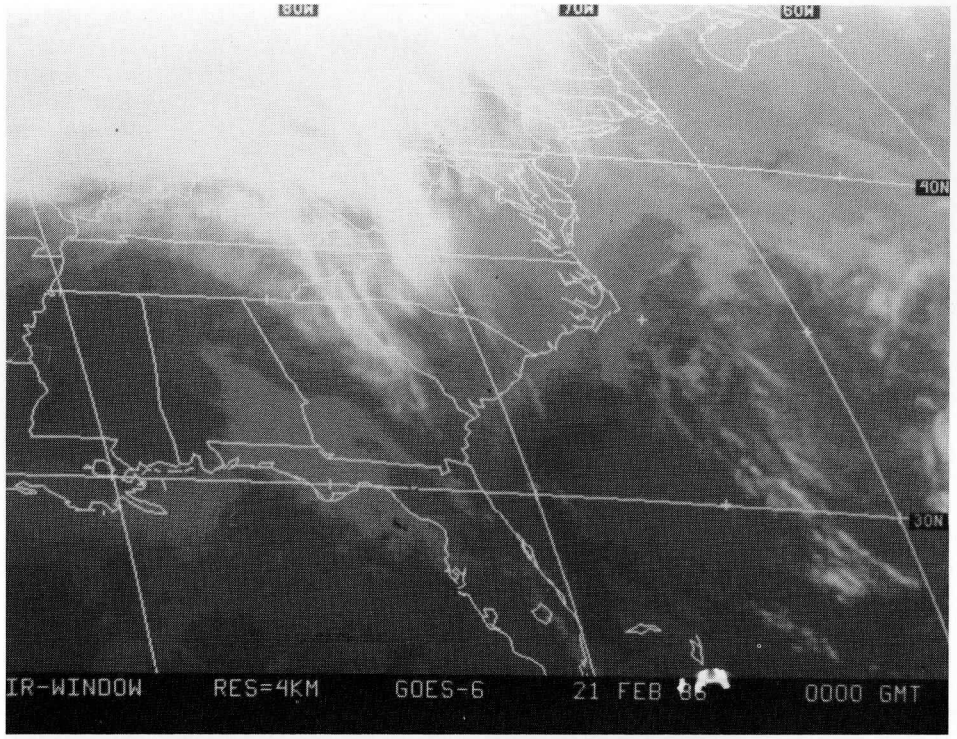
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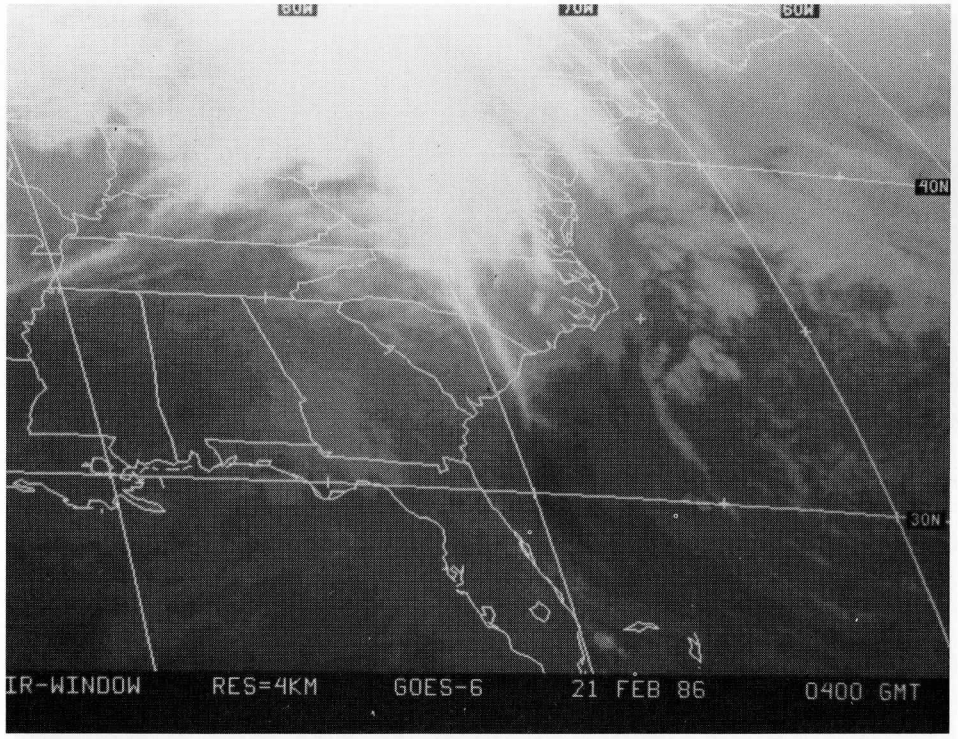
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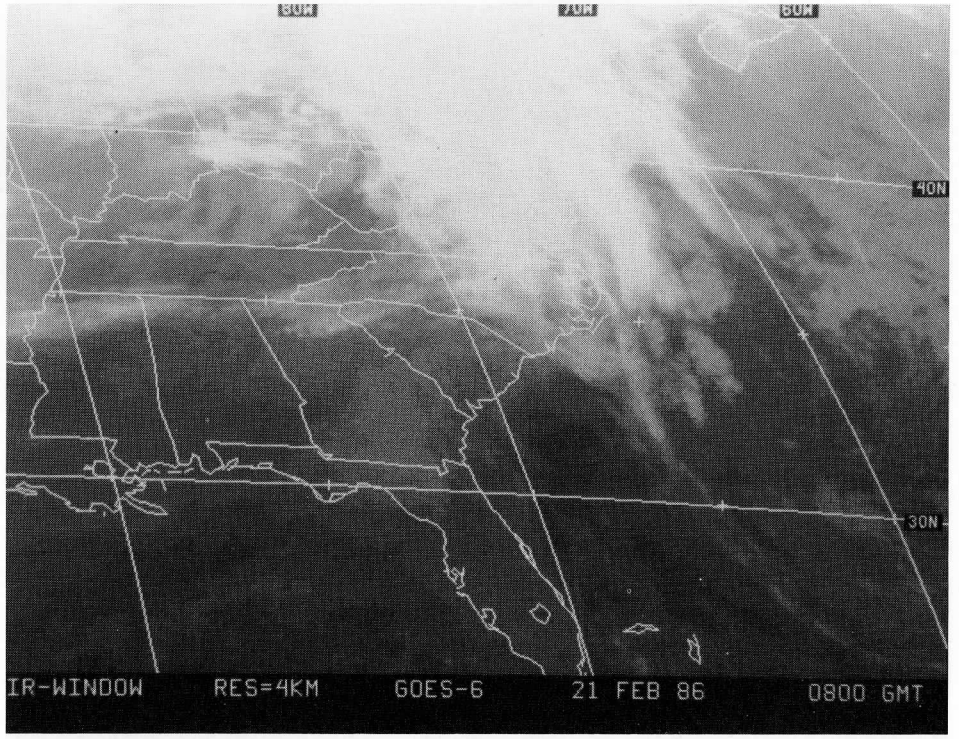
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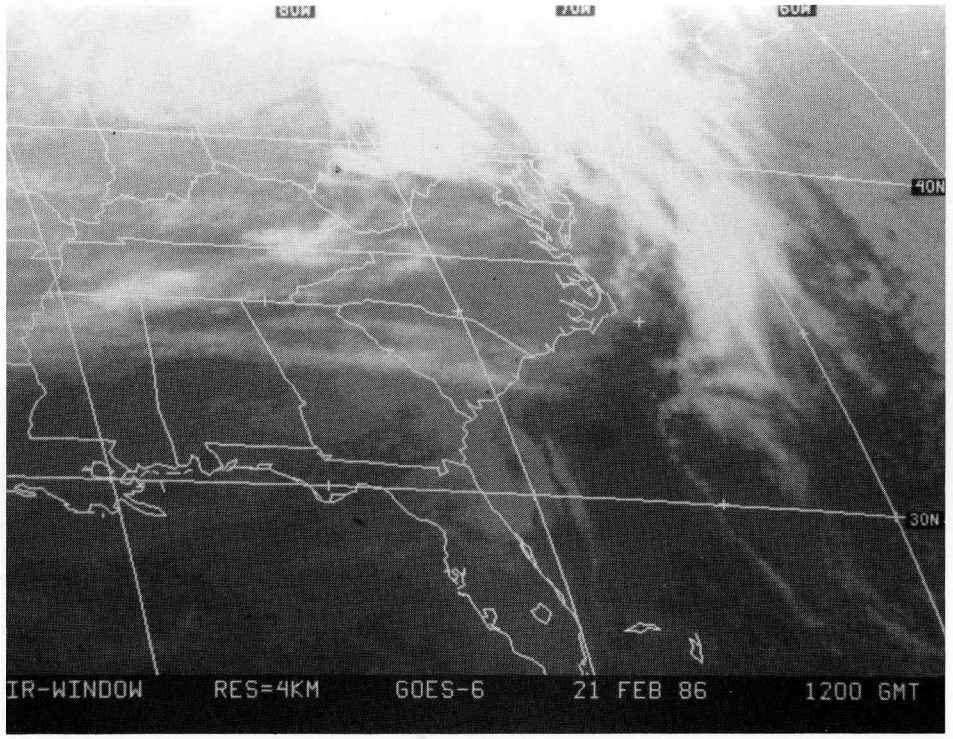
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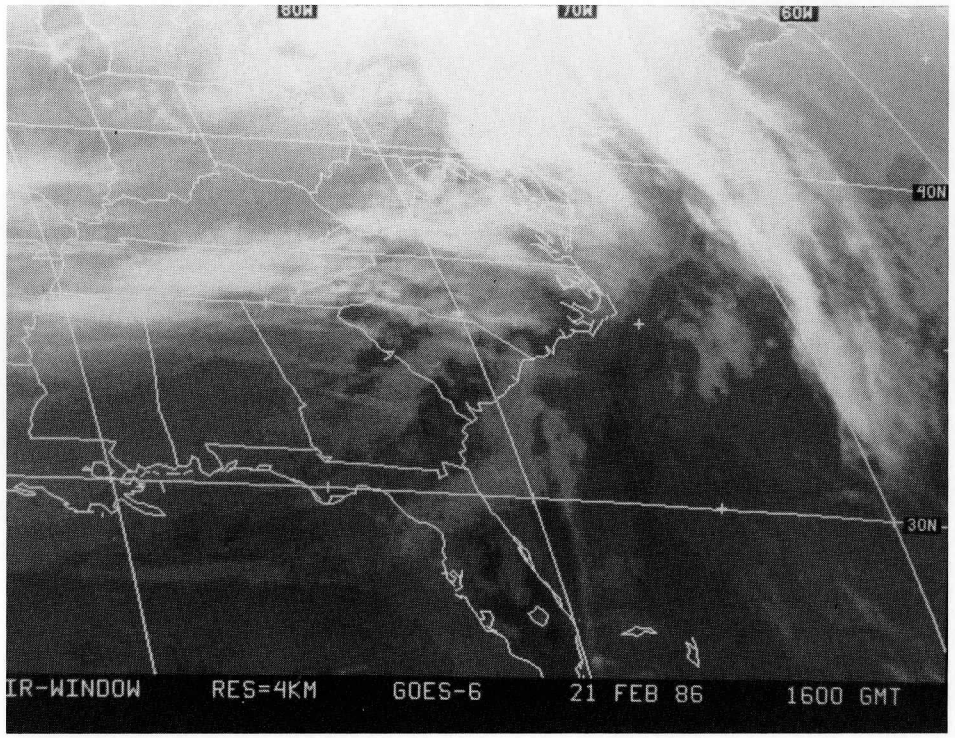
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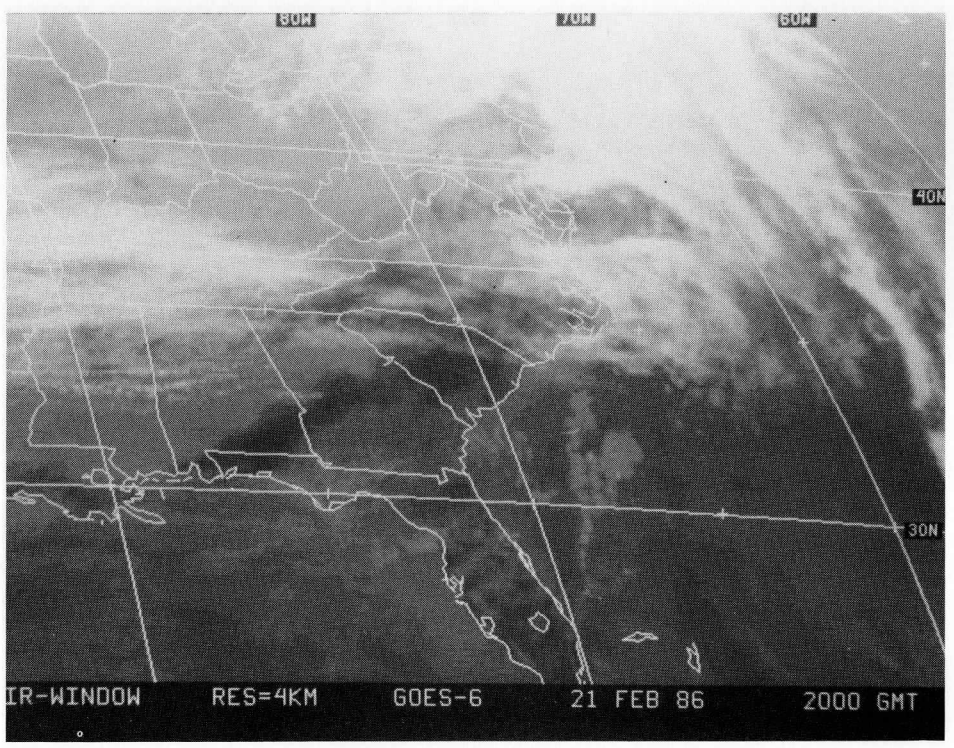
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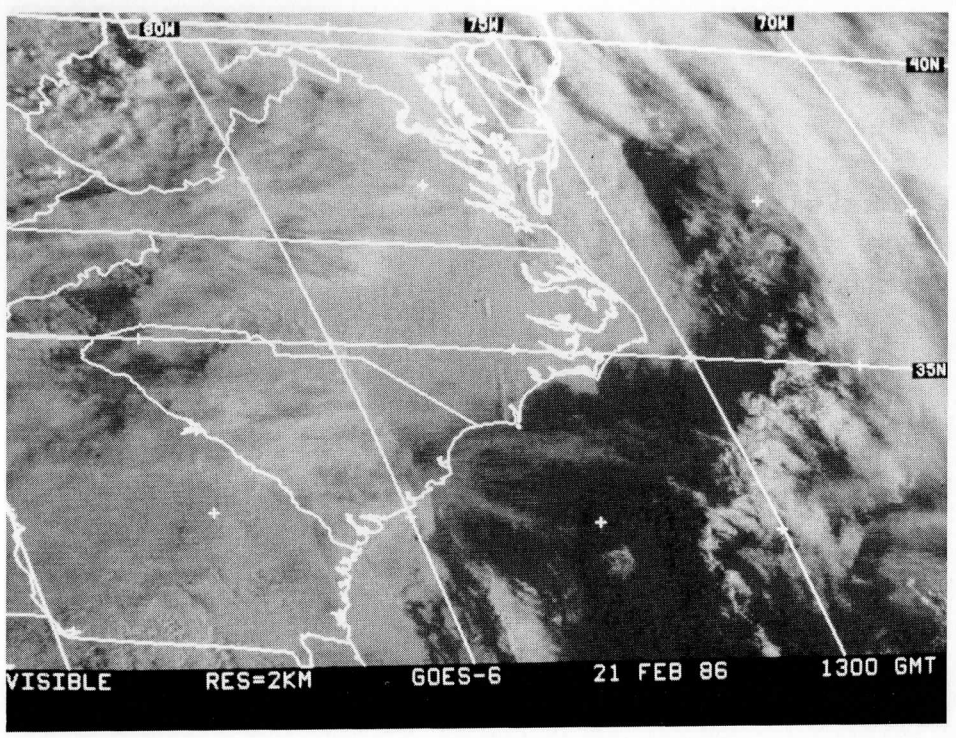
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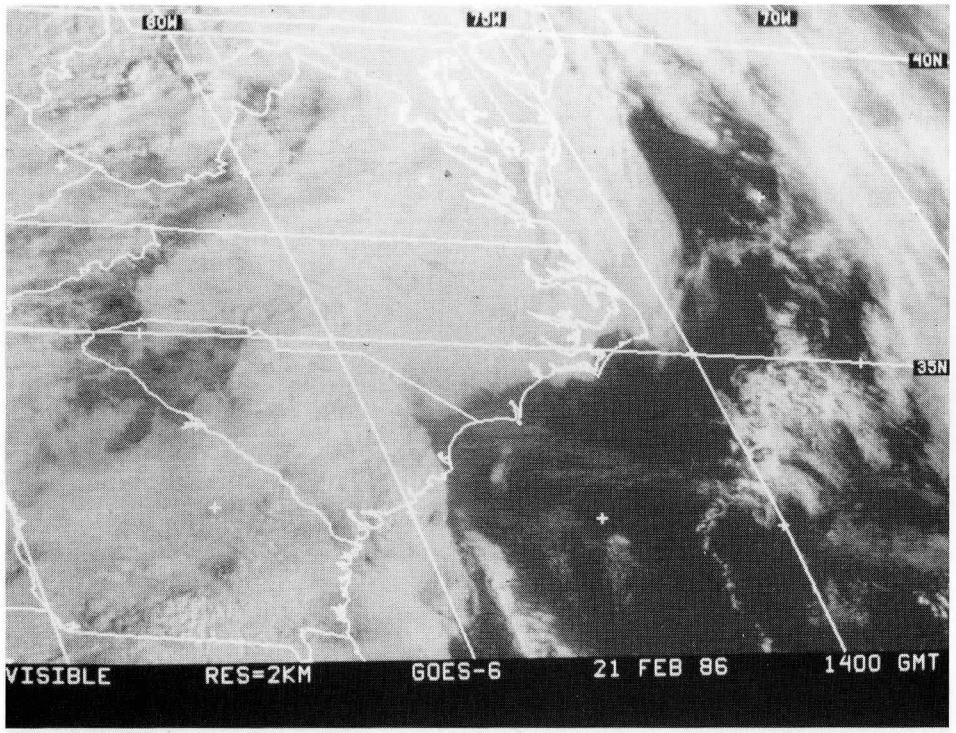
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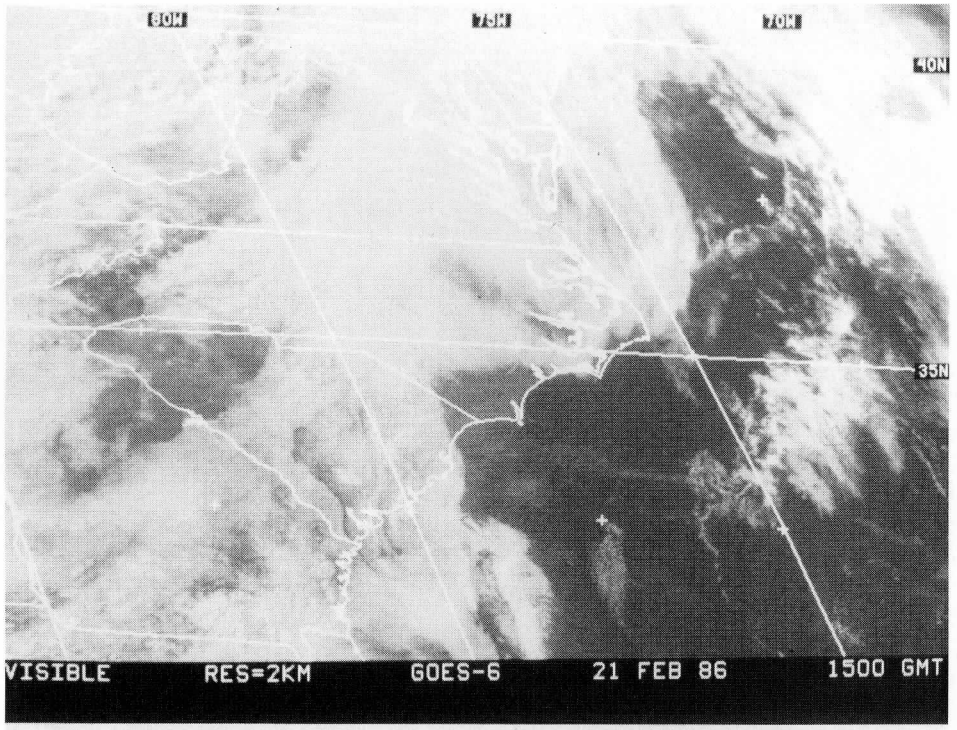
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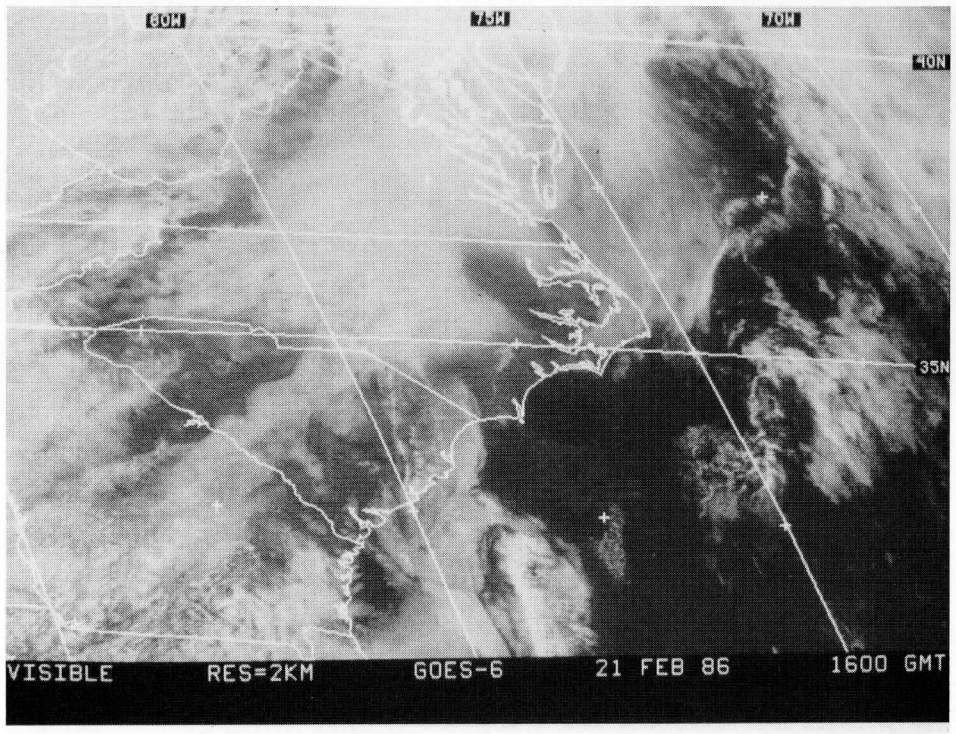
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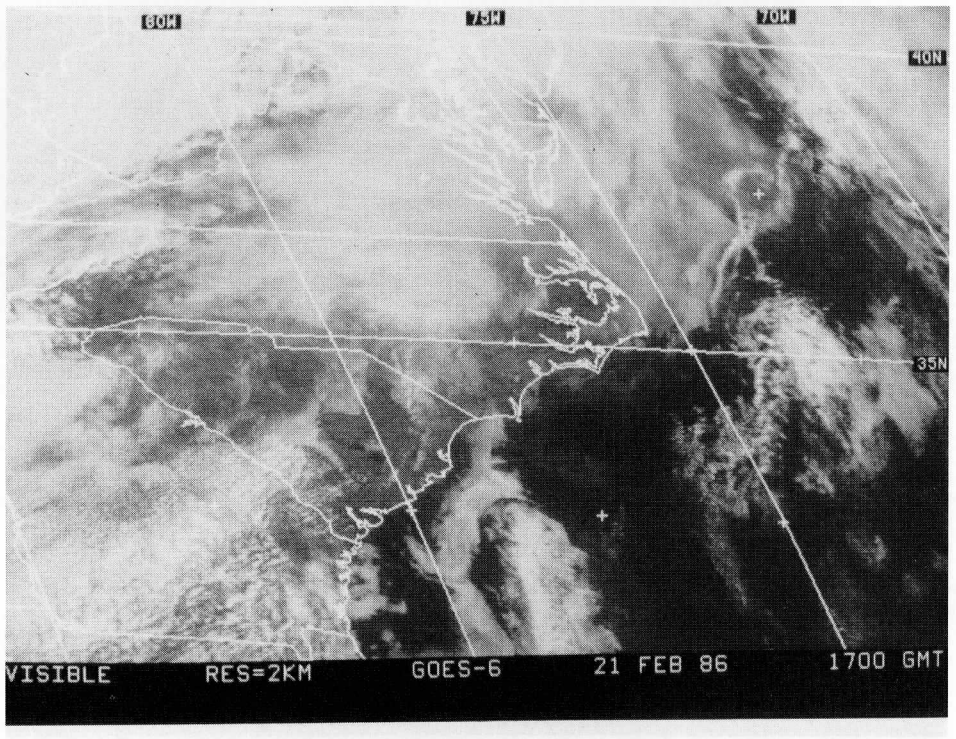
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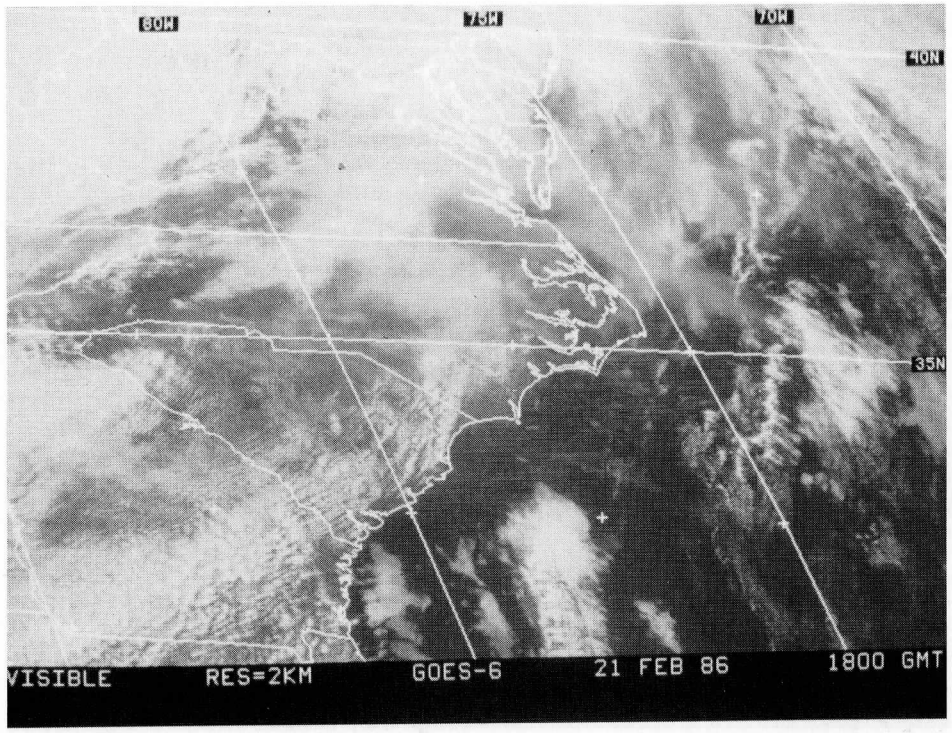
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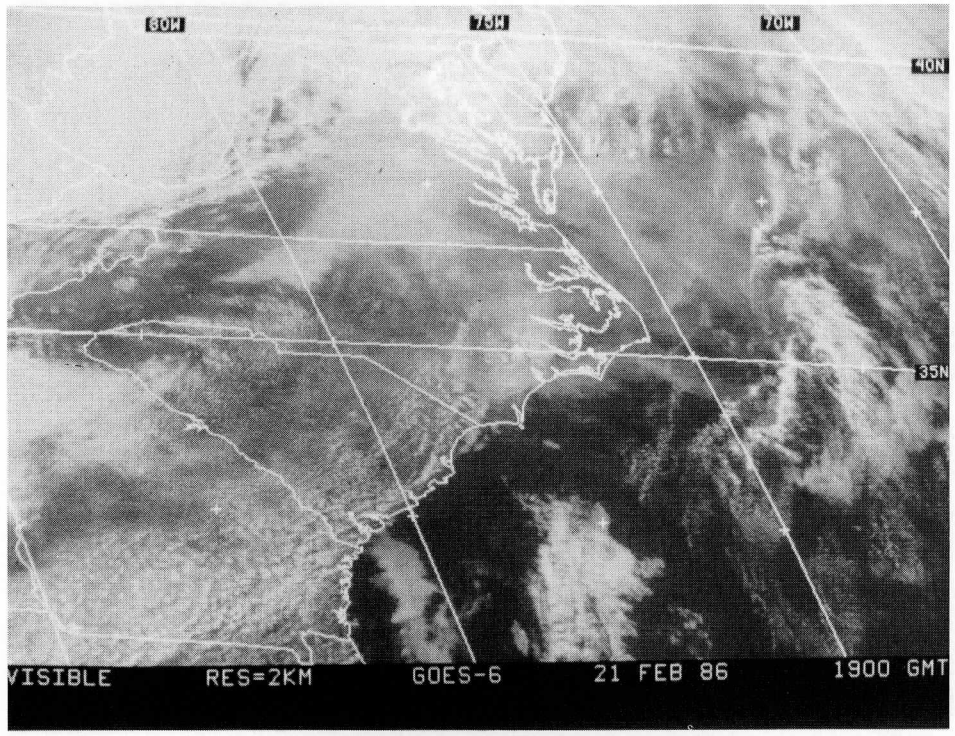
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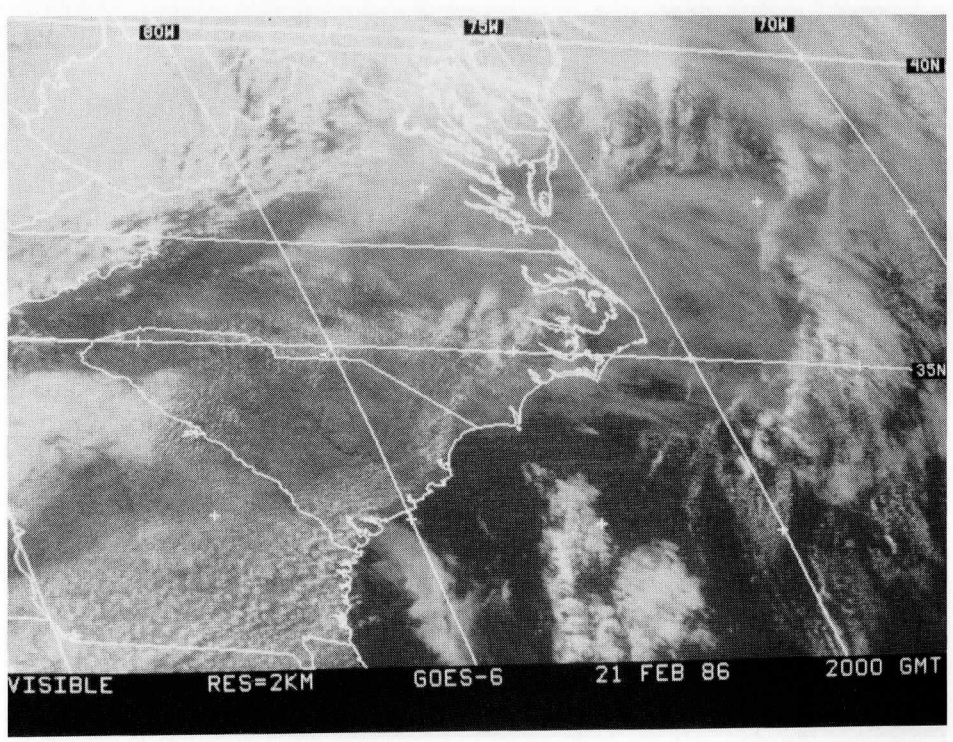
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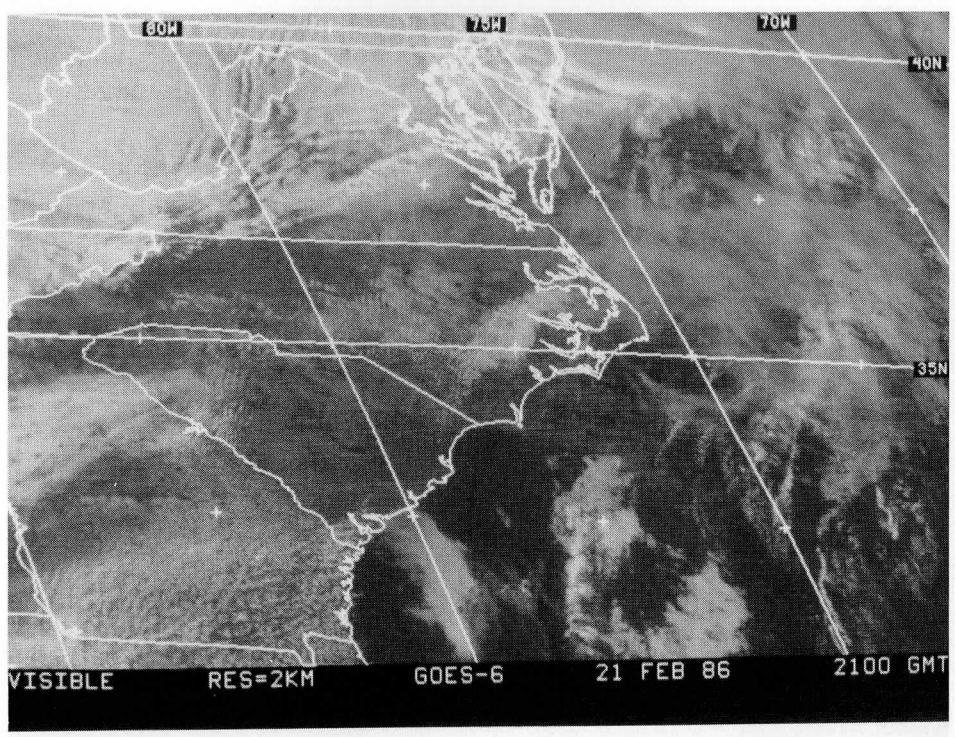
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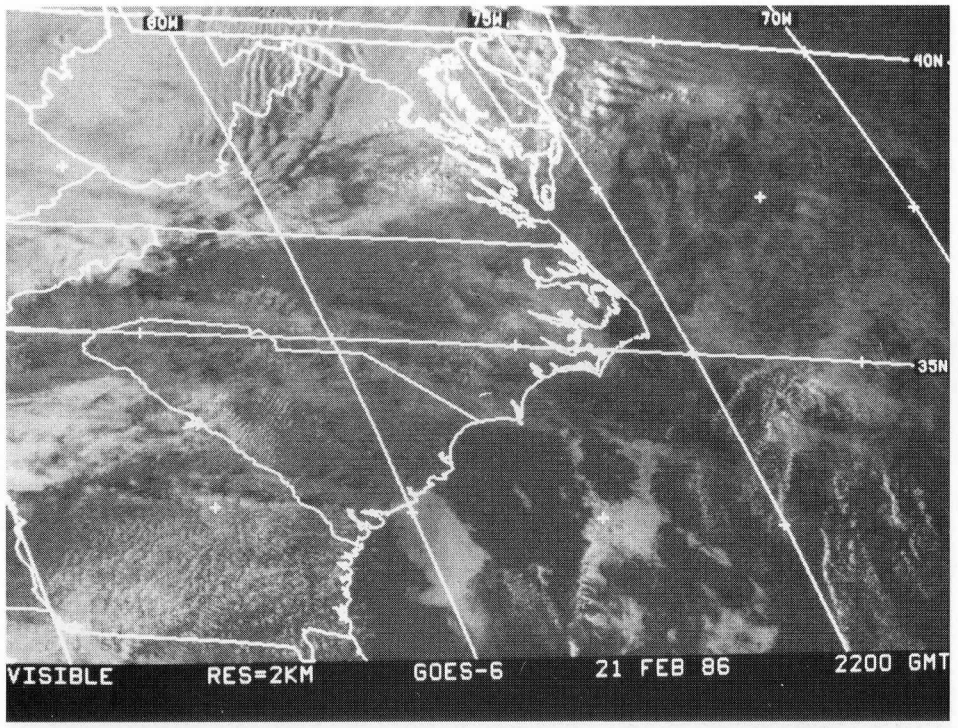
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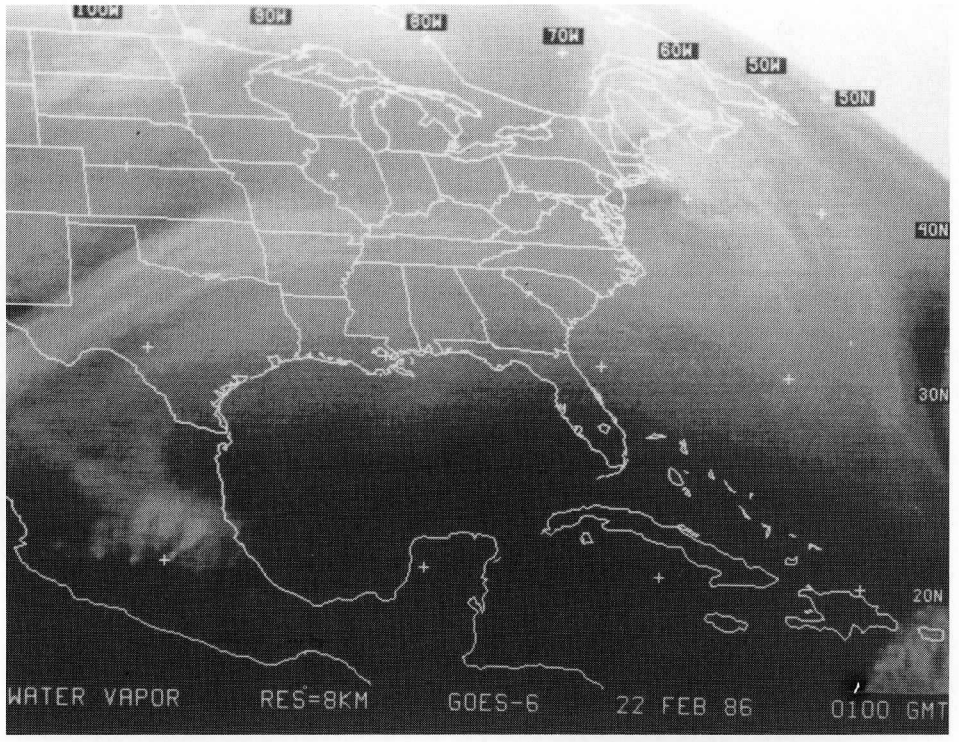
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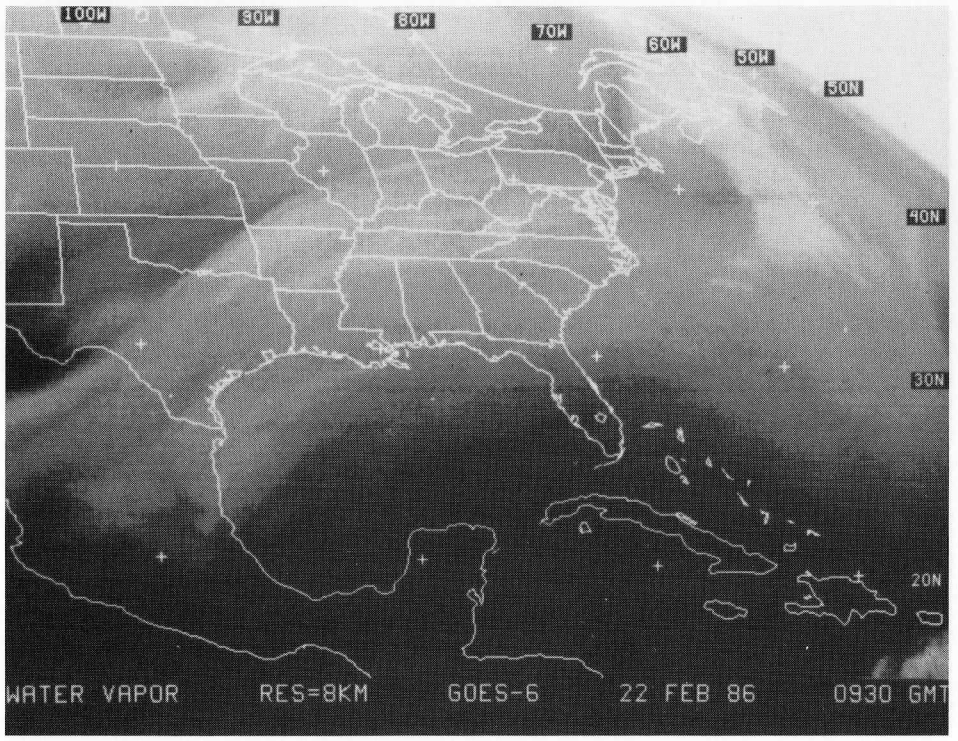
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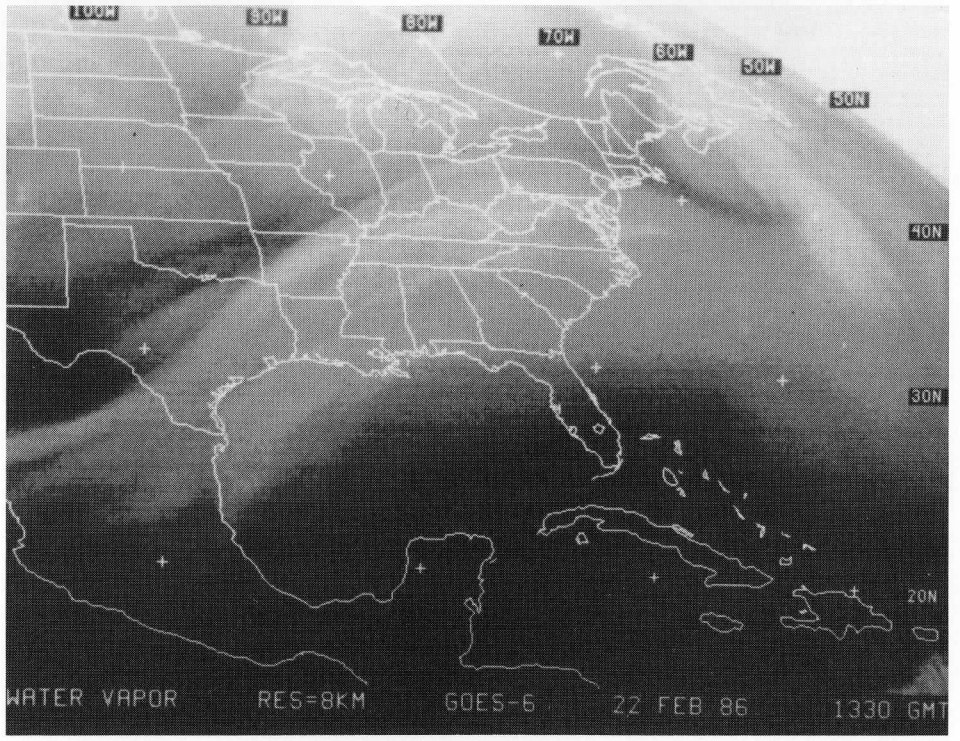
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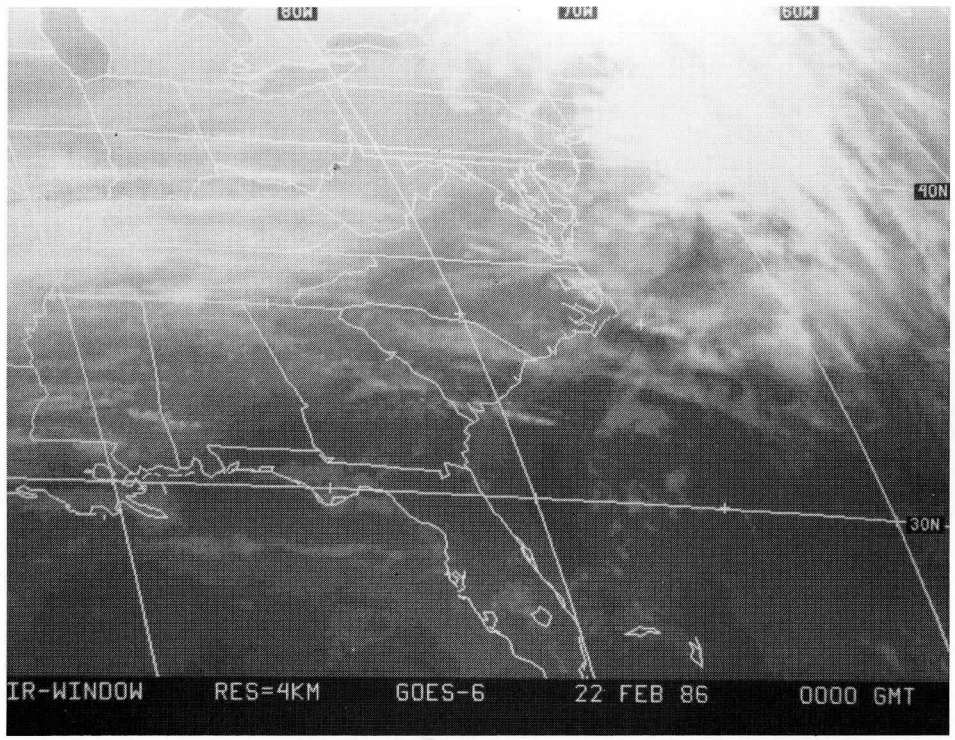
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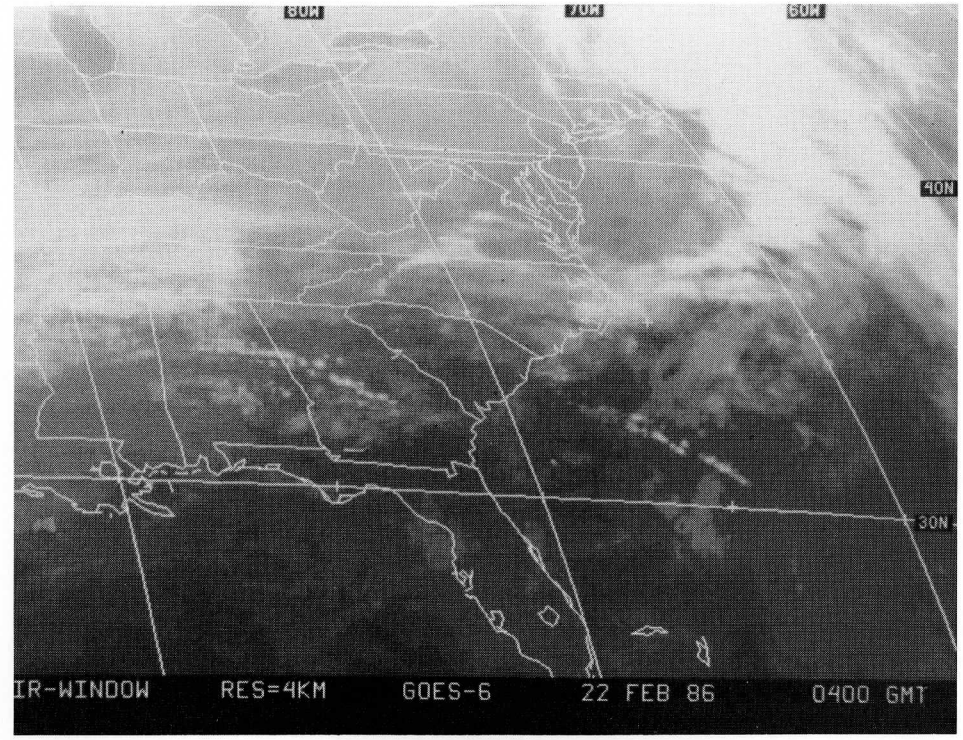
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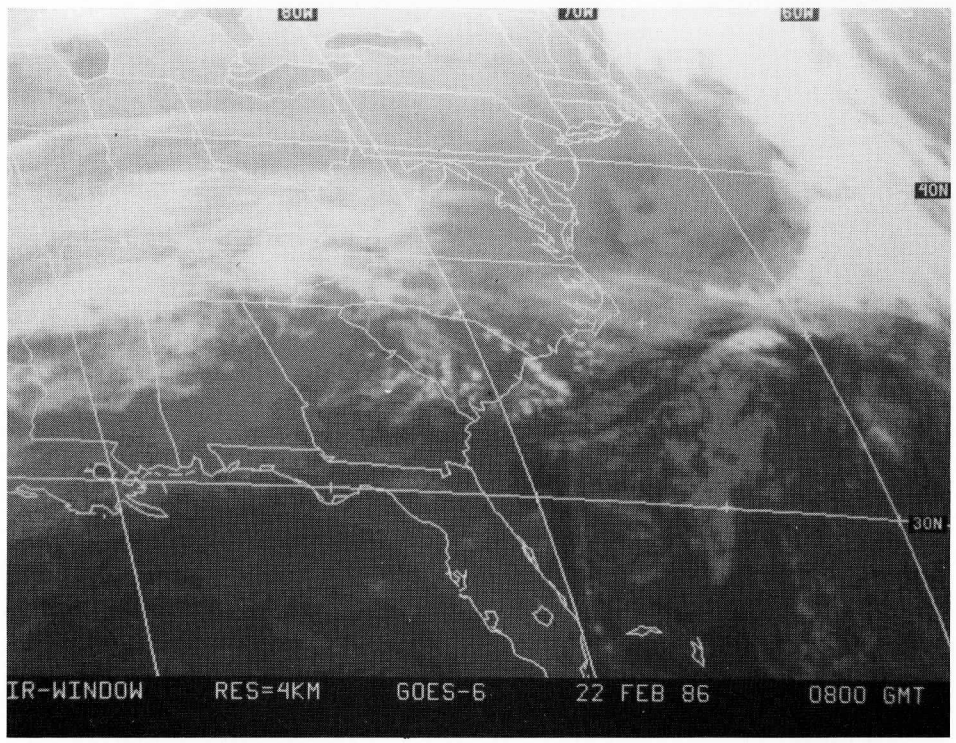
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END OF IOP

IOP #8 - Coastal Cyclogenesis
February 22 - February 24

Satellite Synopsis

Water Vapor

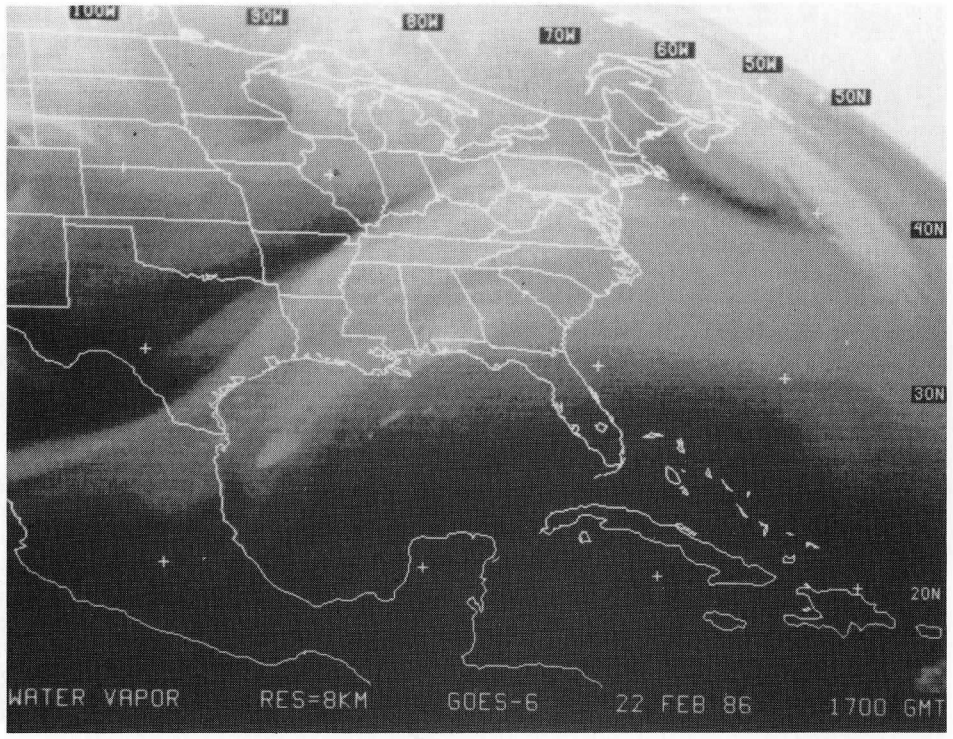
- Wave in Mexico on 22nd amplifies and moves off Cape Hatteras by the 24th. There is a strong subsidence region to the northwest of the wave. Note "S" pattern of moisture.
- Jet axis very evident from Texas to Pennsylvania.

IR

- 22nd, circulation off New England coast.
- Strong southwest flow pattern over GALE region indicated by cirrus pattern.

Visible

- 22nd, convective line with rope cloud over Gulf Stream dissipates late.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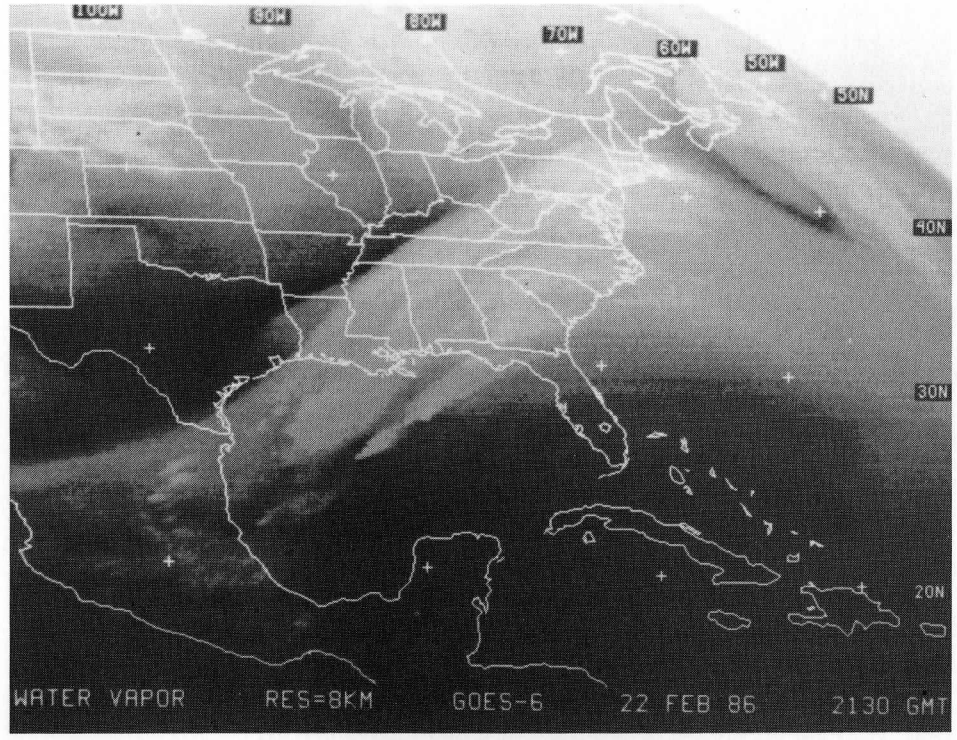
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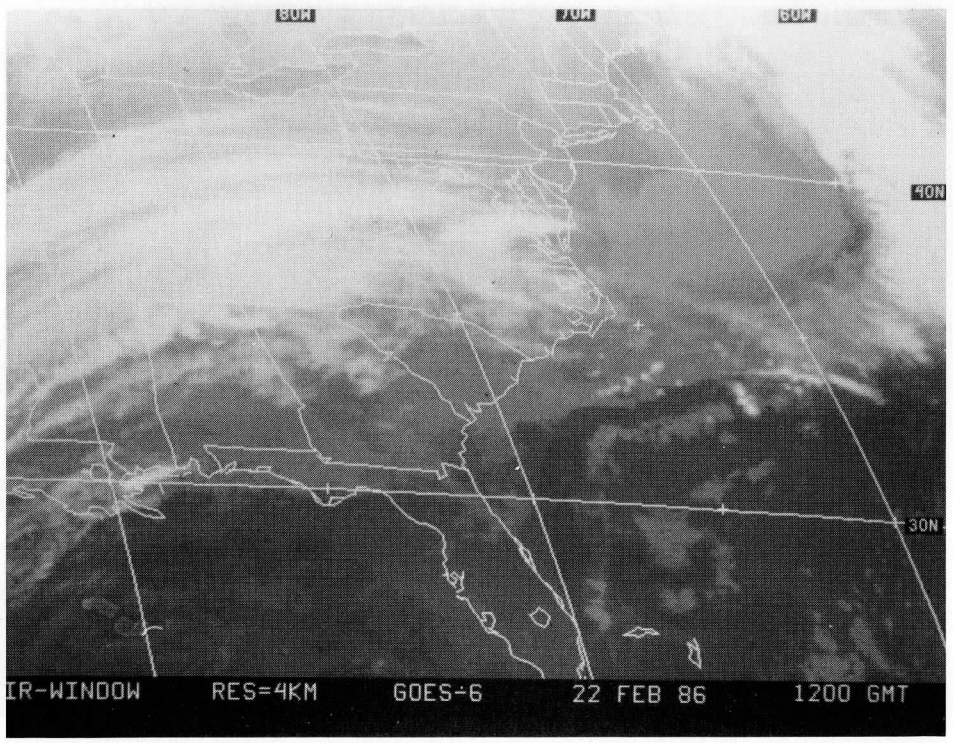
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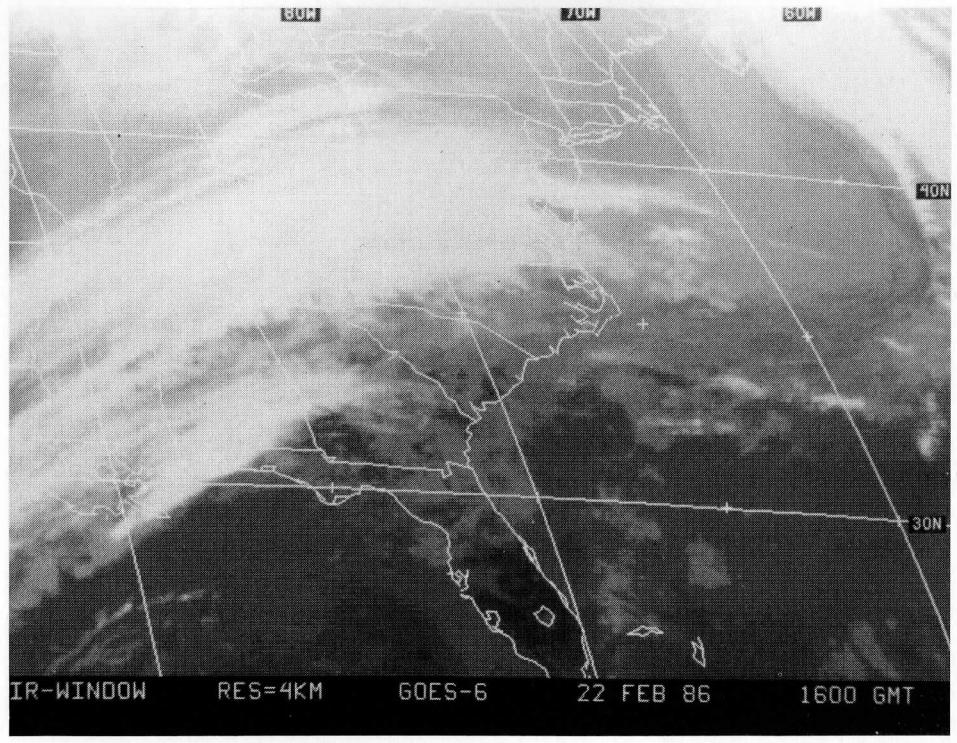
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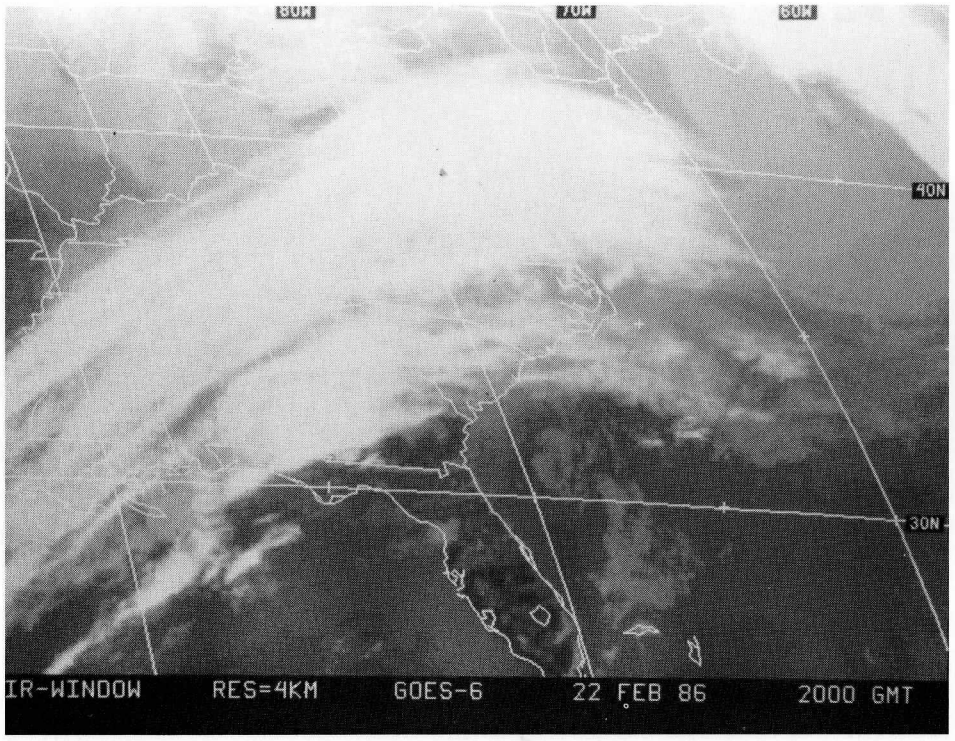
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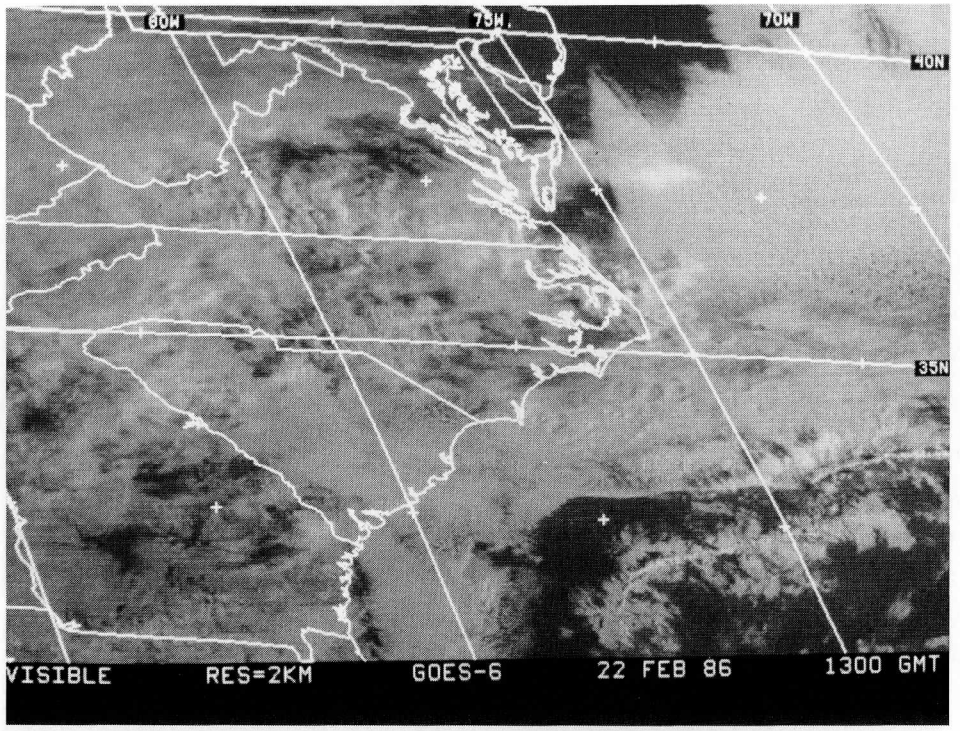
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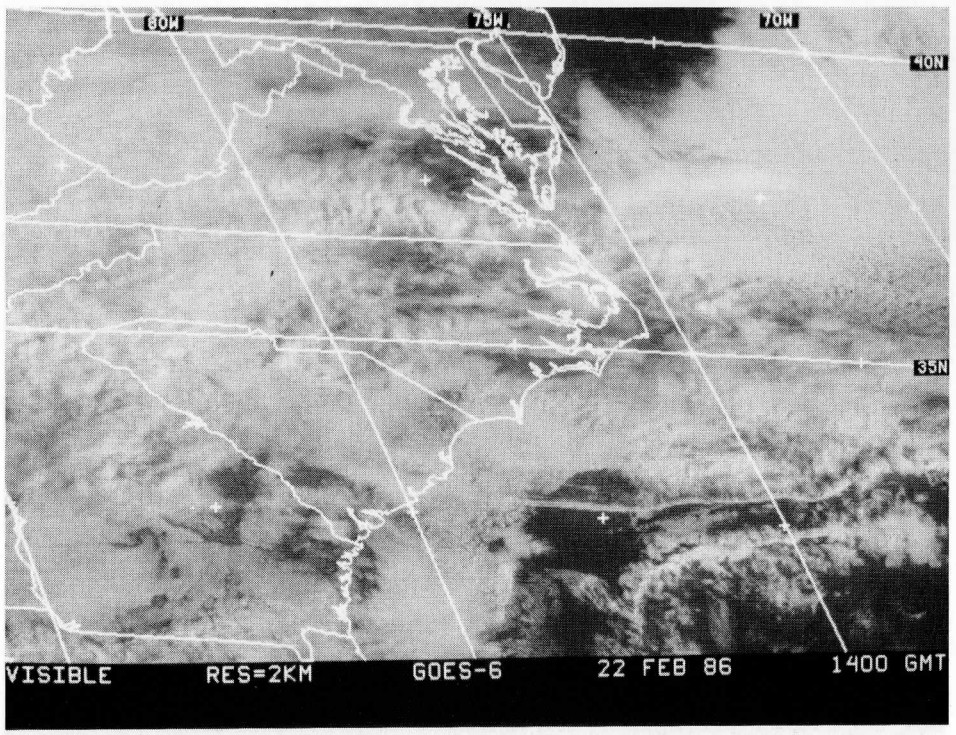
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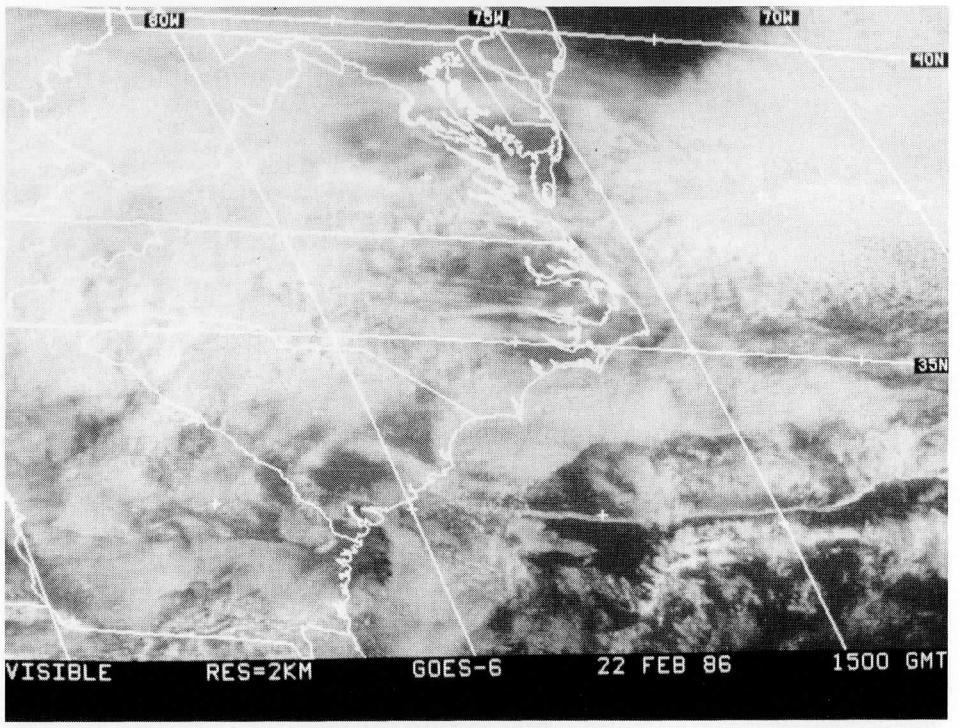
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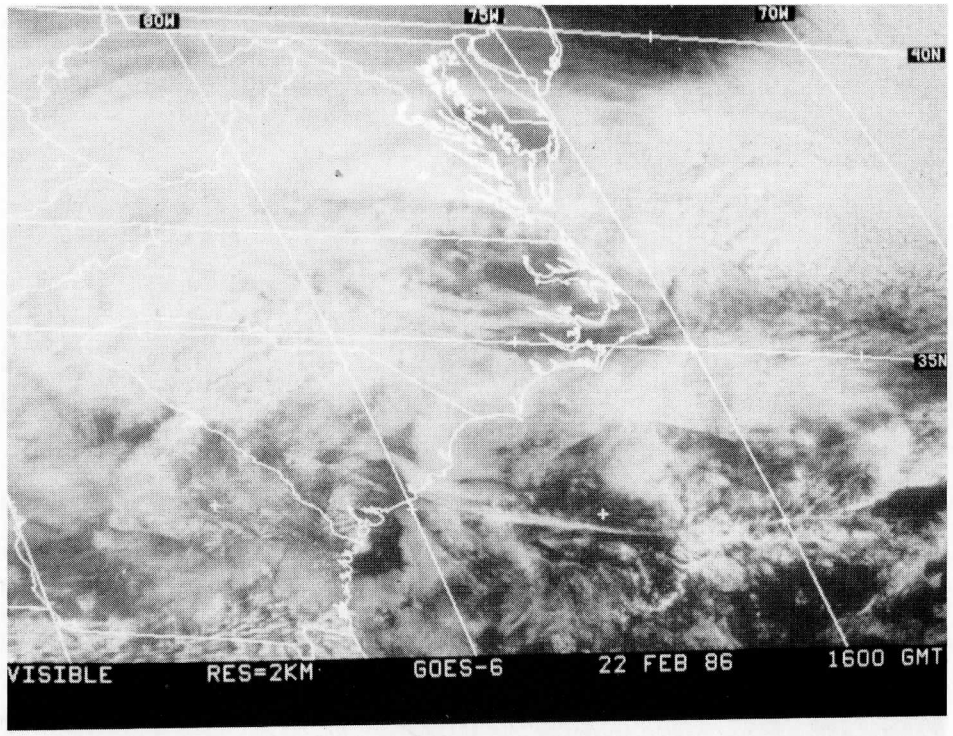
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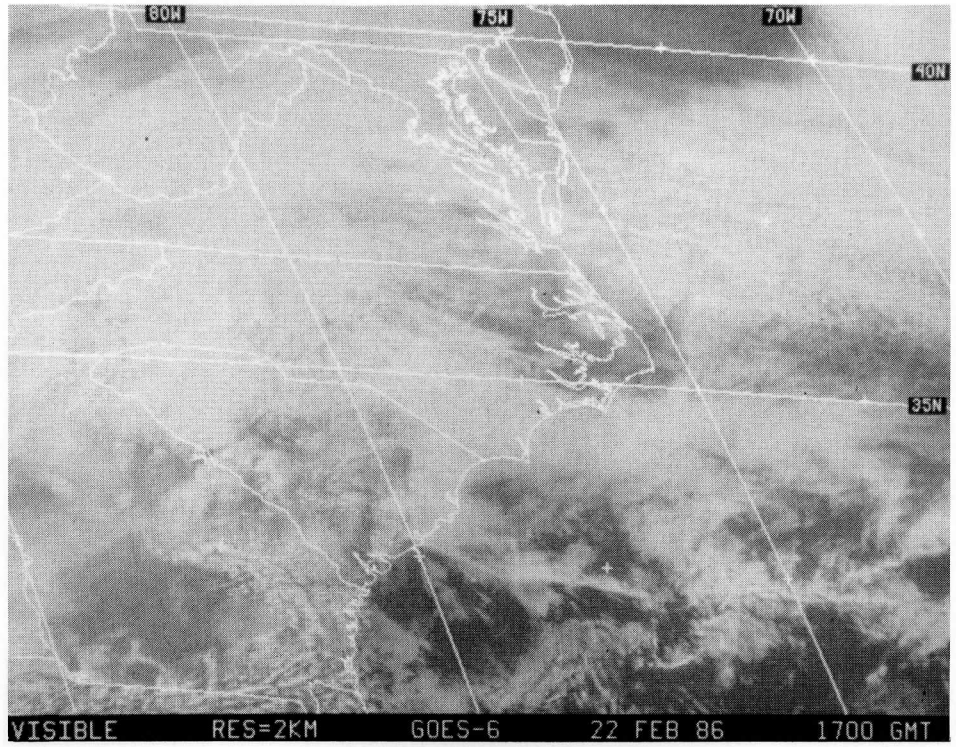
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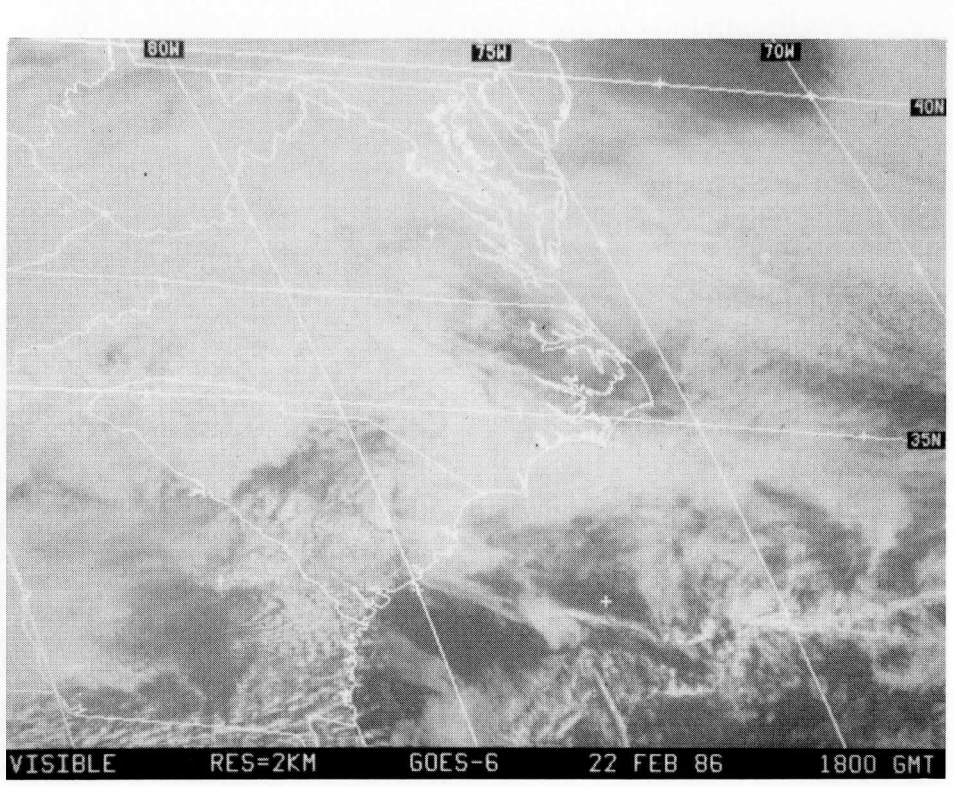
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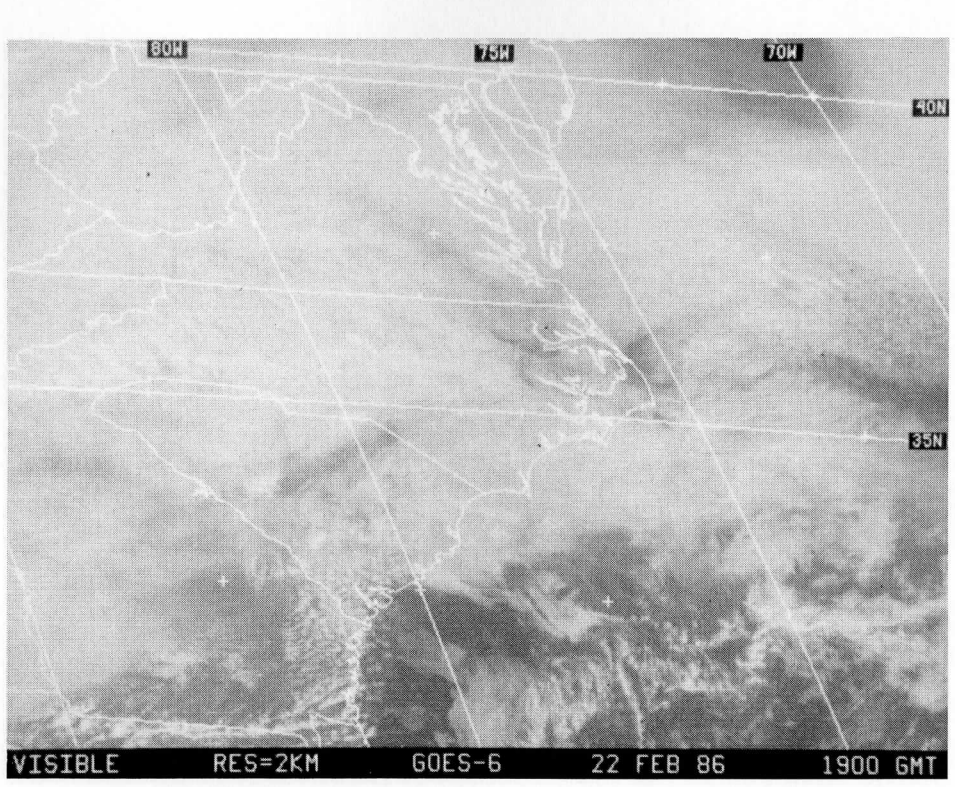
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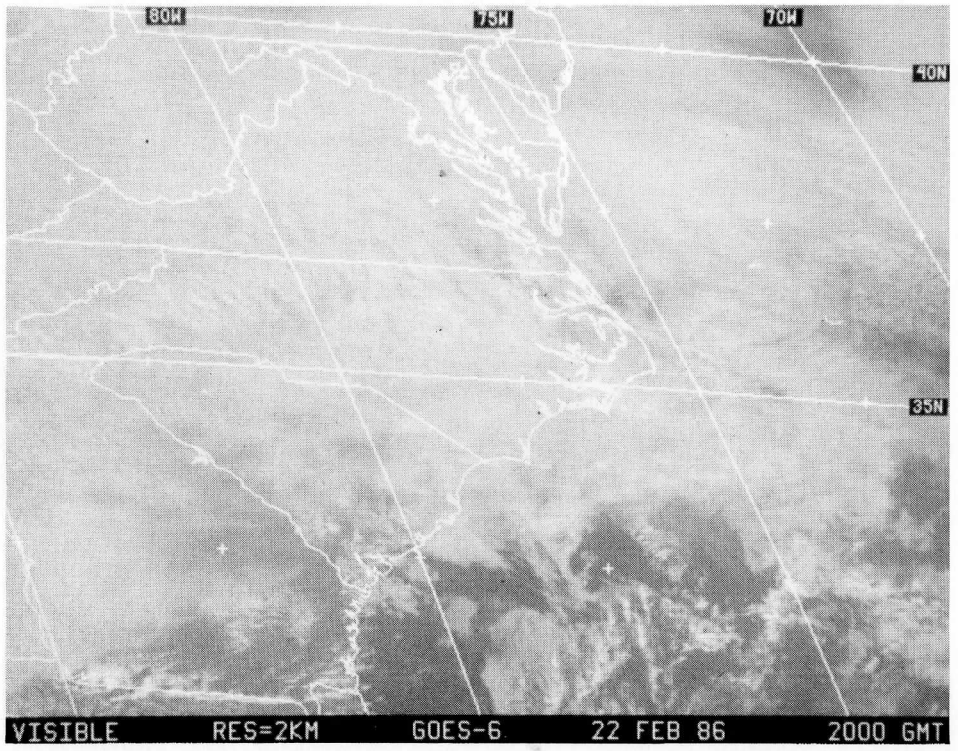
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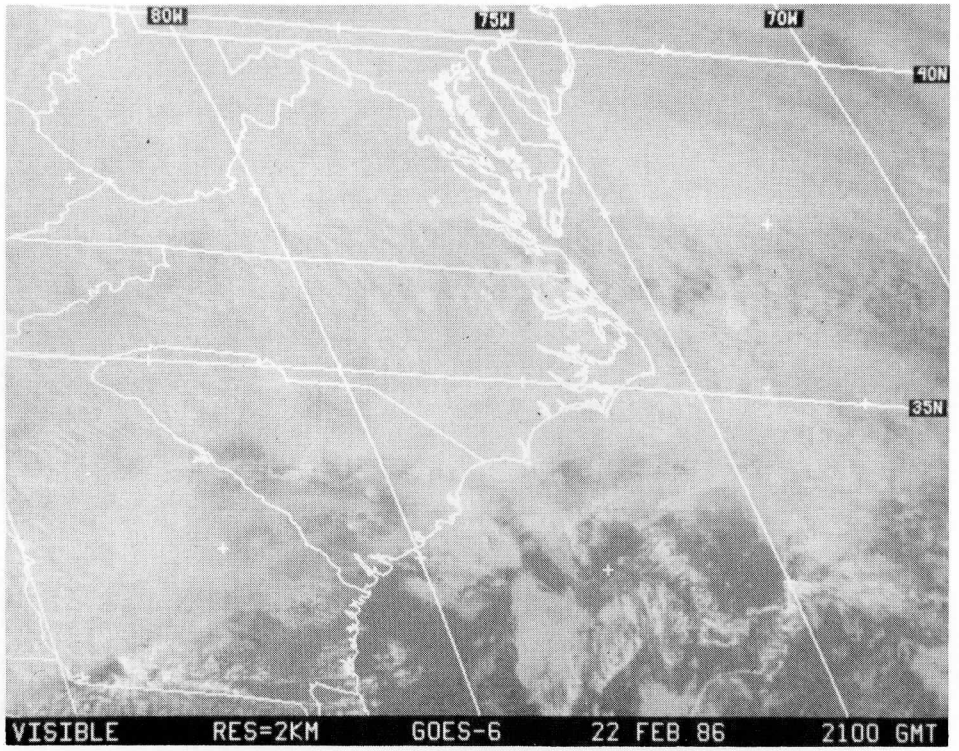
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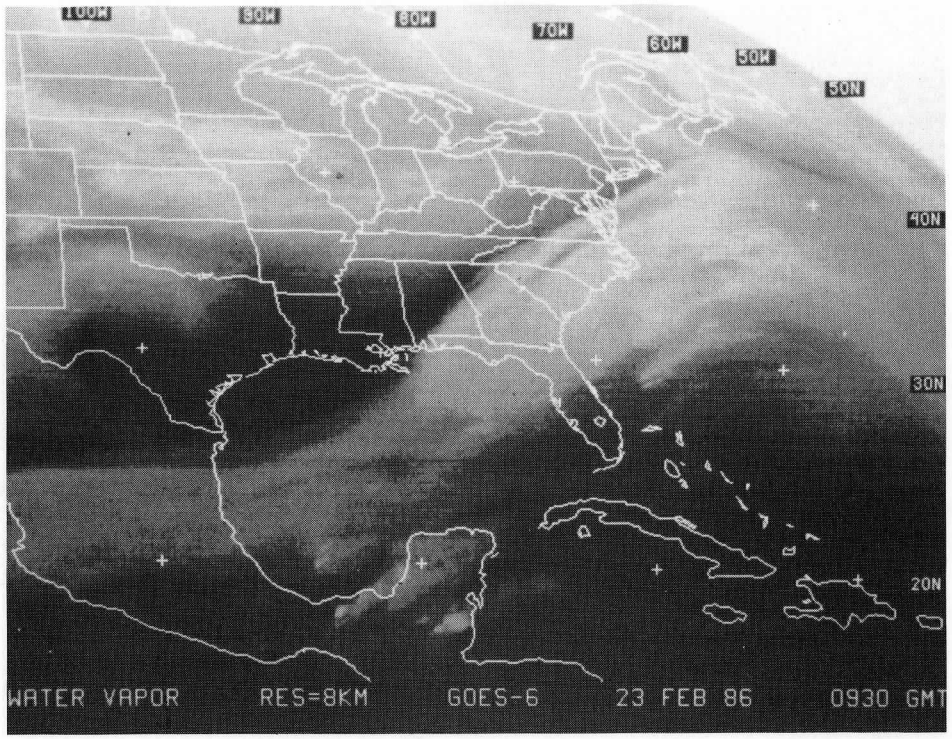
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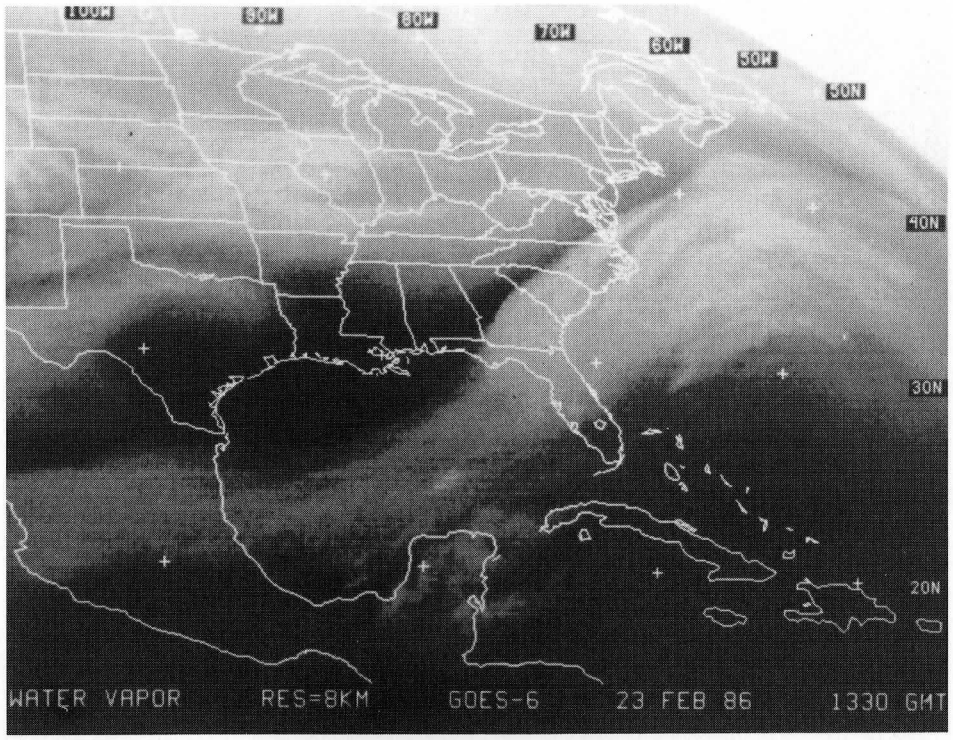
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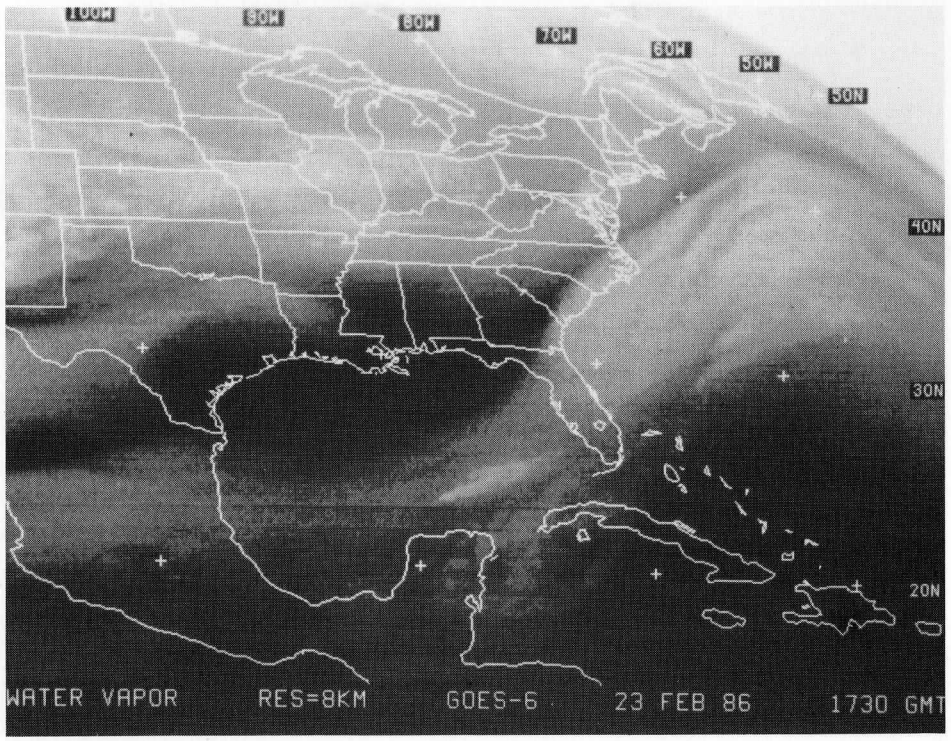
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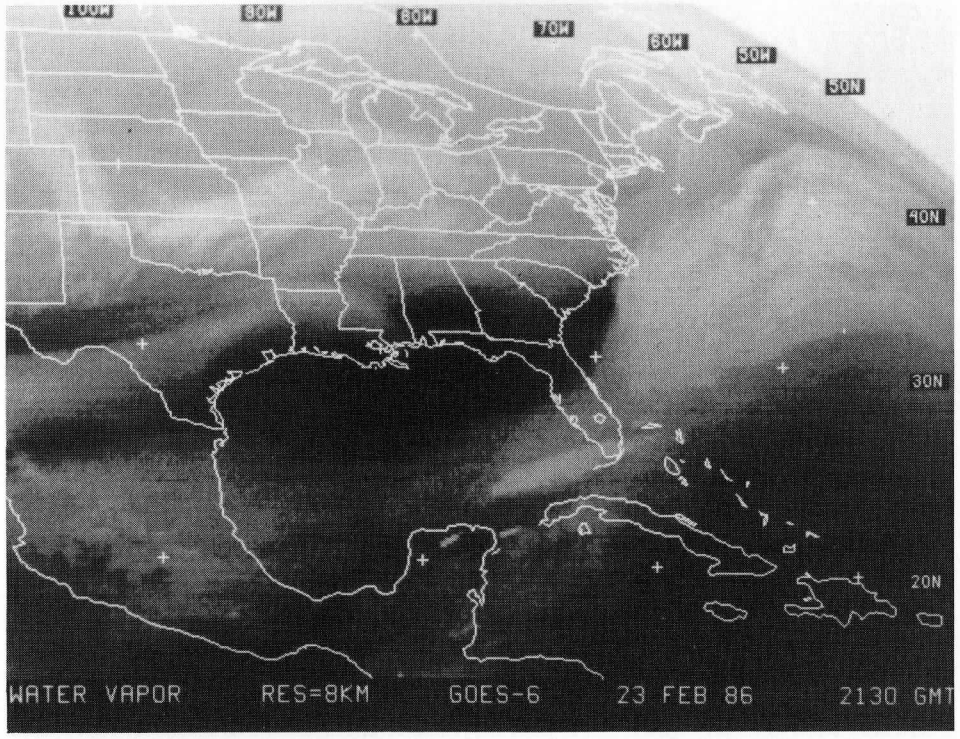
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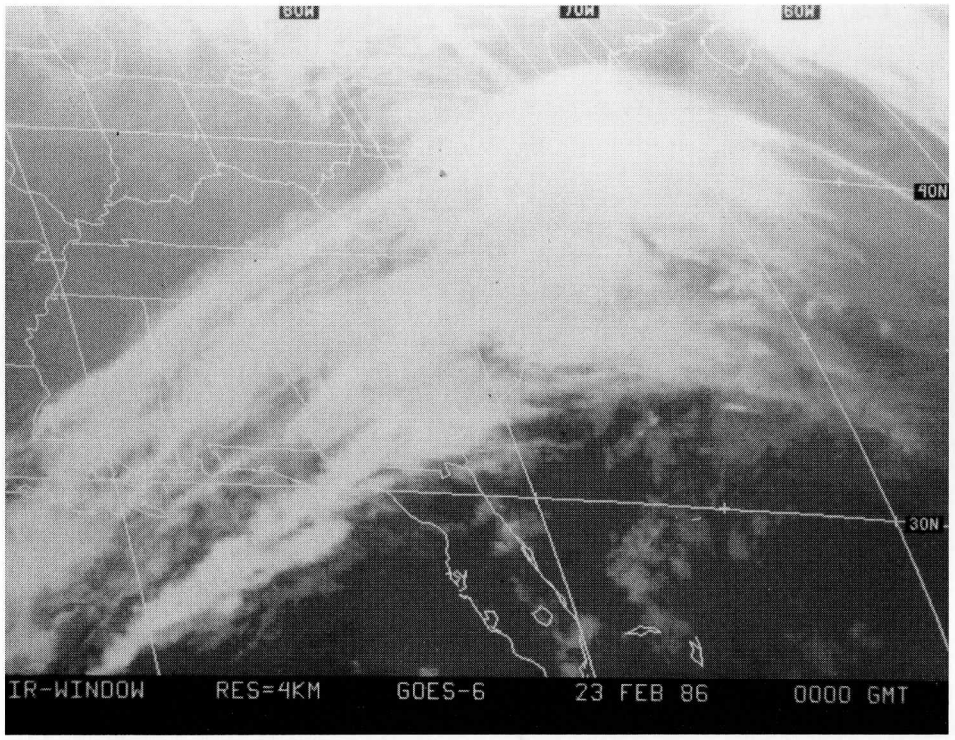
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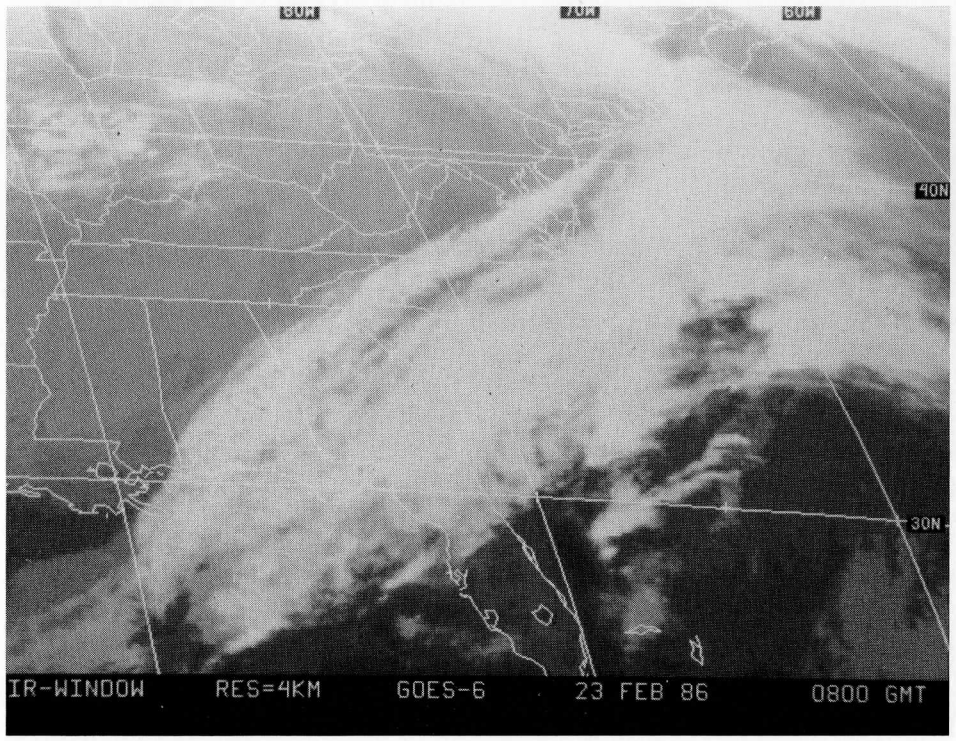
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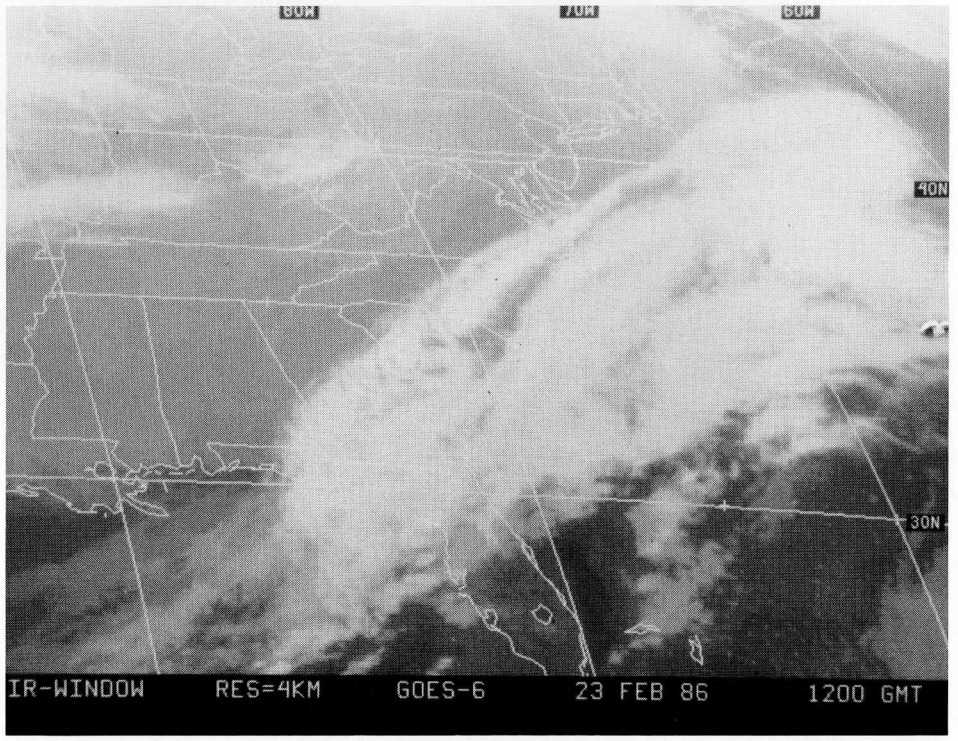
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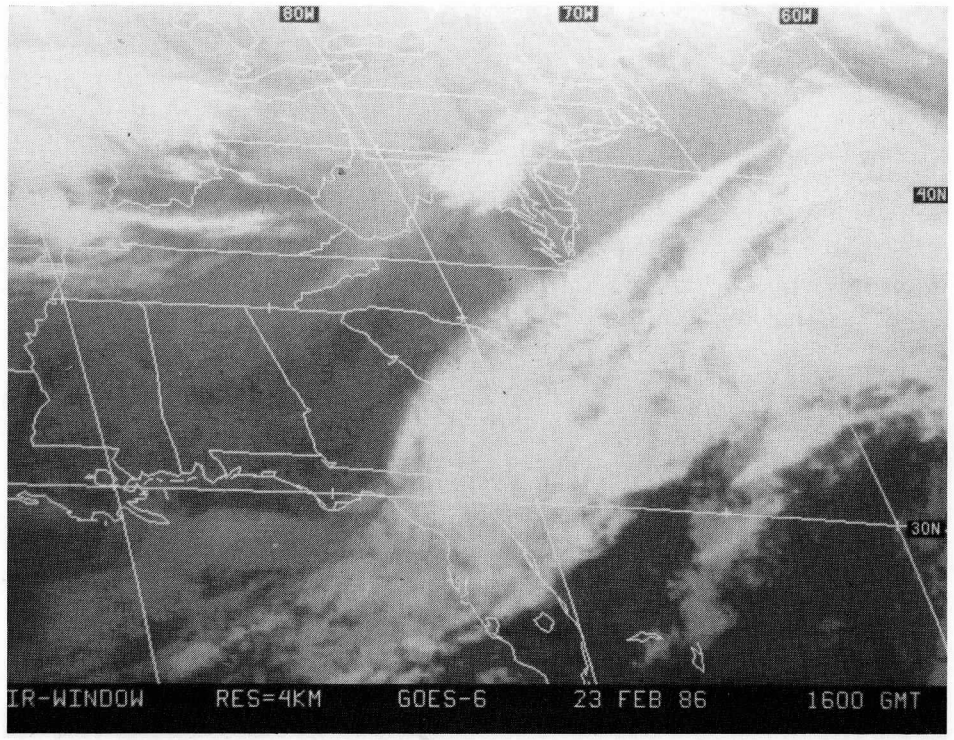
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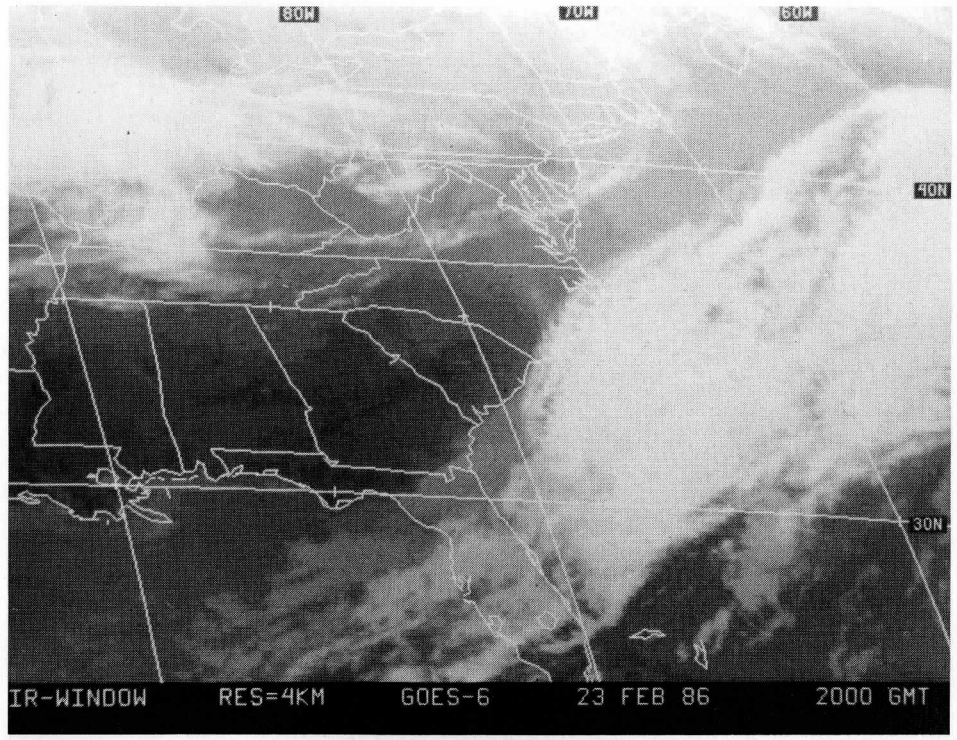
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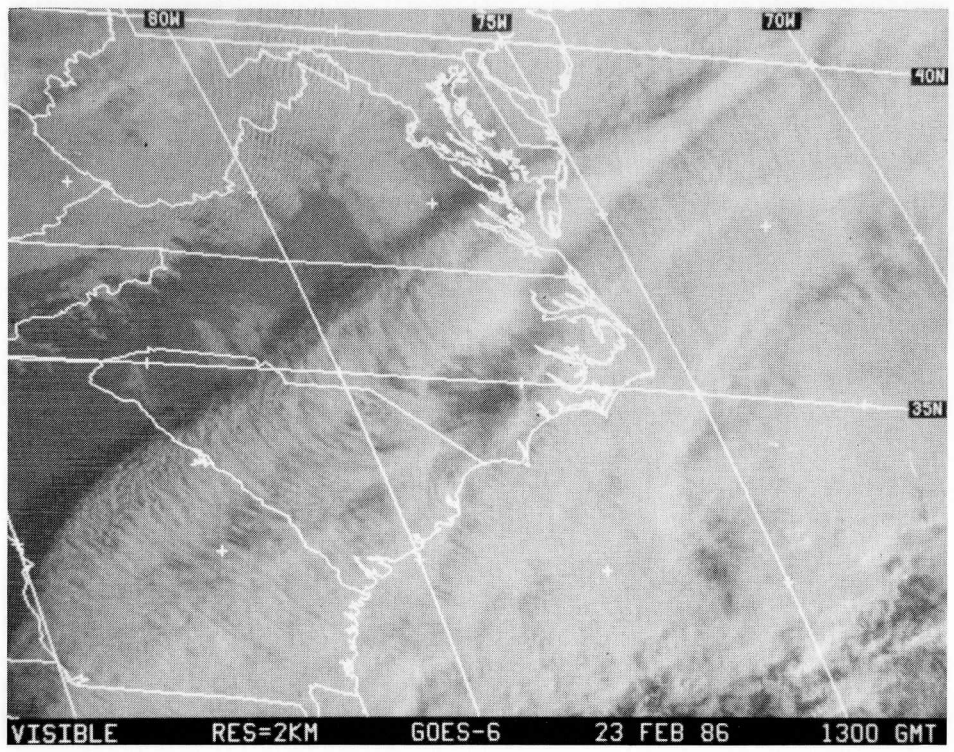
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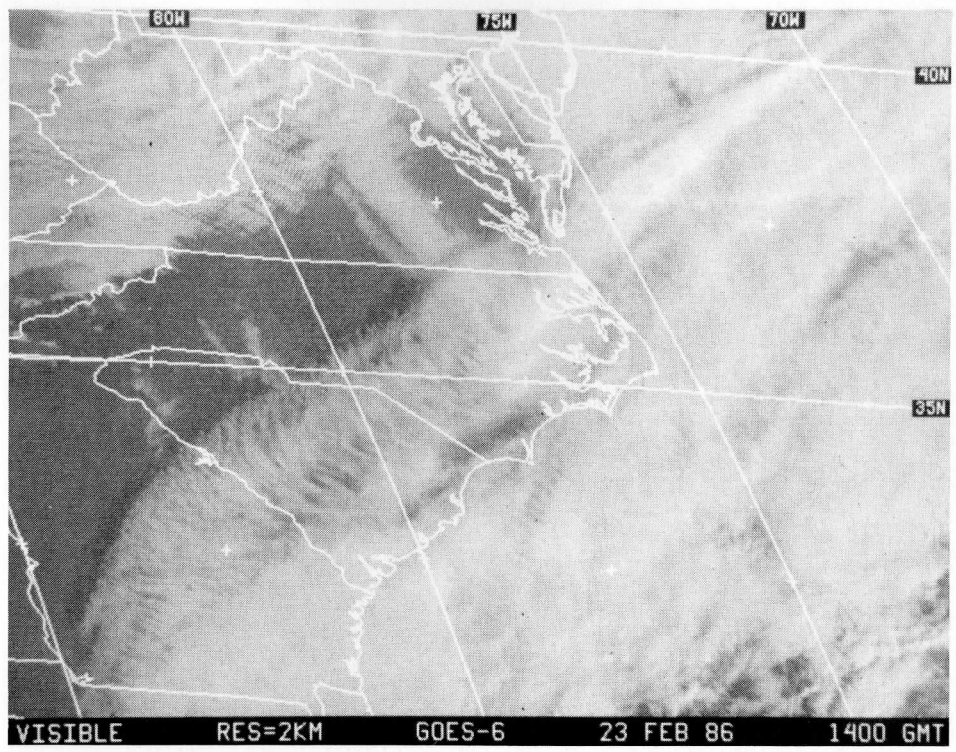
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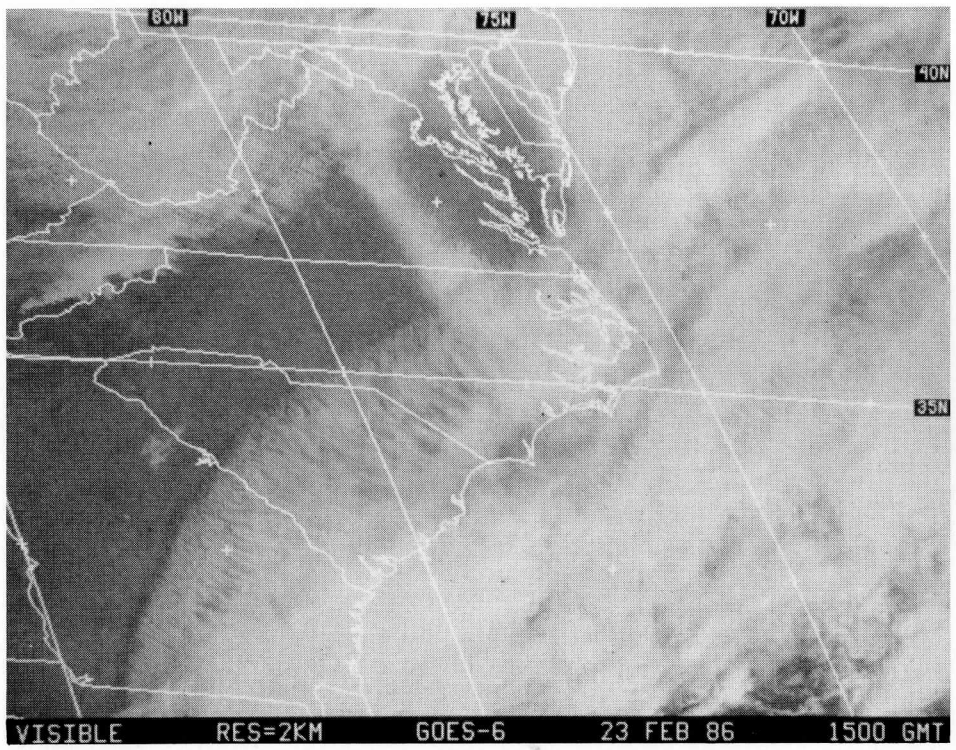
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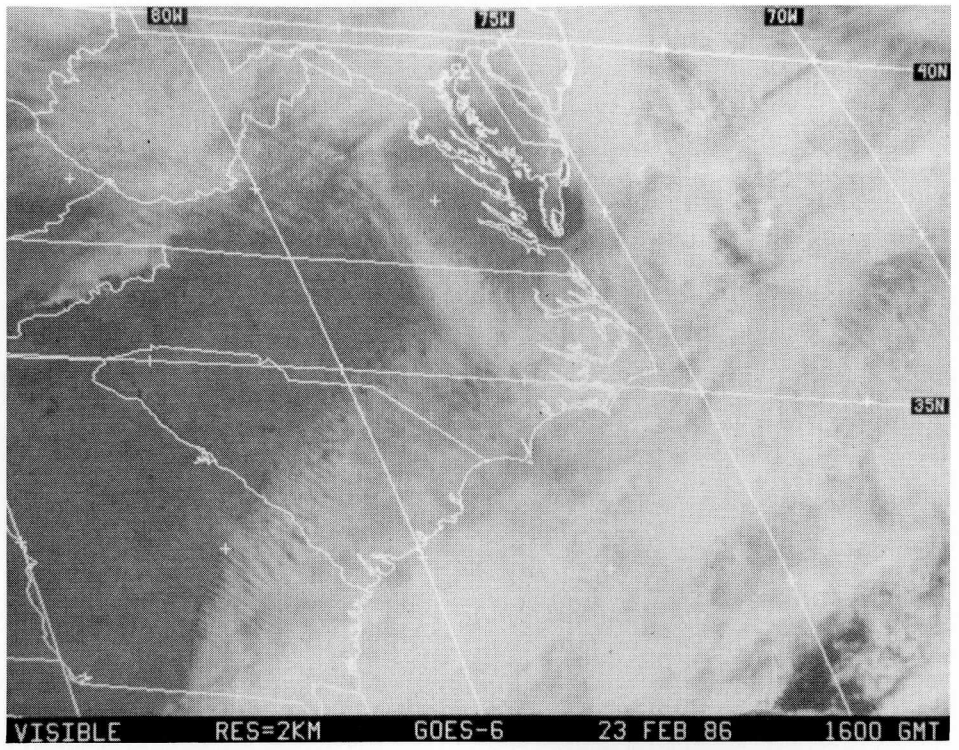
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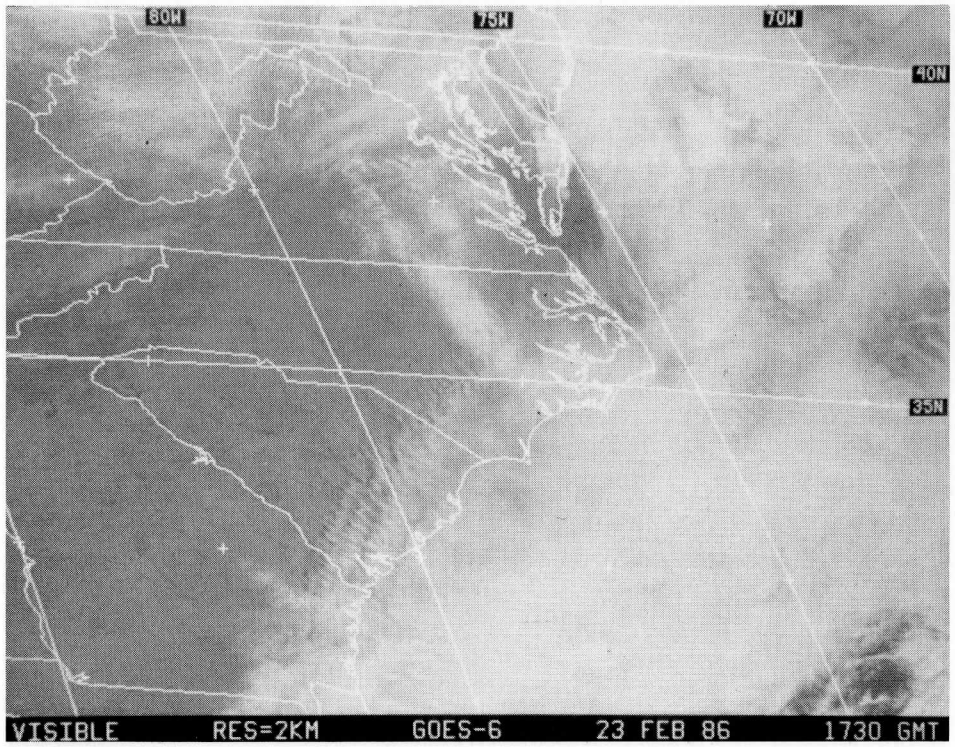
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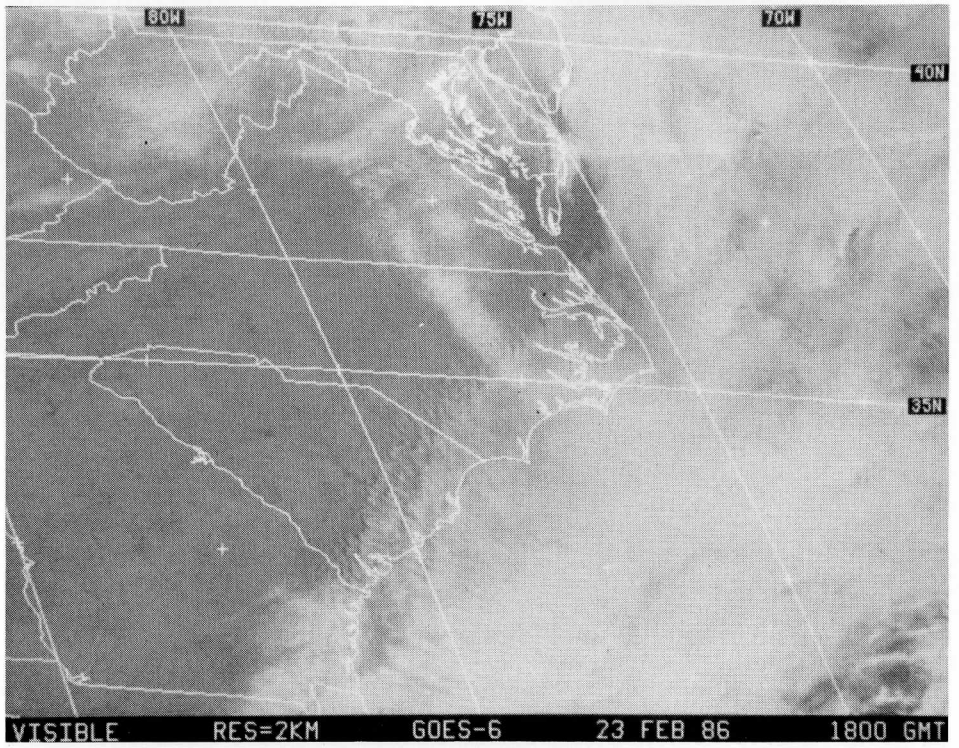
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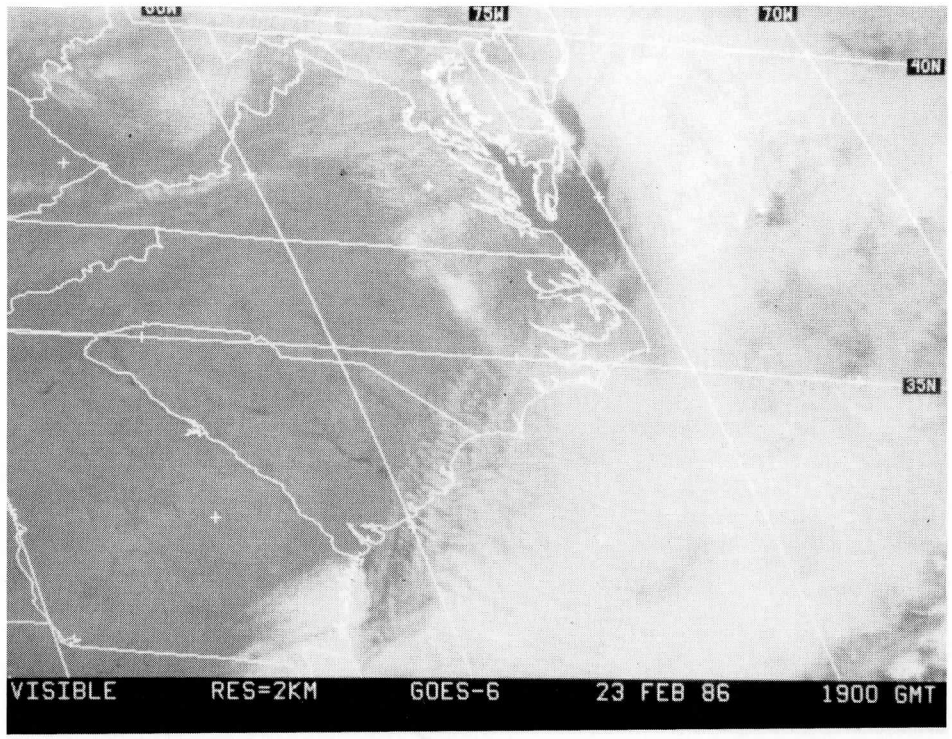
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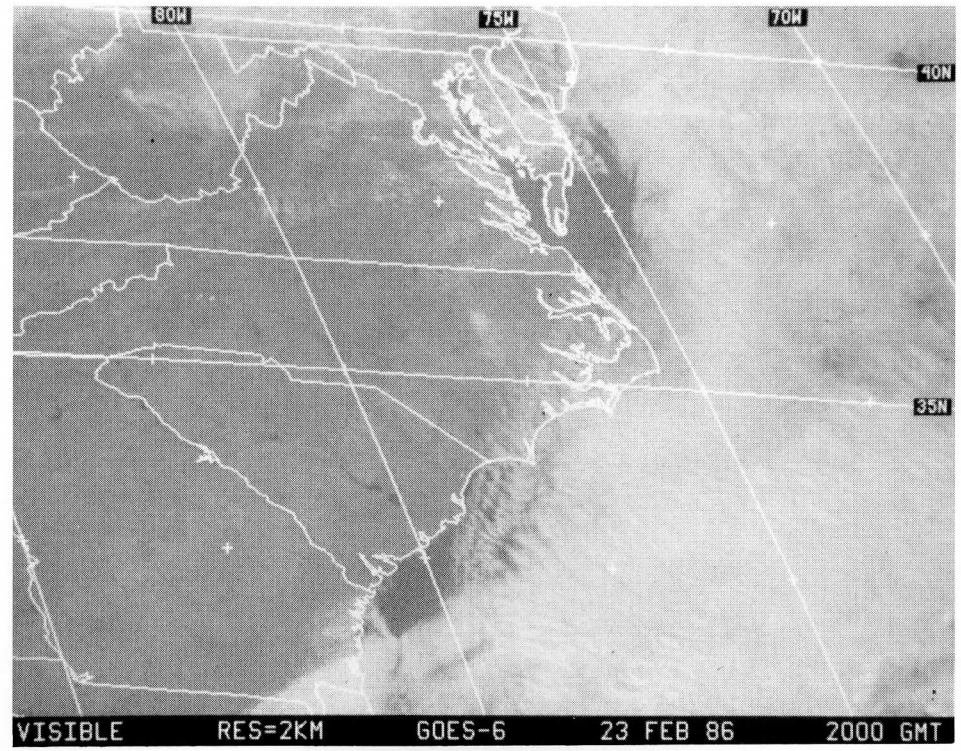
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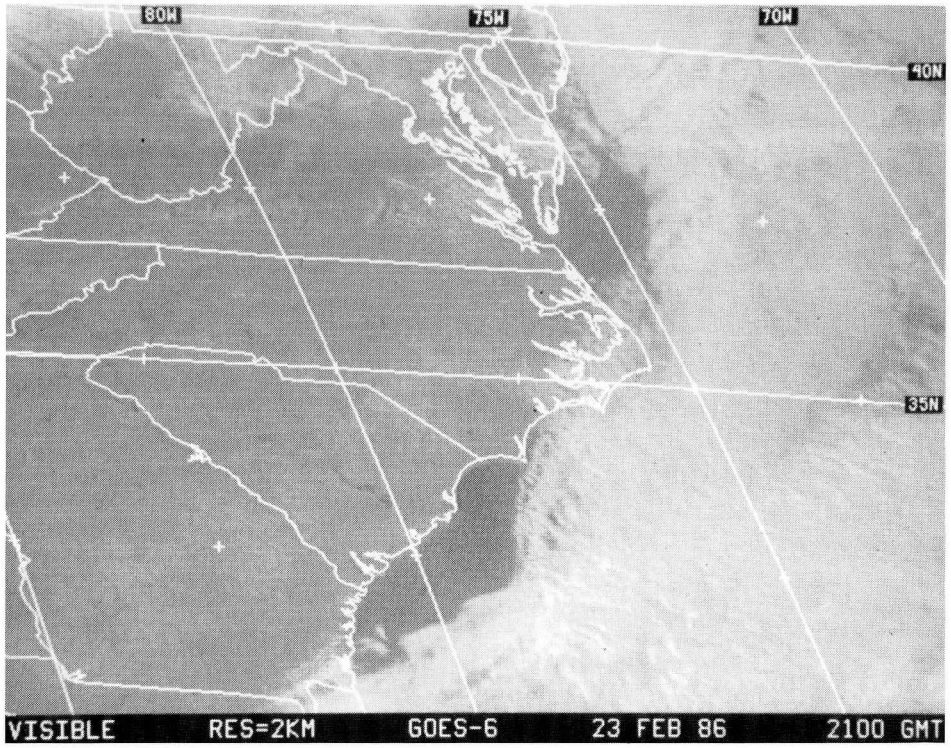
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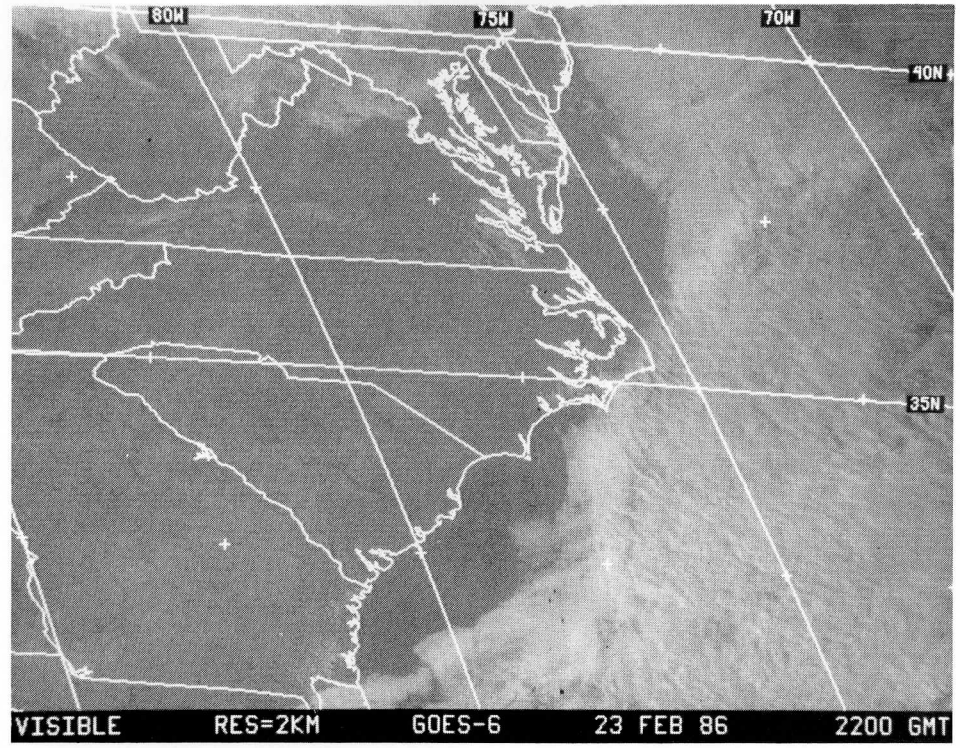
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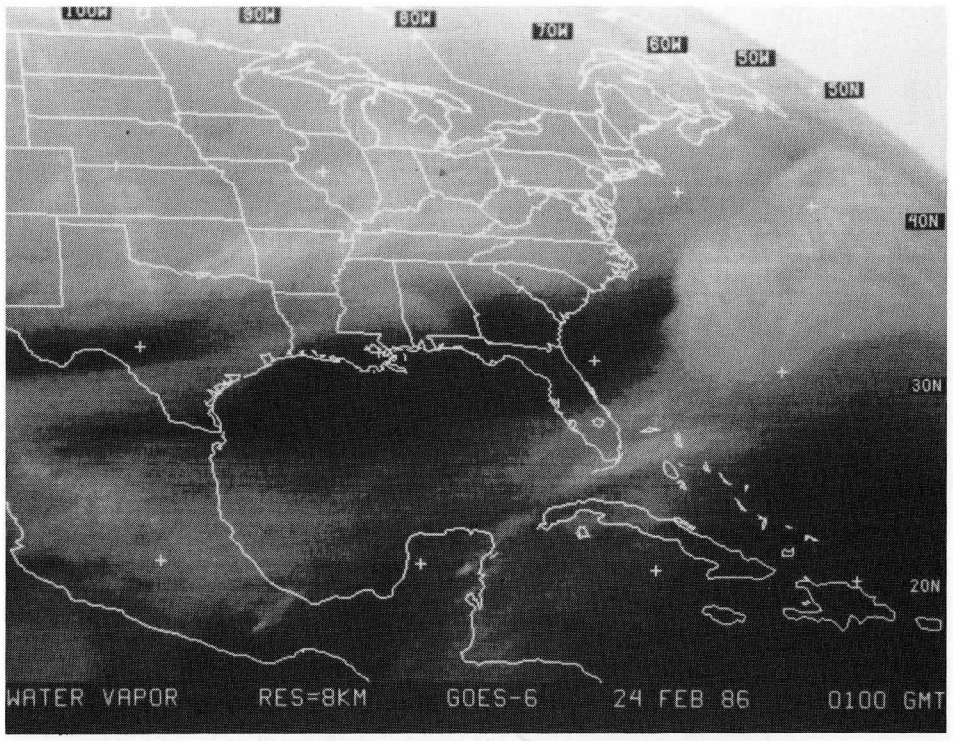
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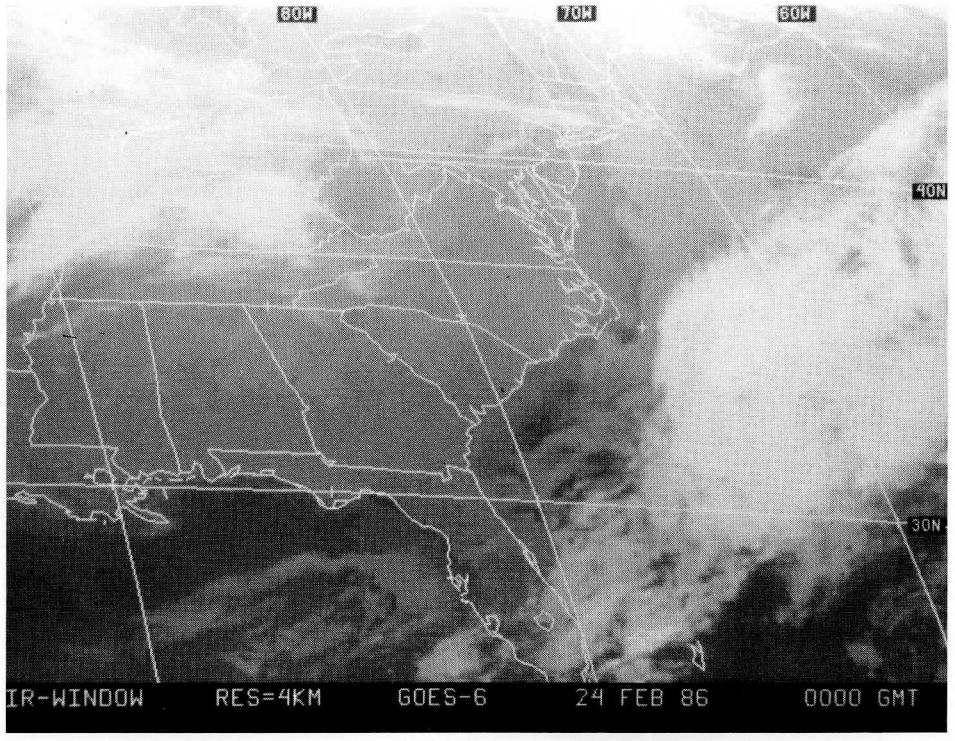
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END OF IOP

IOP #9 - Weak Onshore Cyclone / Rapid Development Offshore
February 24 - February 26

Satellite Synopsis

Water Vapor

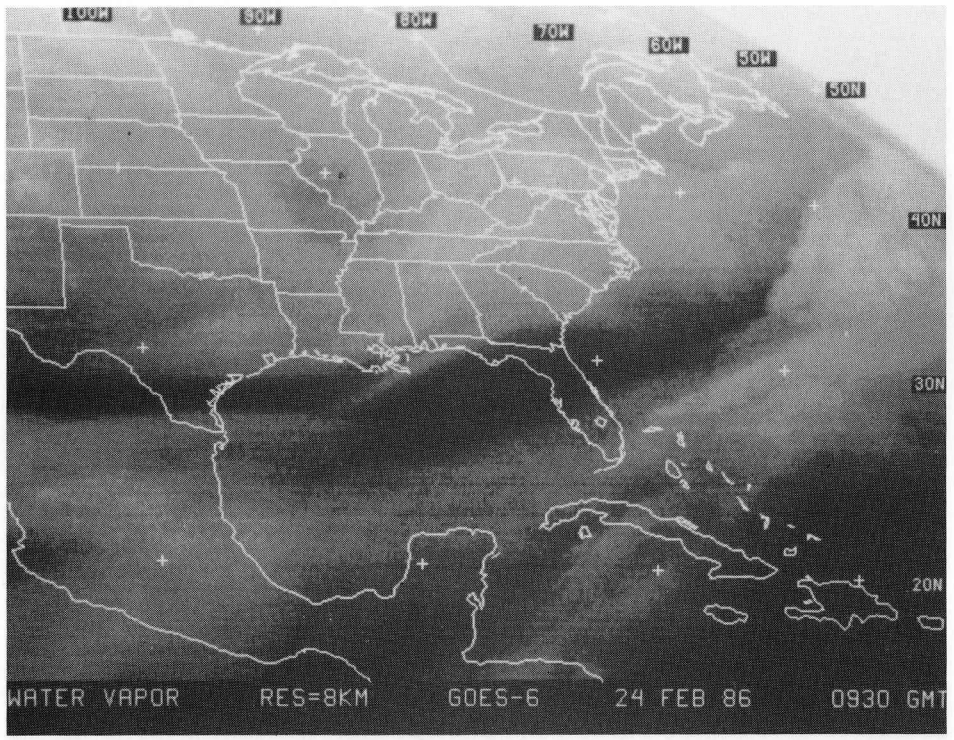
- Dry band from western Mexico east through Florida.
- Hint of short wave circulation on the 24th in the Ohio valley moves to northeast of Cape Hatteras and strengthens on the 25th.

IR

- Strong banding of low level stratocumulus well offshore on 26th.
- Fairly disorganized swirl with short wave.

Visible

- 24th, dissipating fog in southeast Georgia.
- Some weak convergence lines, clusters in Gulf.
- Frontal band clouds move through Georgia and South Carolina with limited convection.
- 25th, cloud streets and open-celled structure over the Atlantic.
- 26th, cloud streets well offshore with convergence lines and banding parallel to the wind.
- 26th, warm air advective-type clouds move over the GALE region.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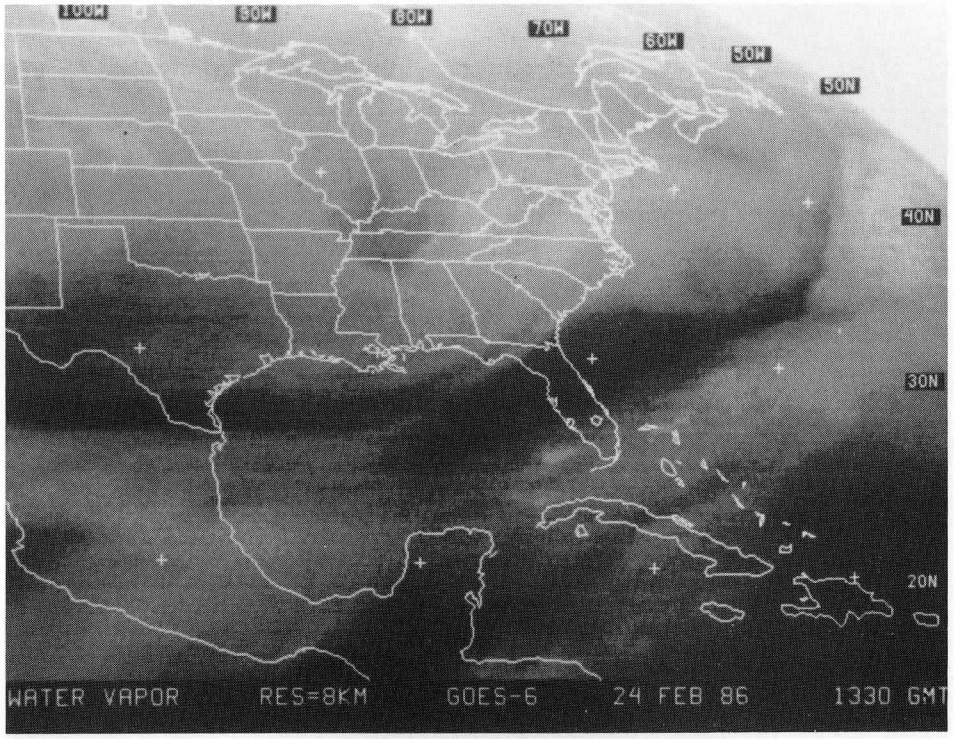
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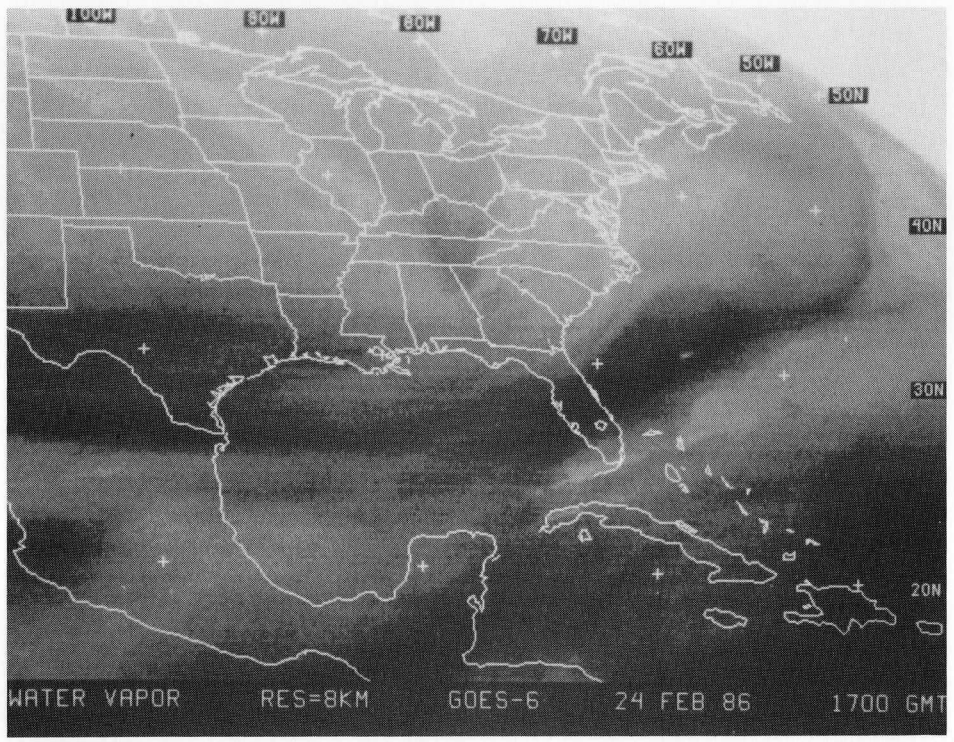
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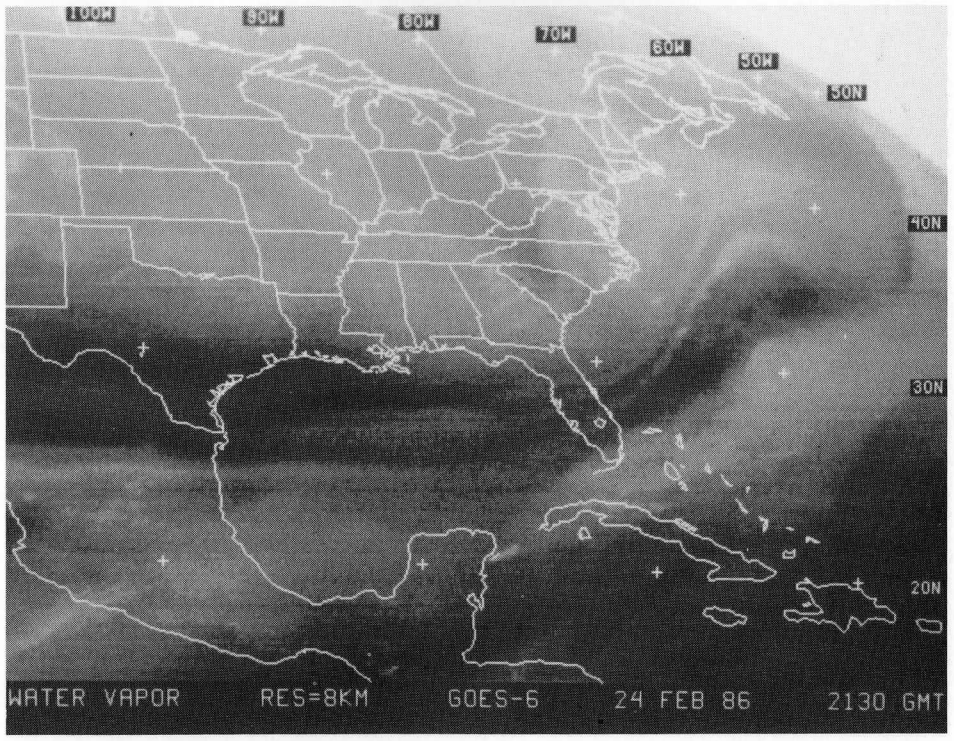
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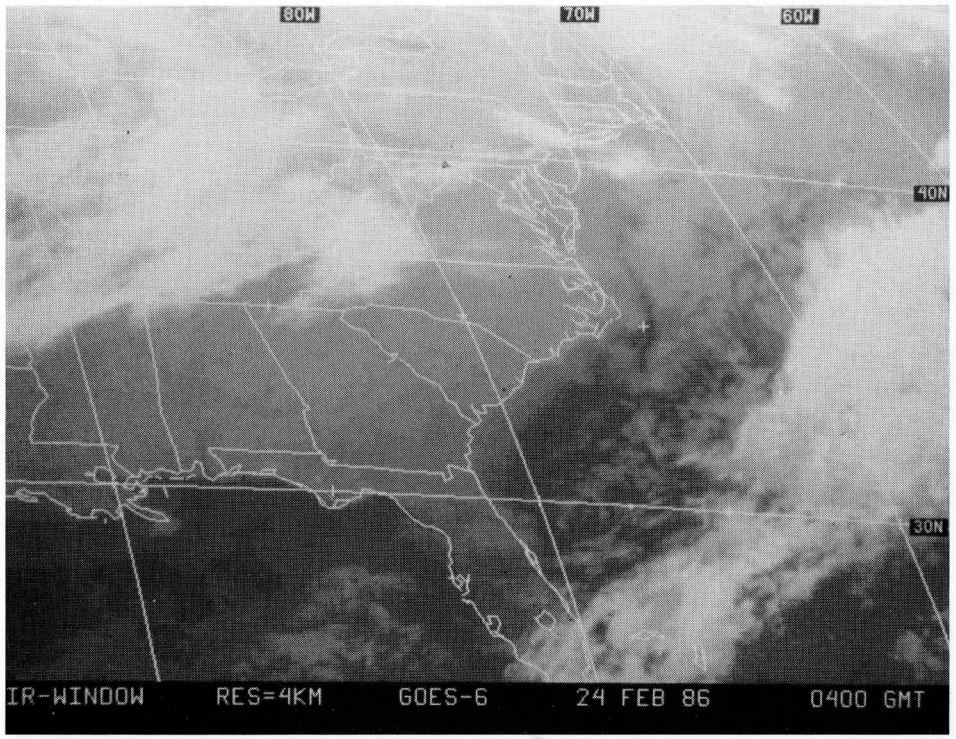
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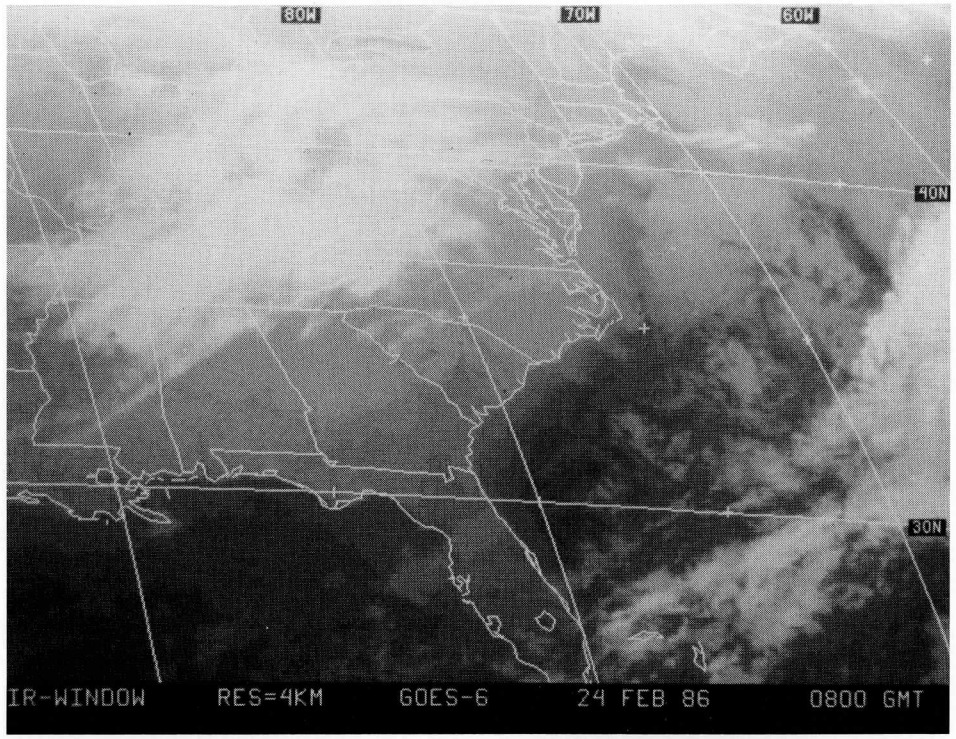
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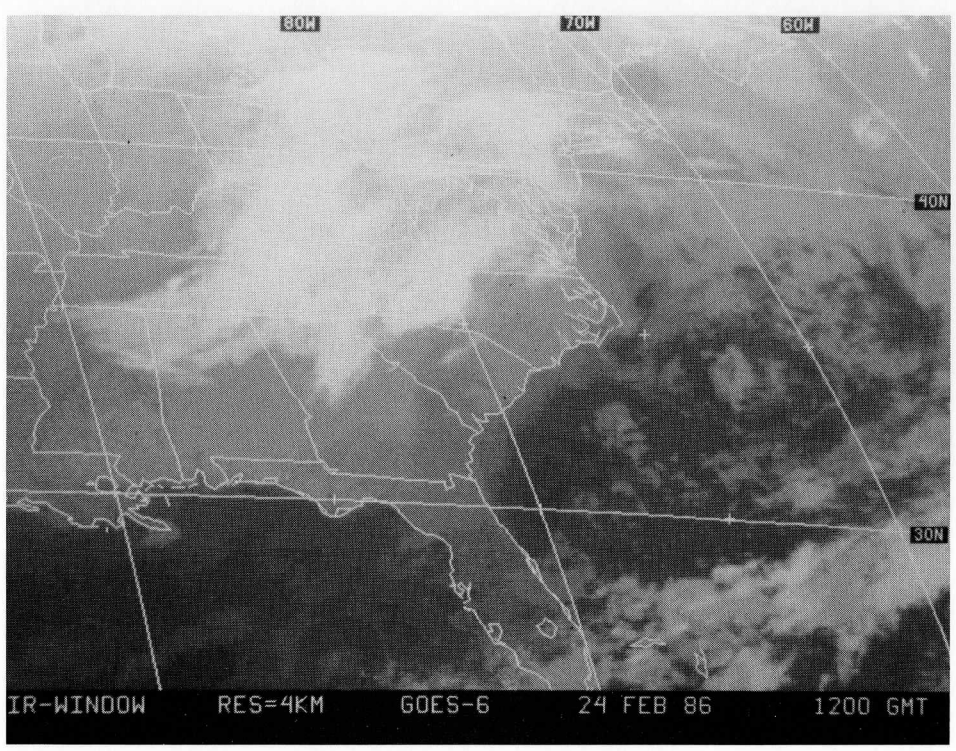
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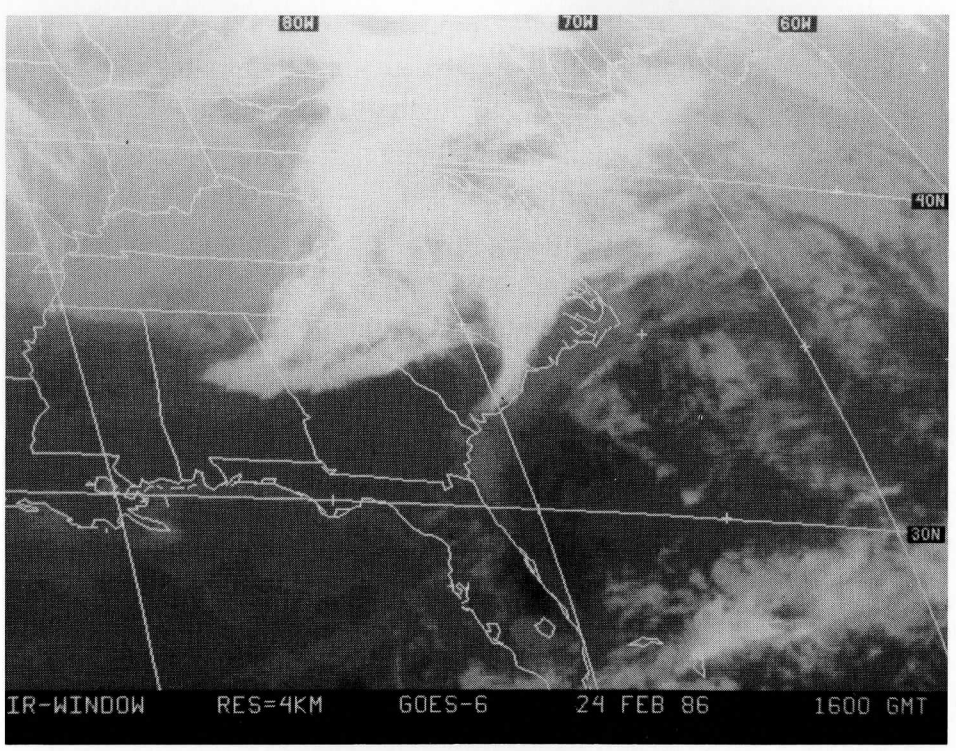
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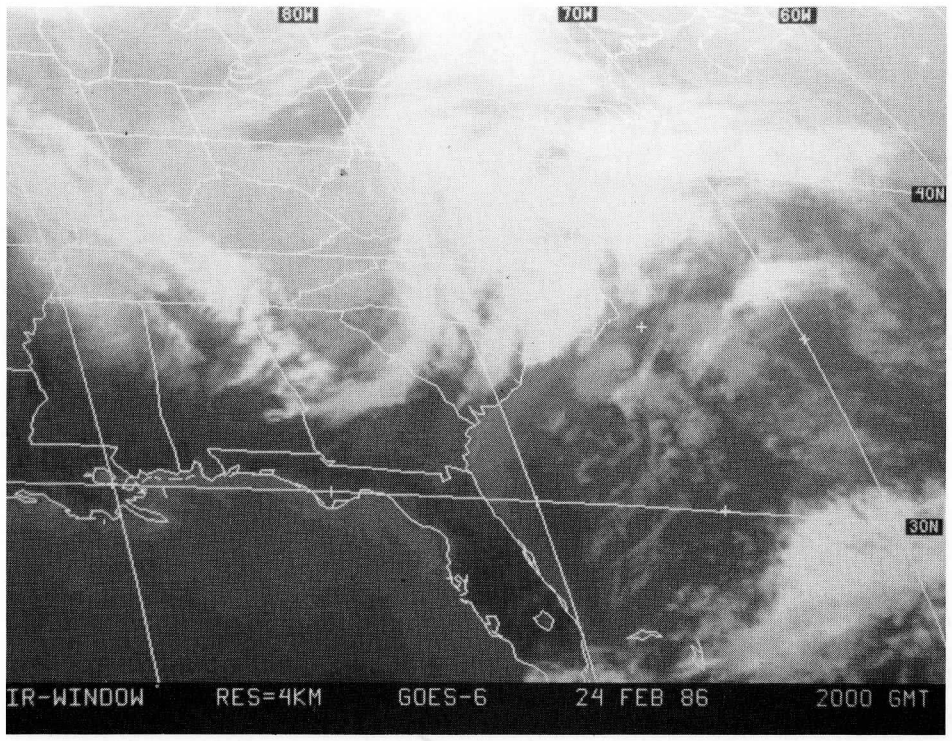
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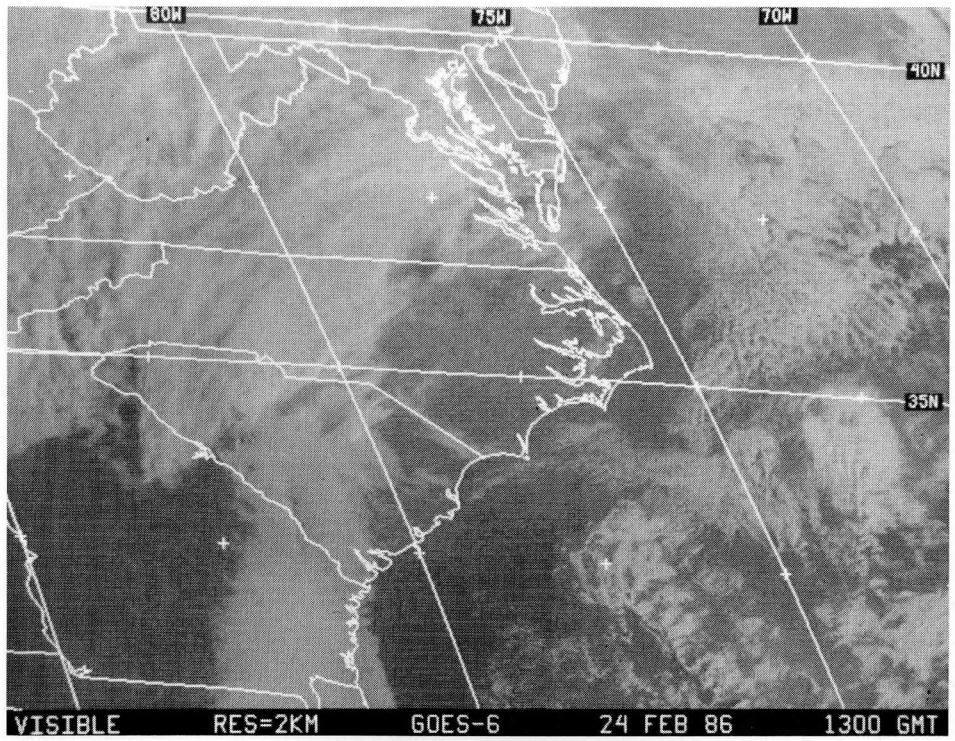
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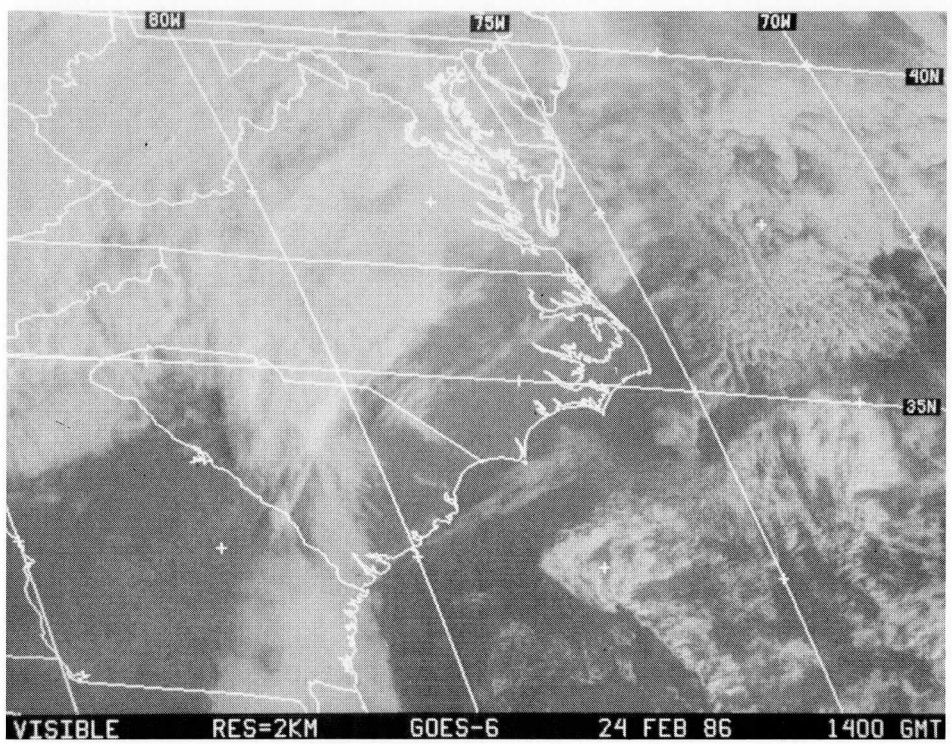
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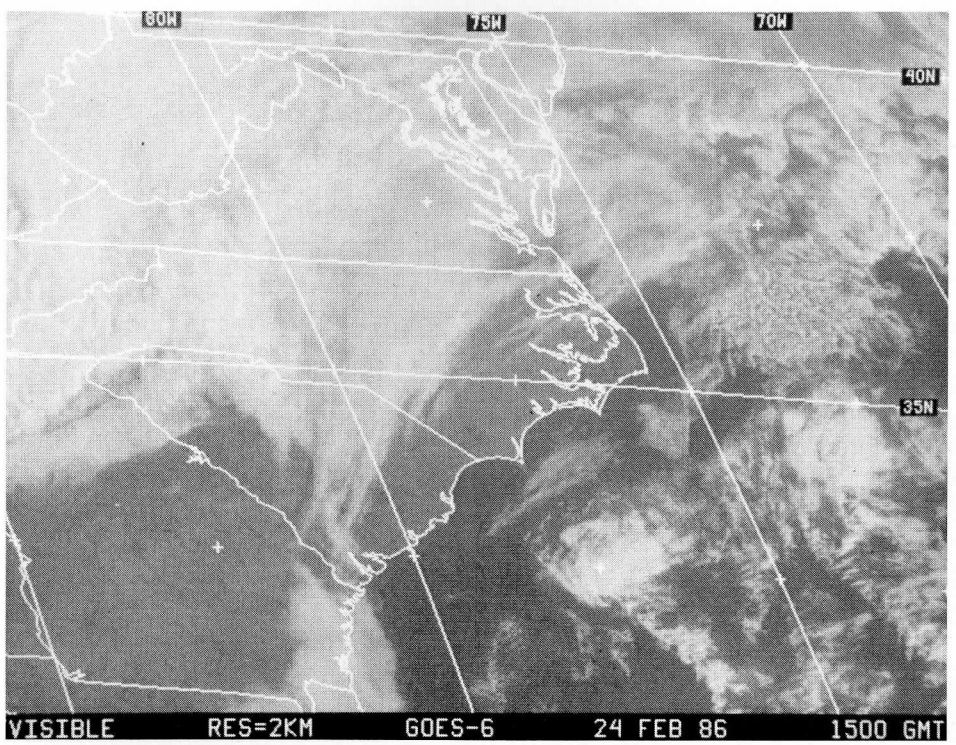
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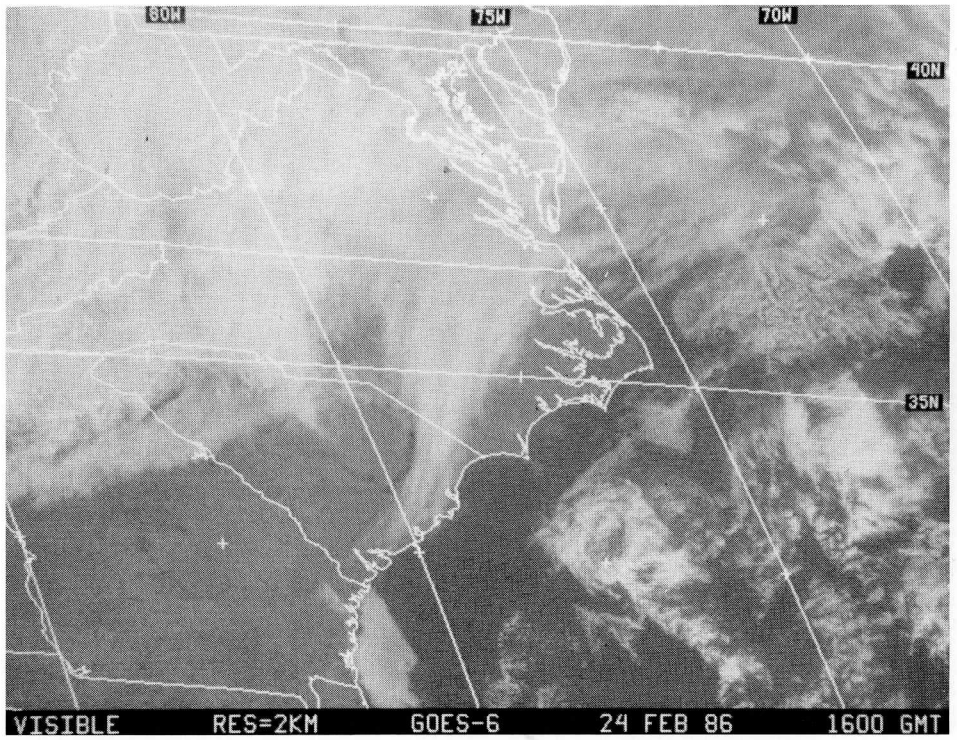
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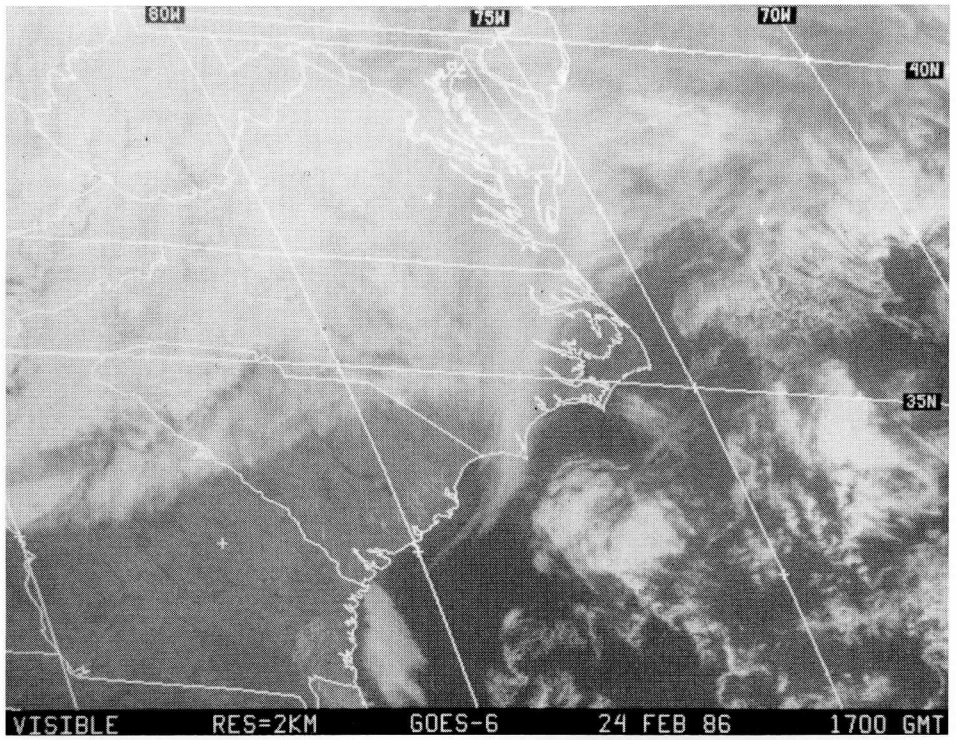
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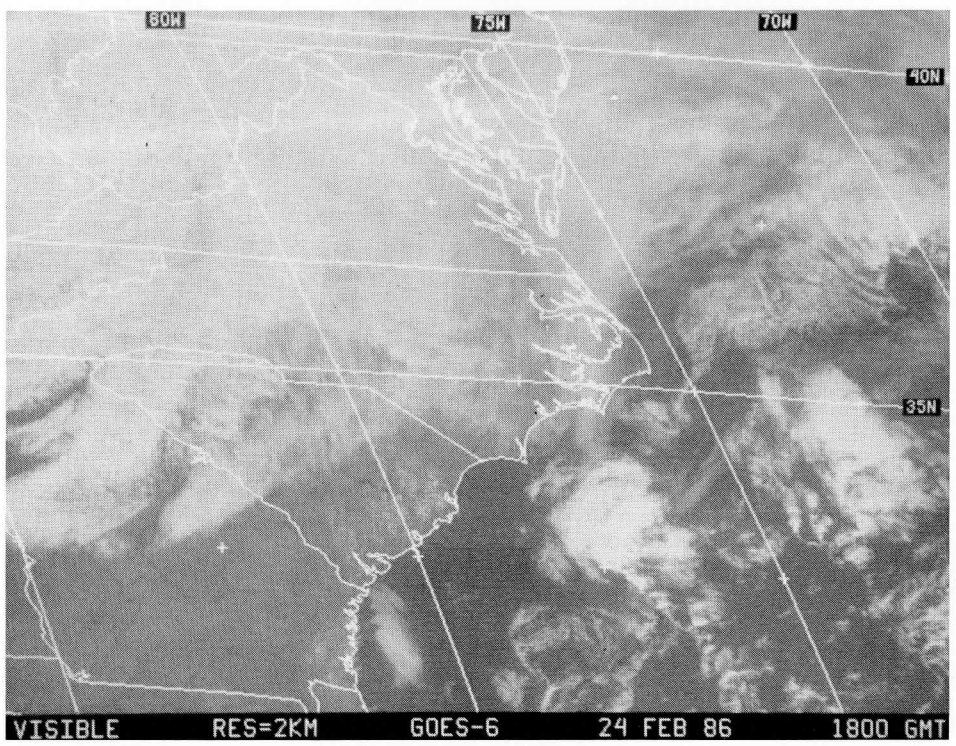
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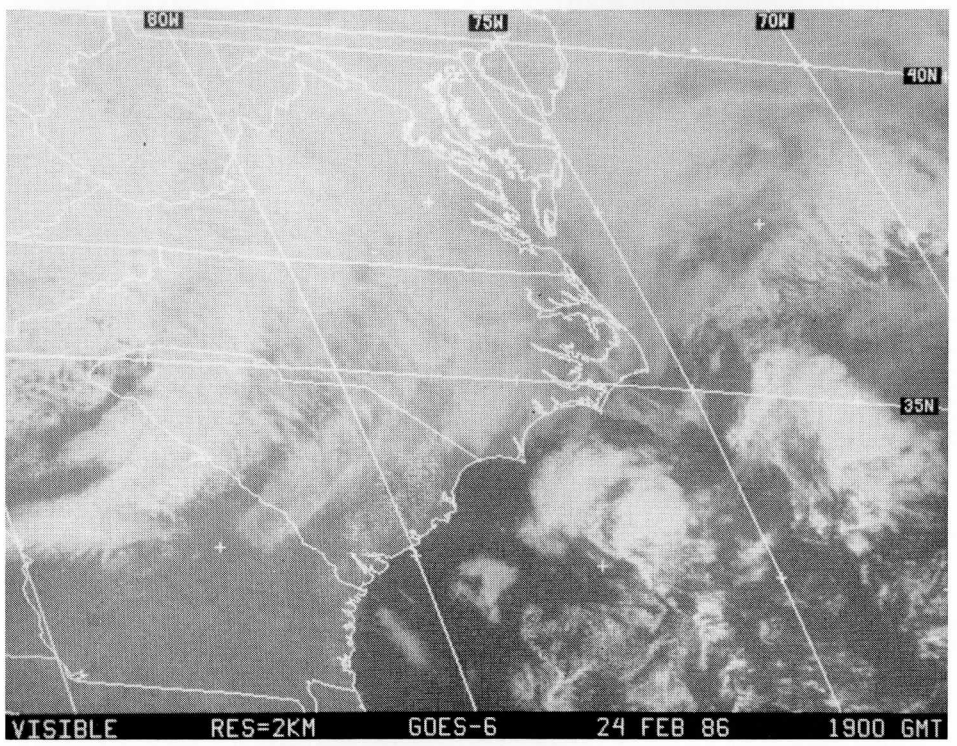
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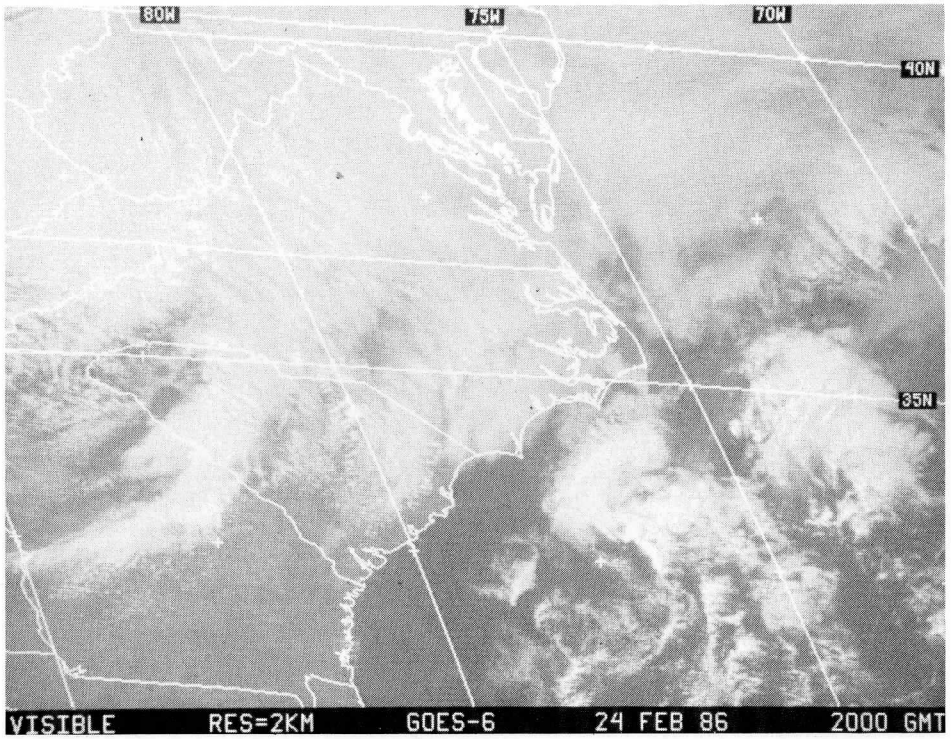
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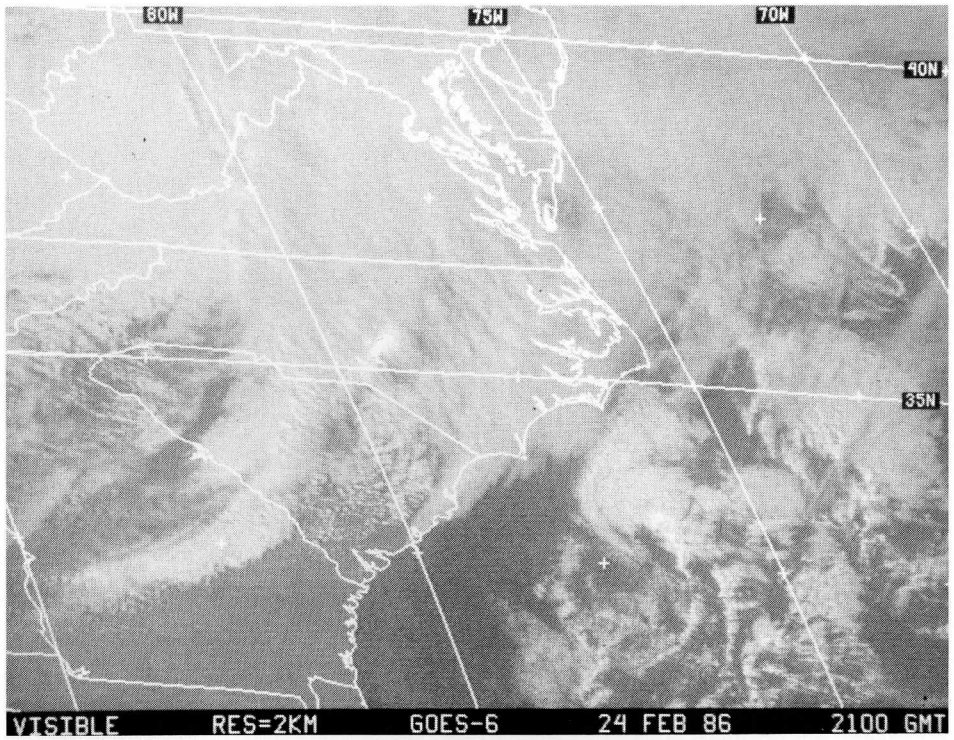
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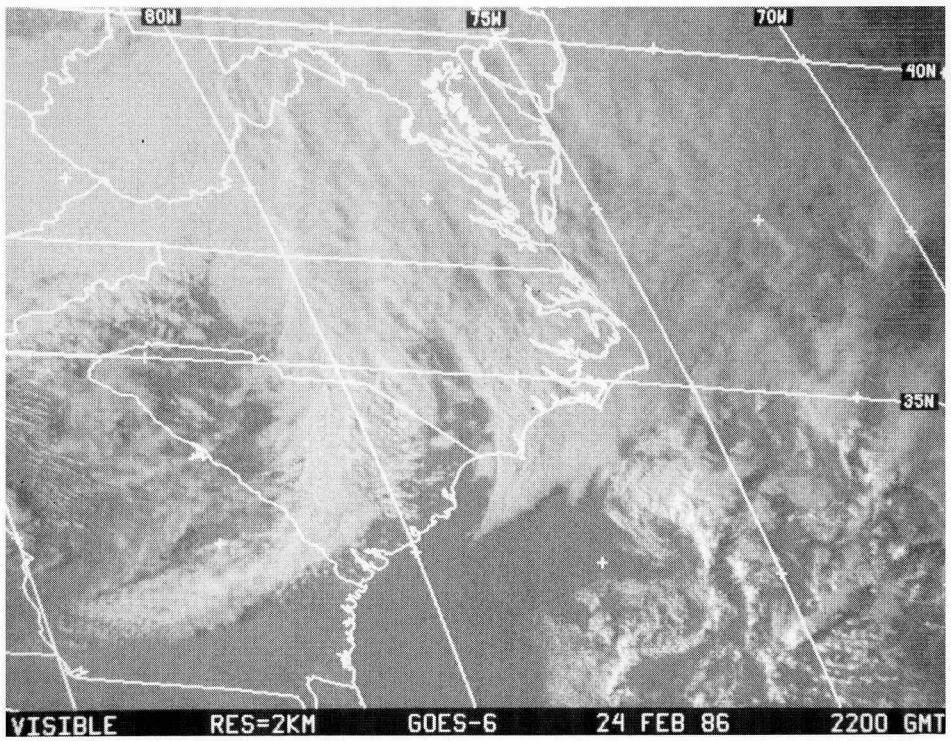
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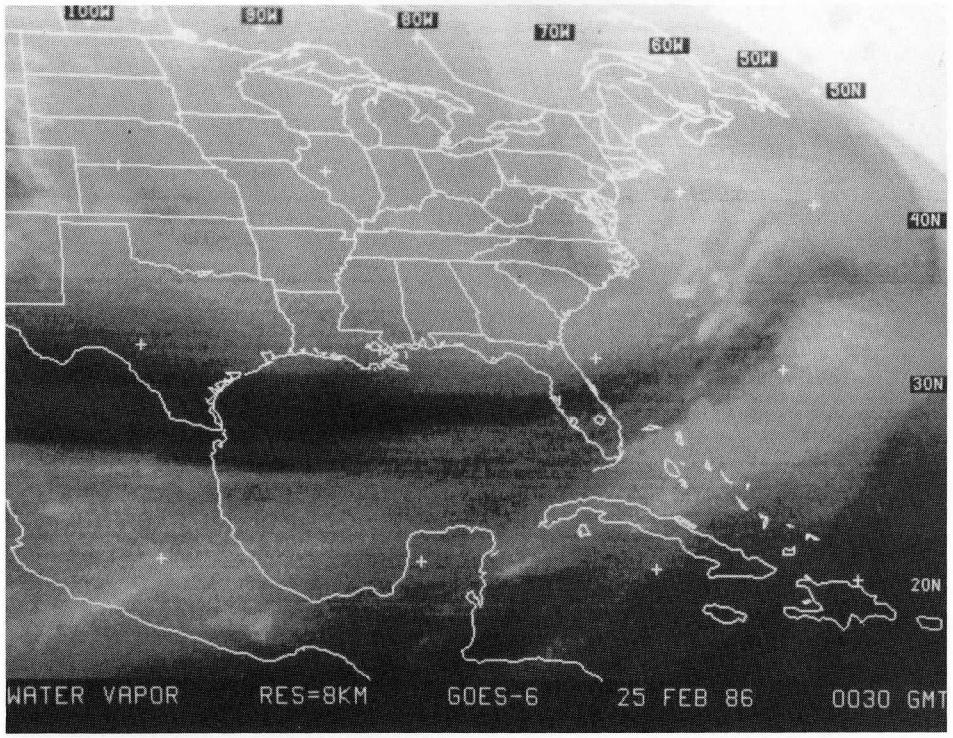
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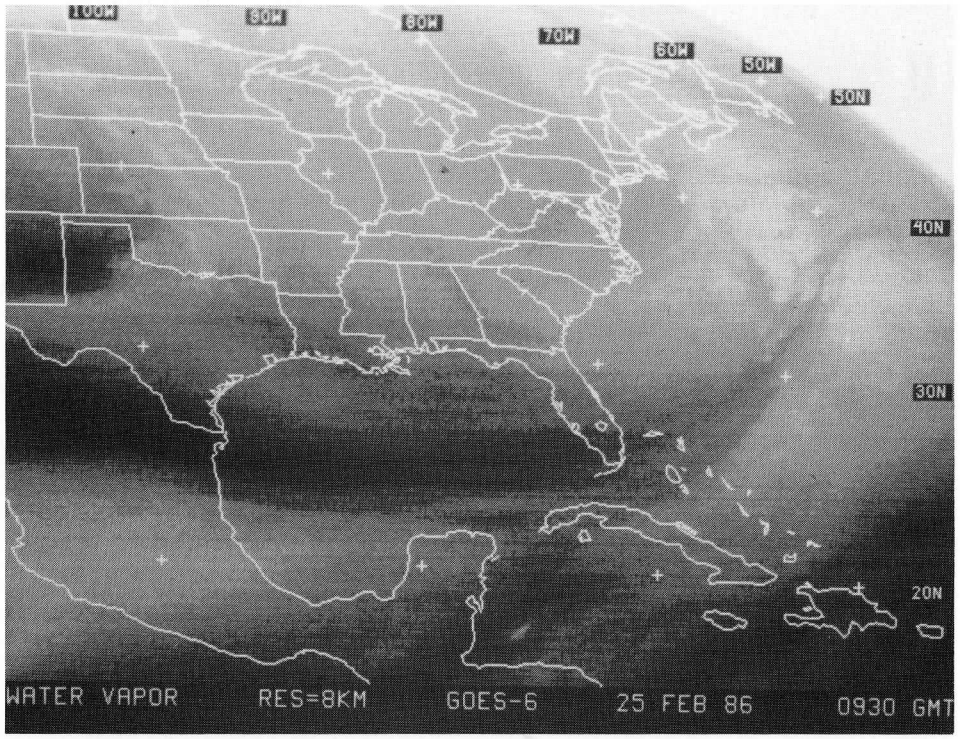
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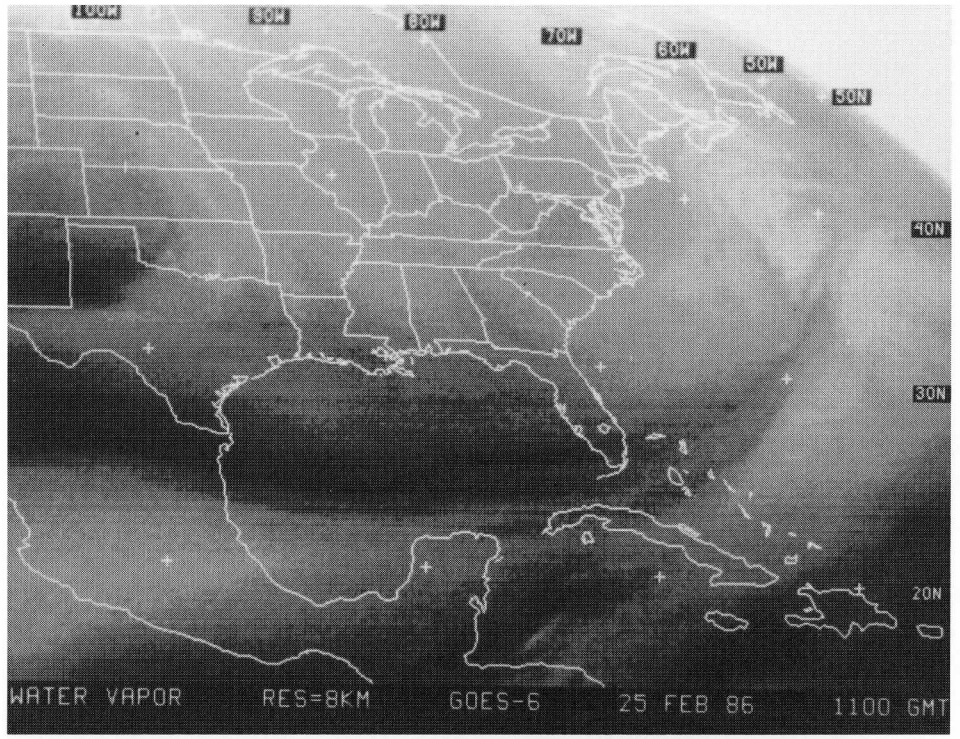
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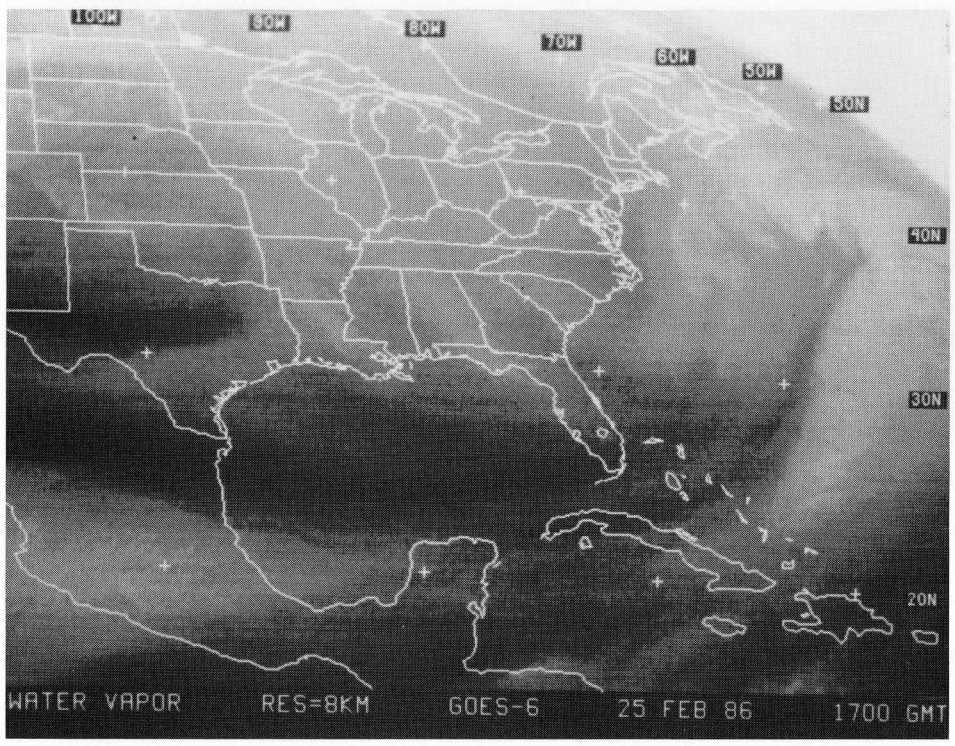
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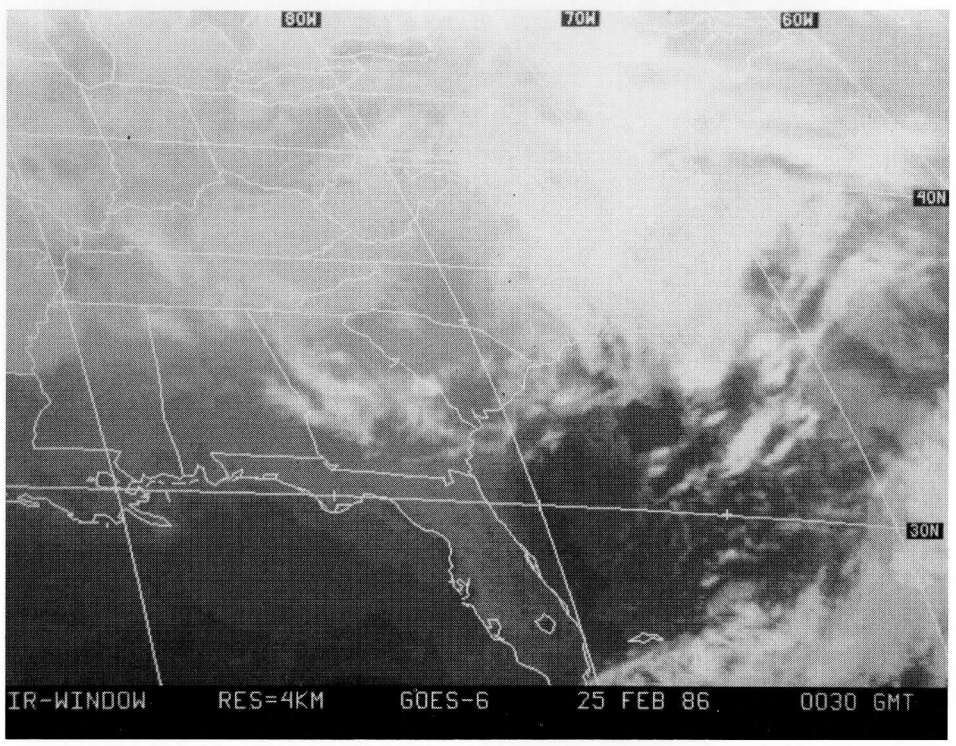
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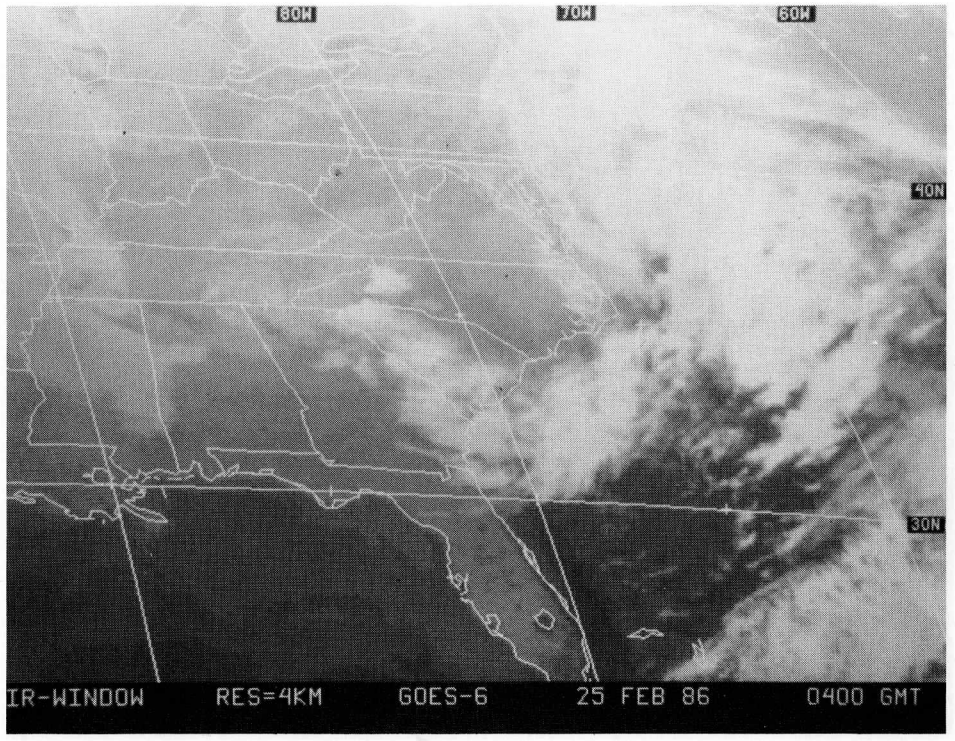
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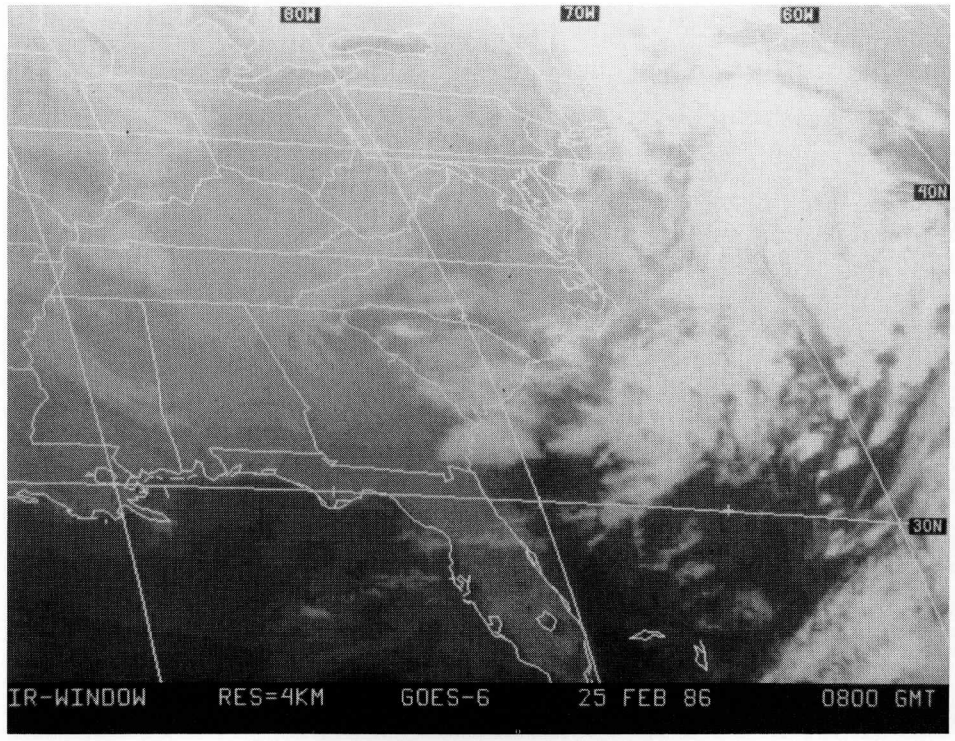
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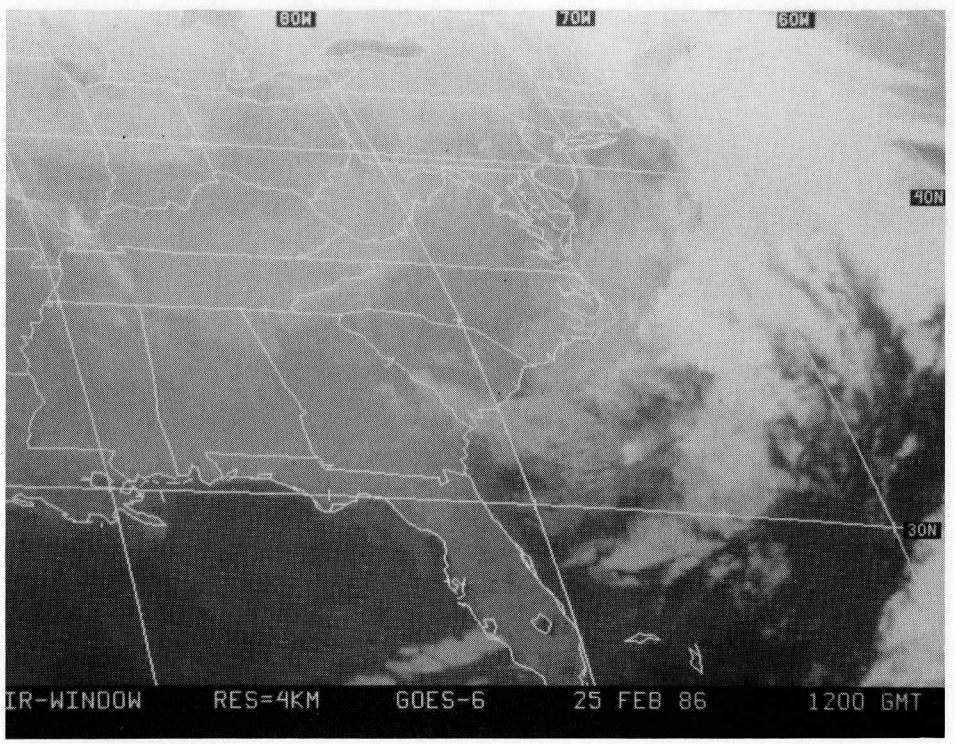
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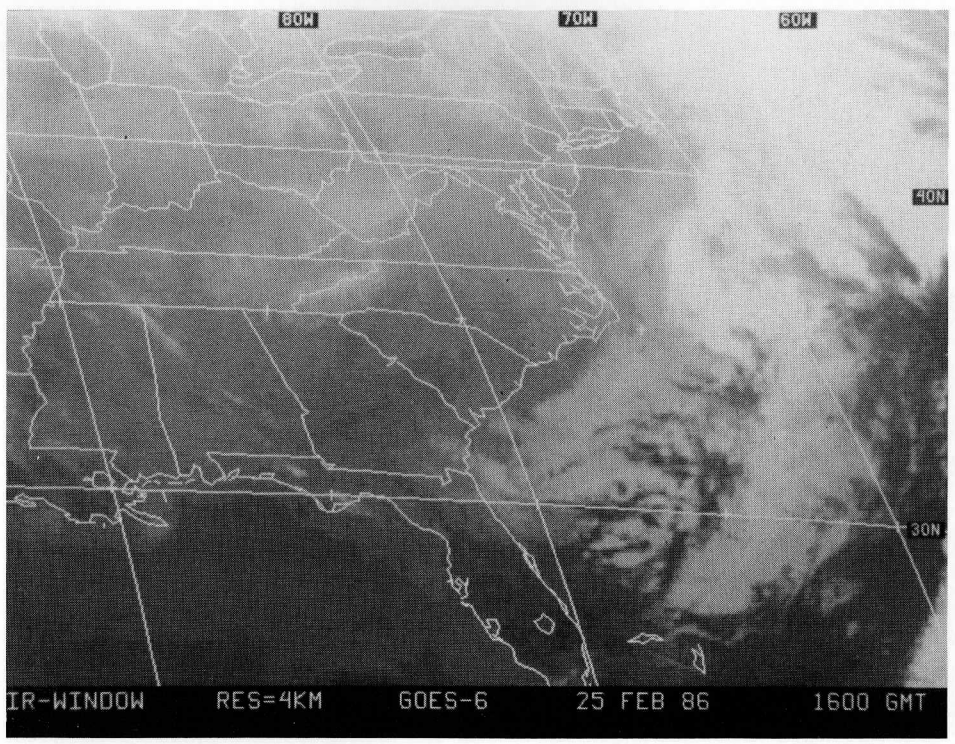
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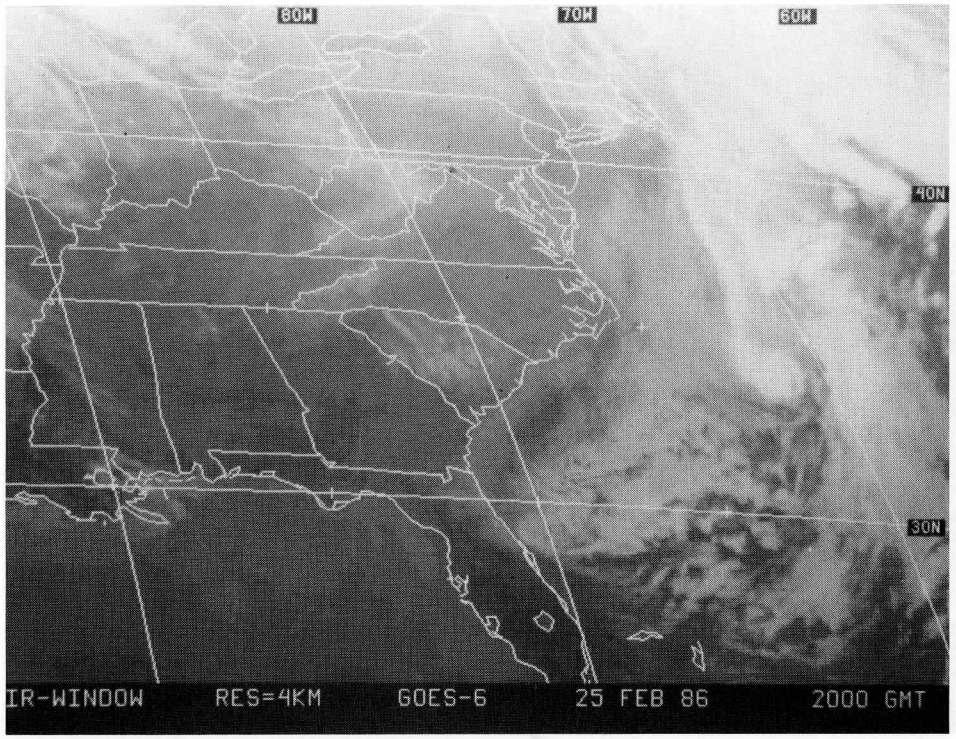
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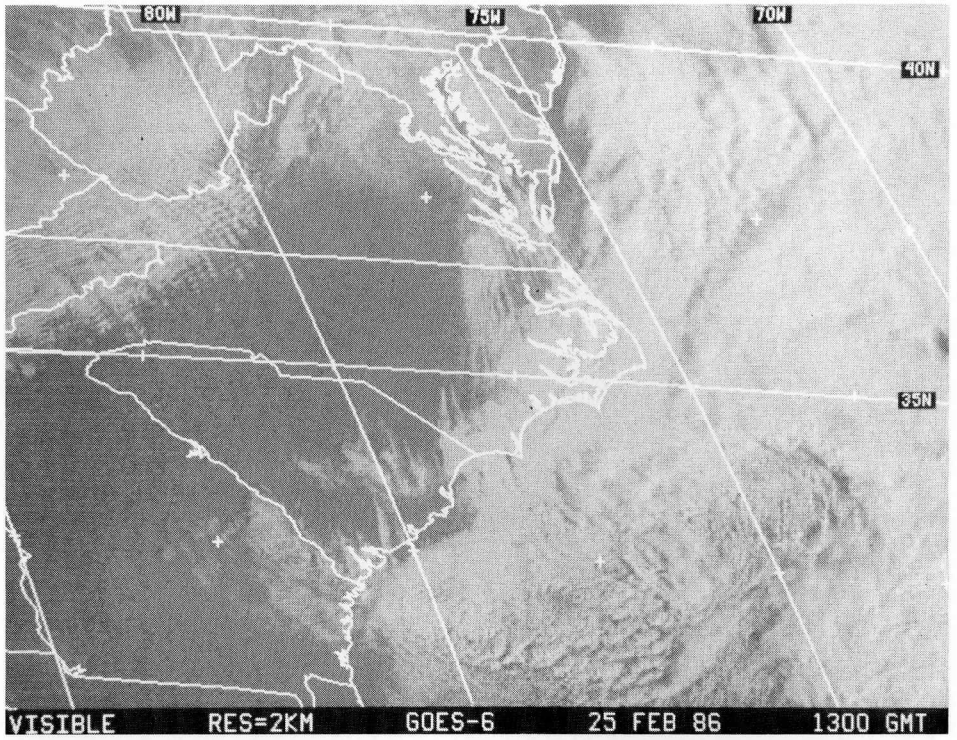
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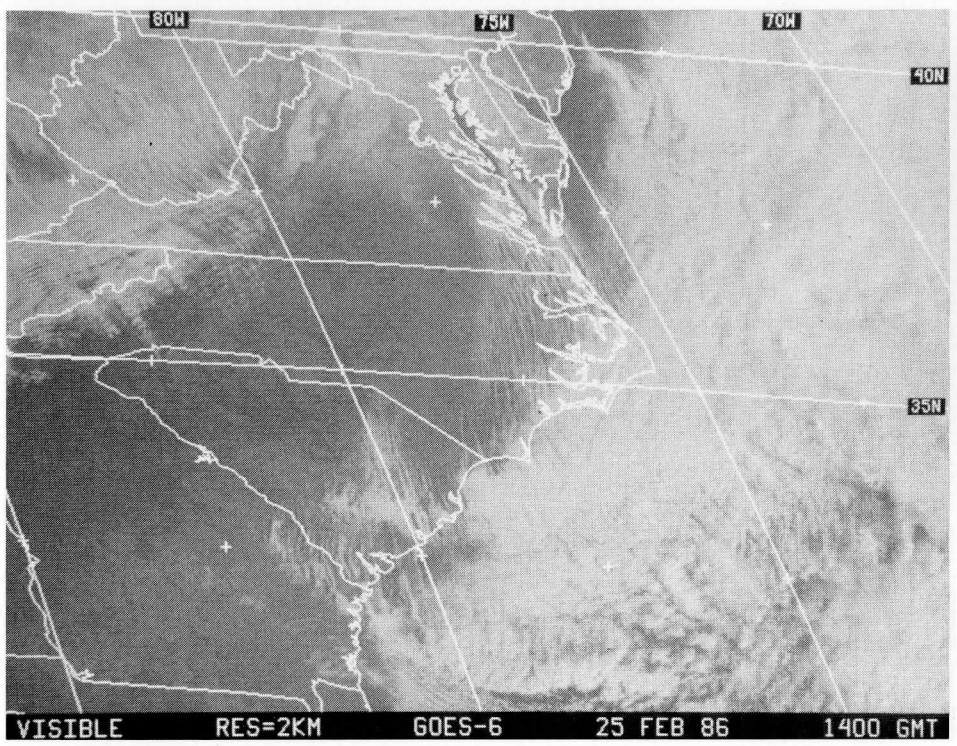
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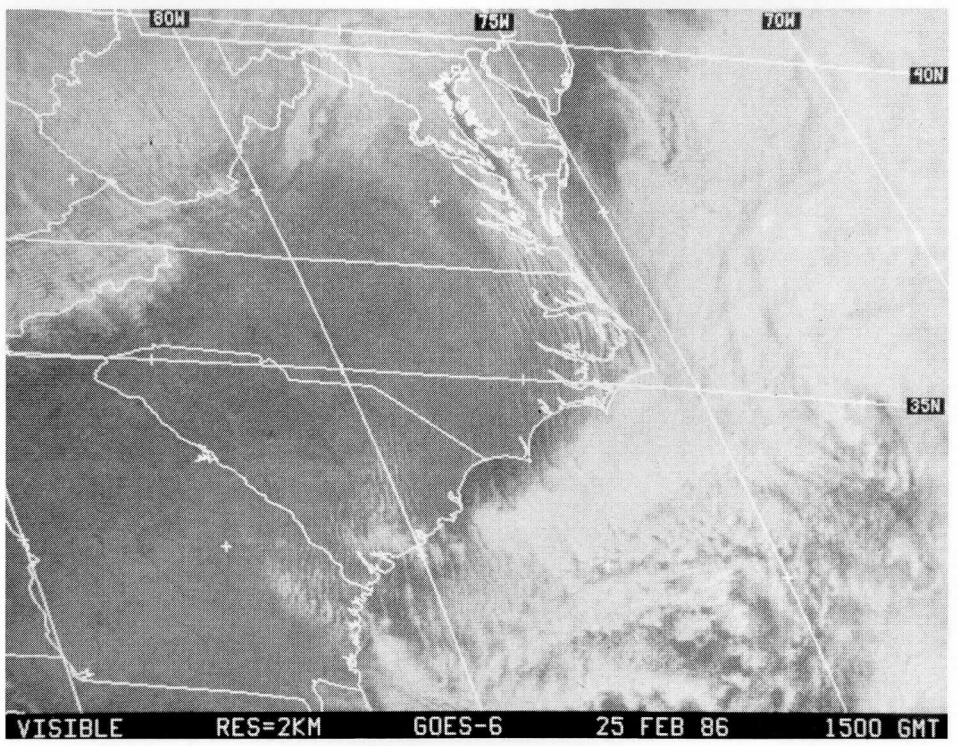
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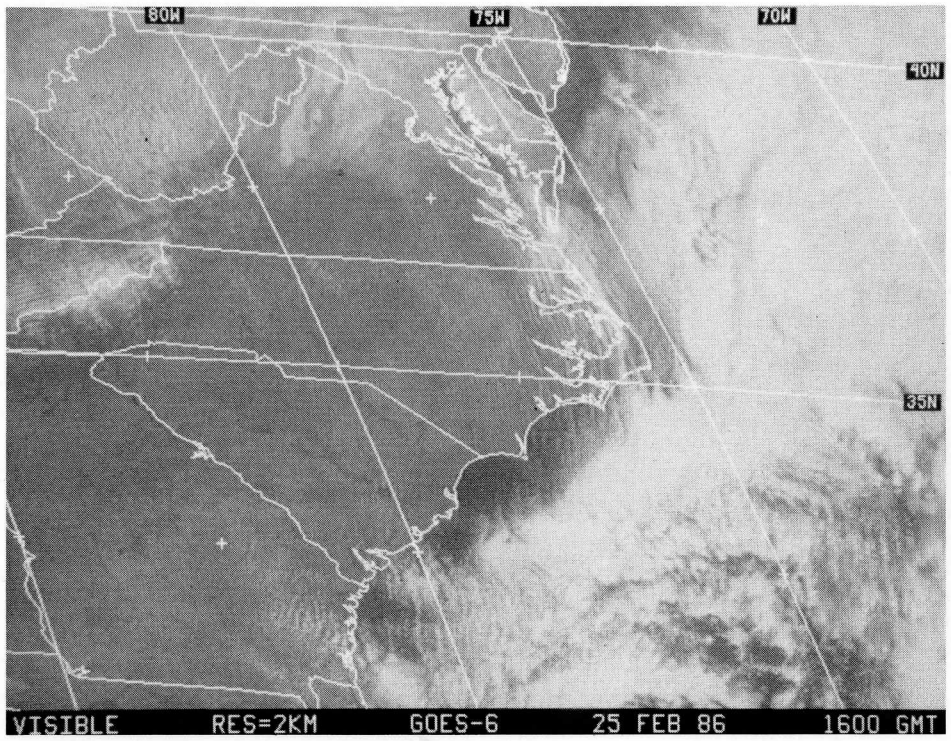
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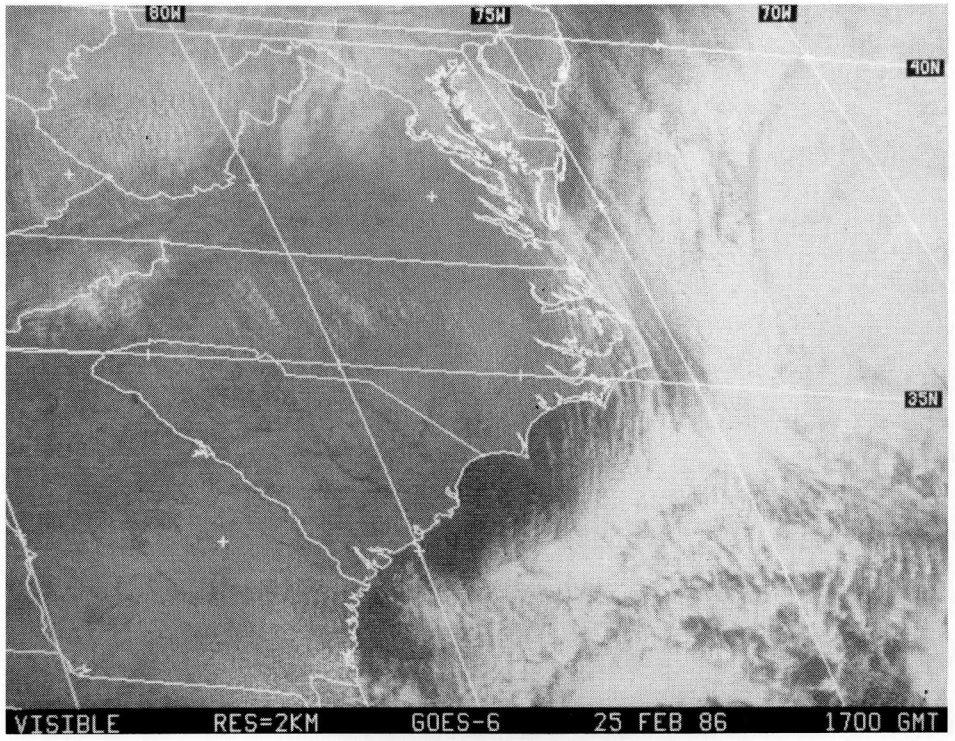
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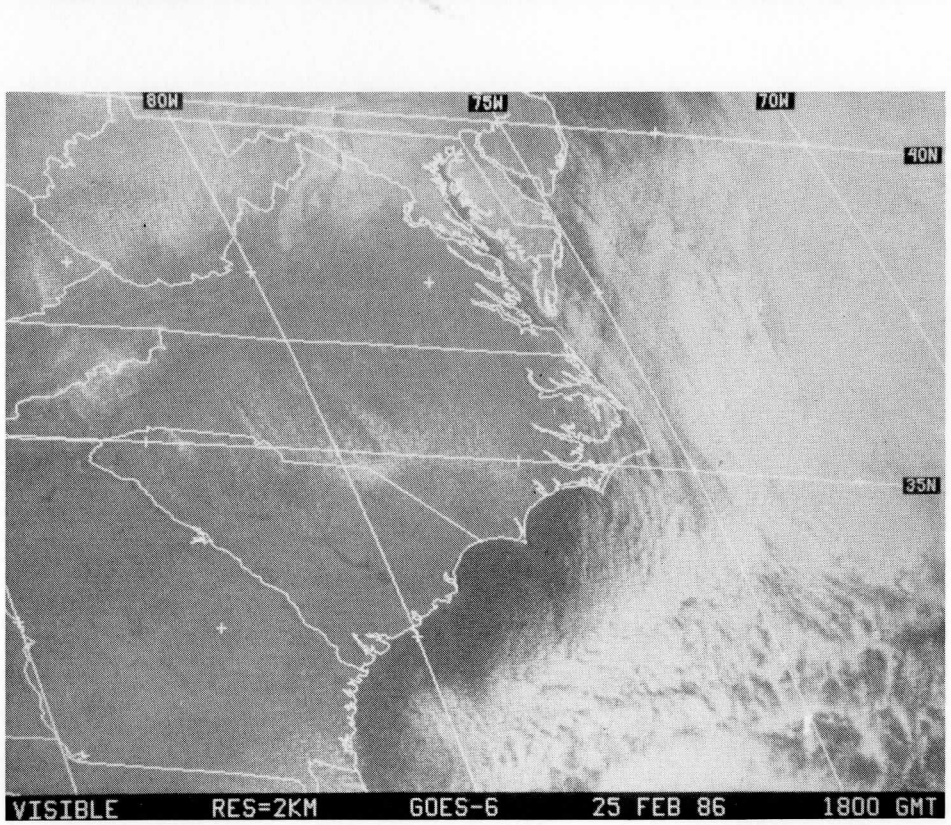
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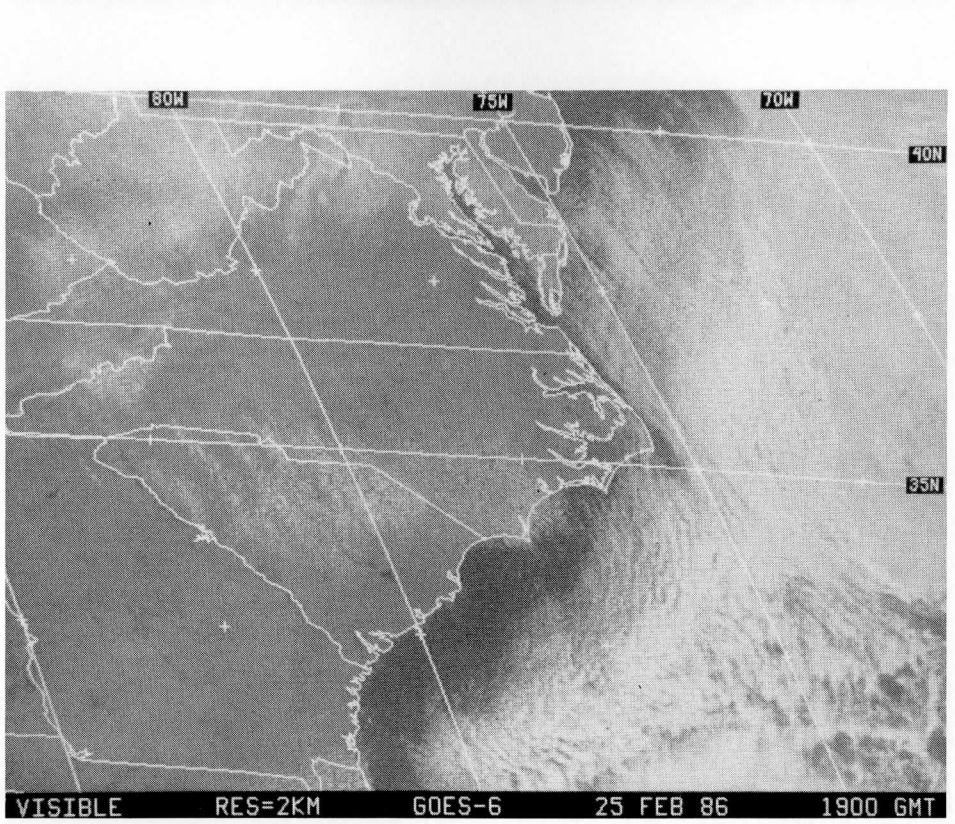
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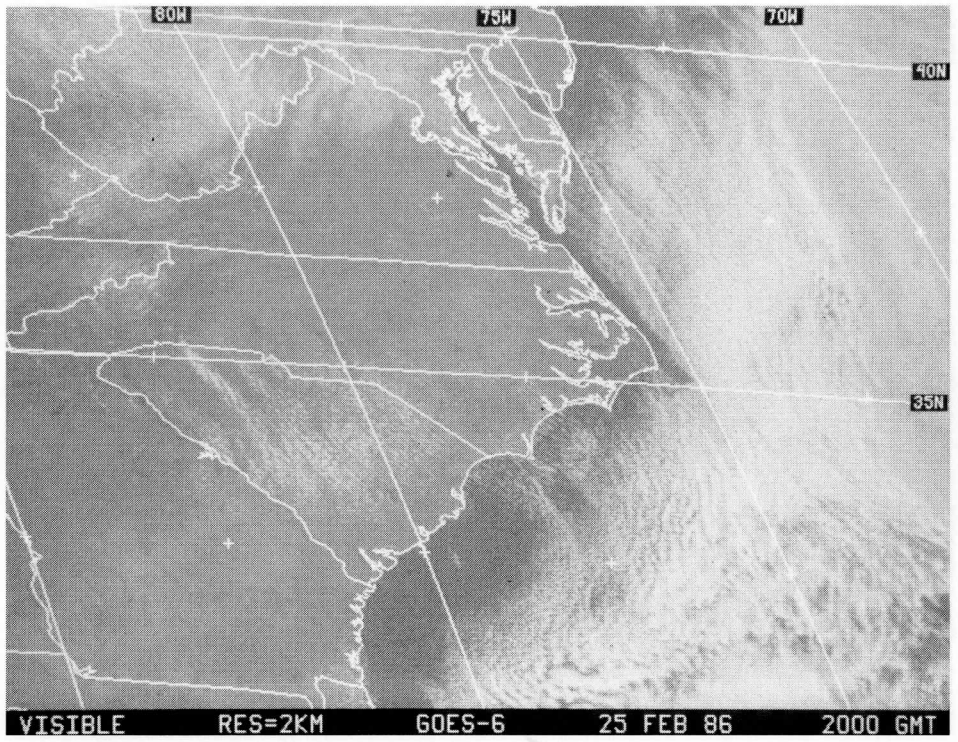
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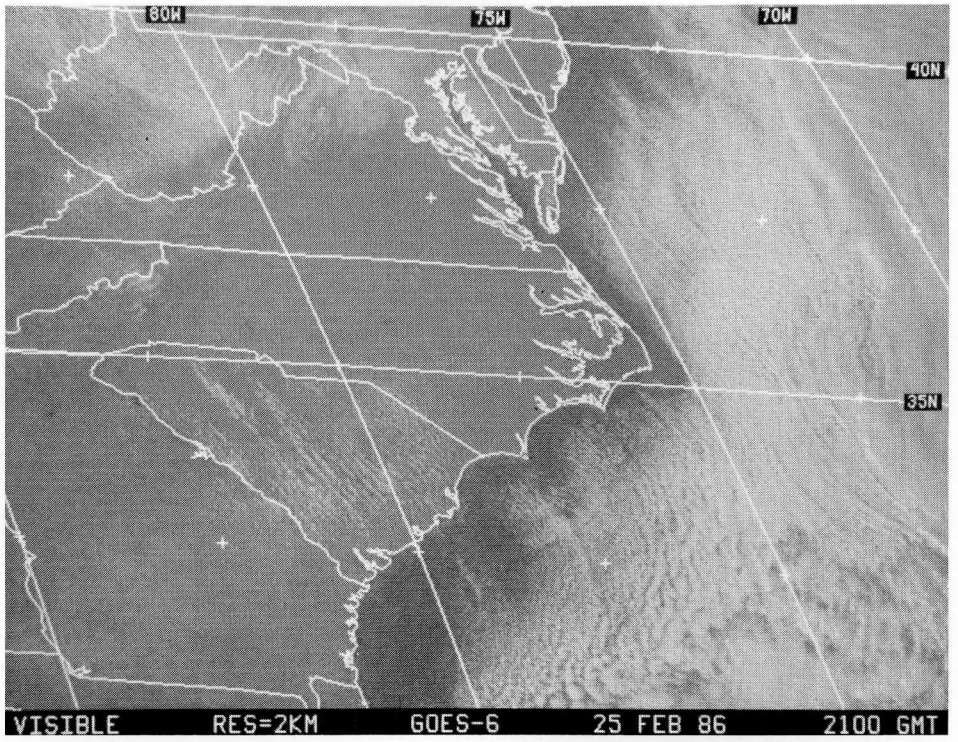
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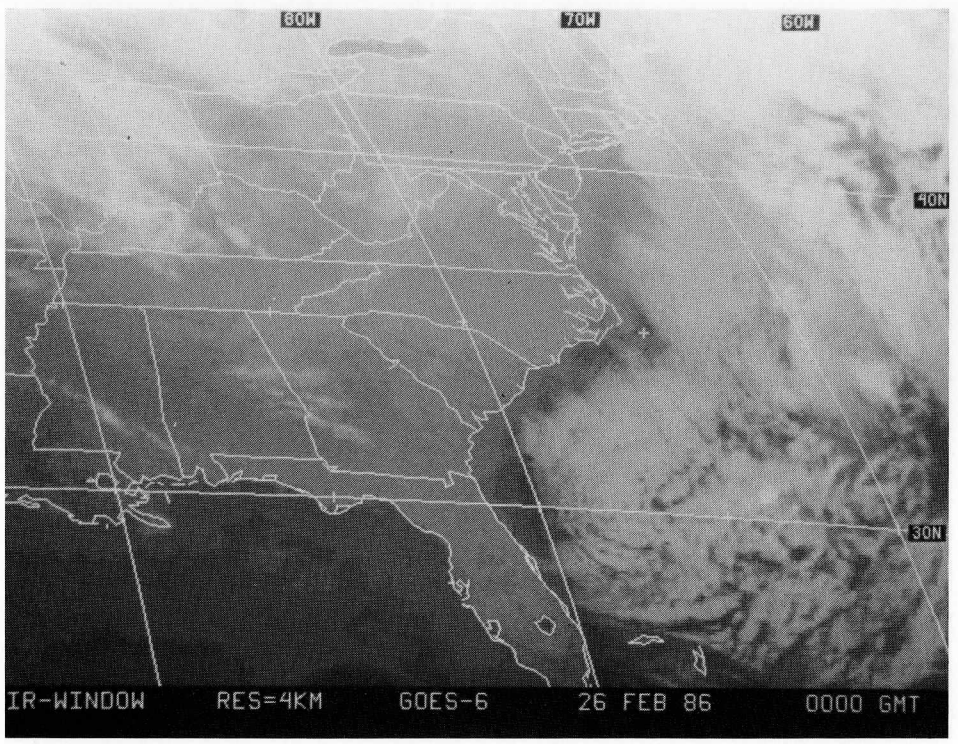
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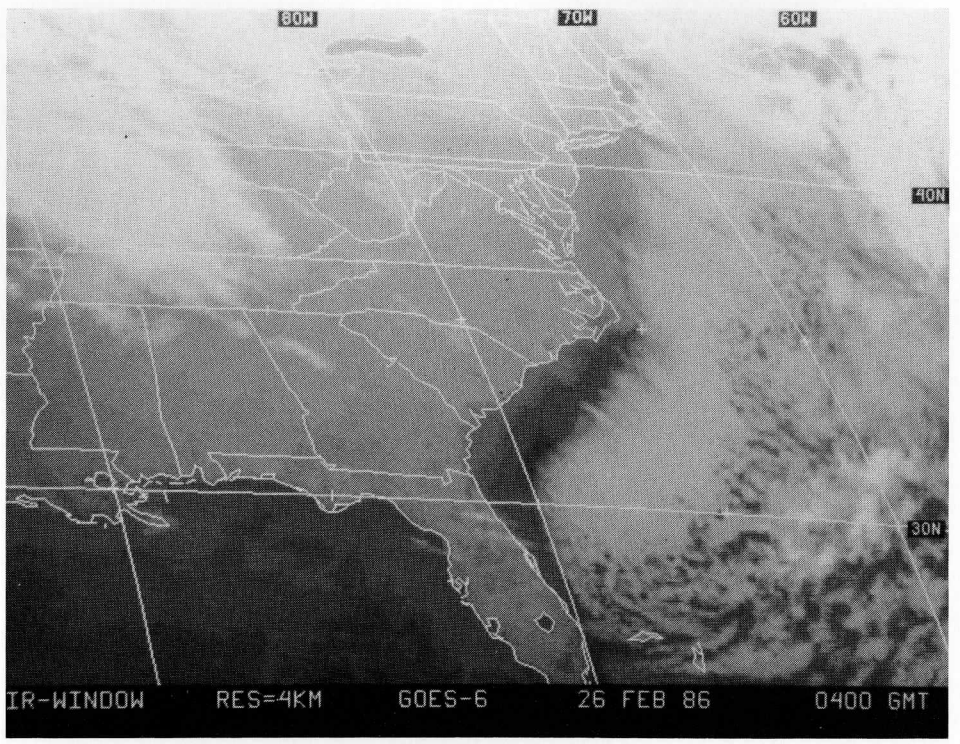
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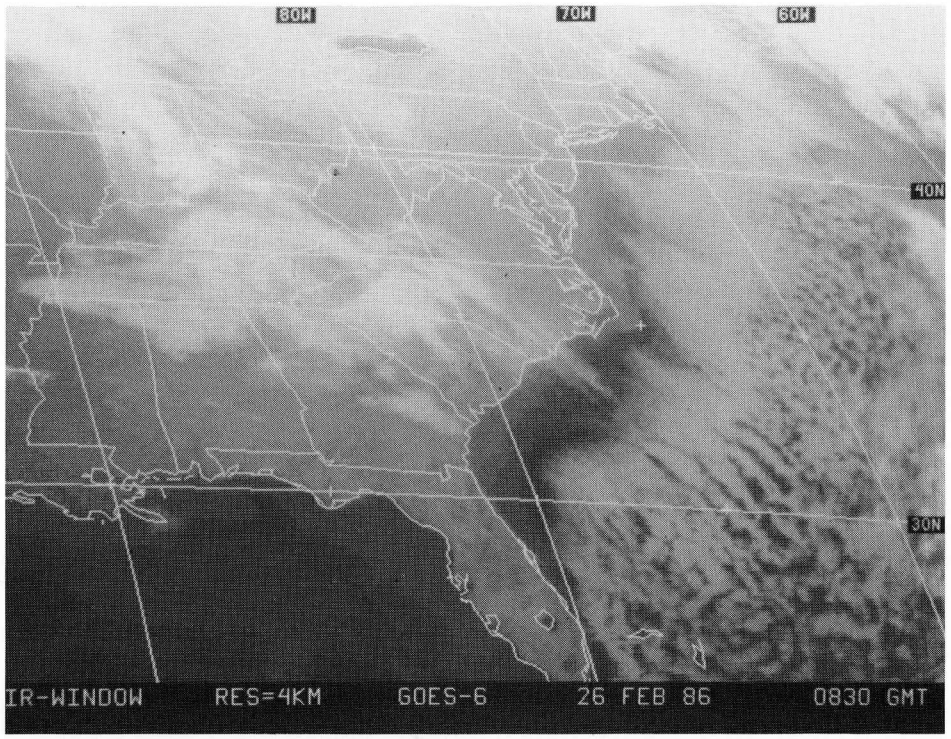
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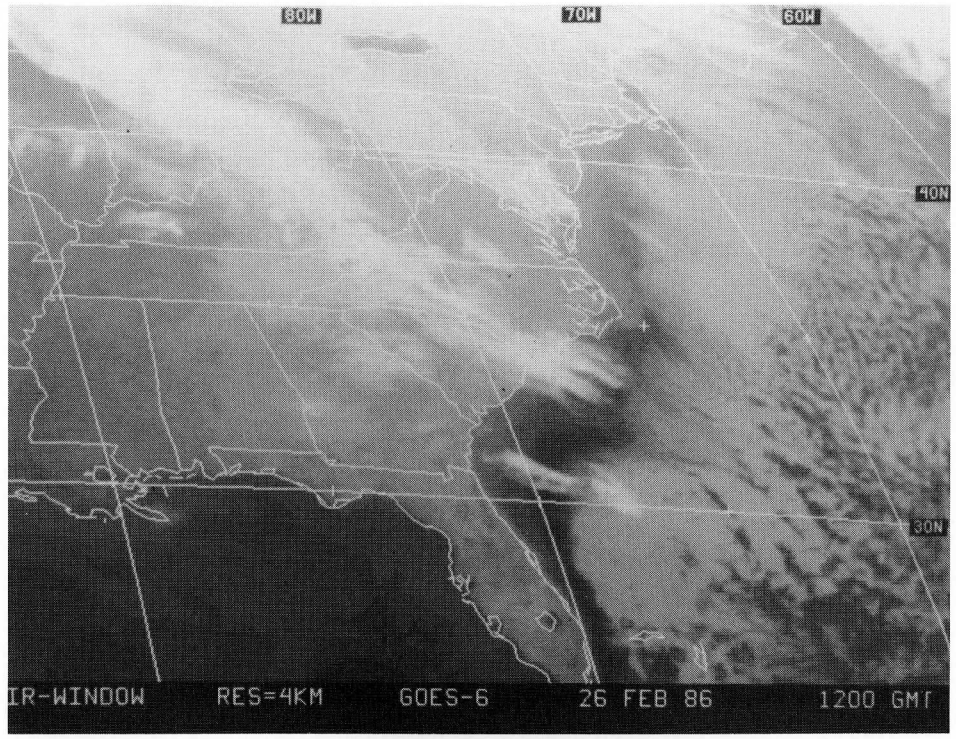
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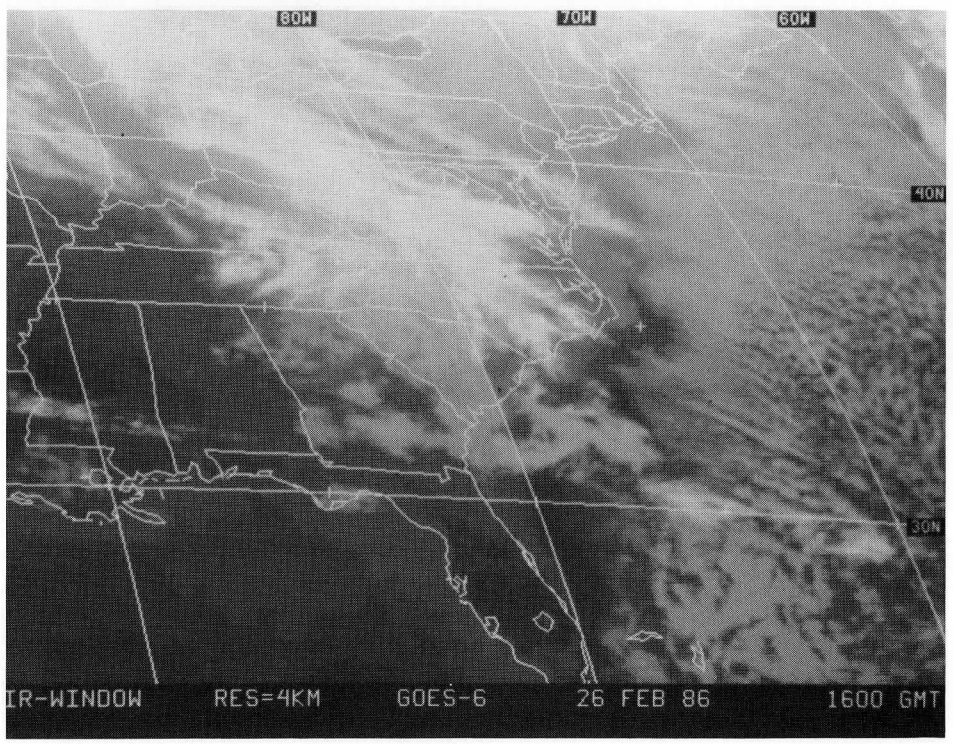
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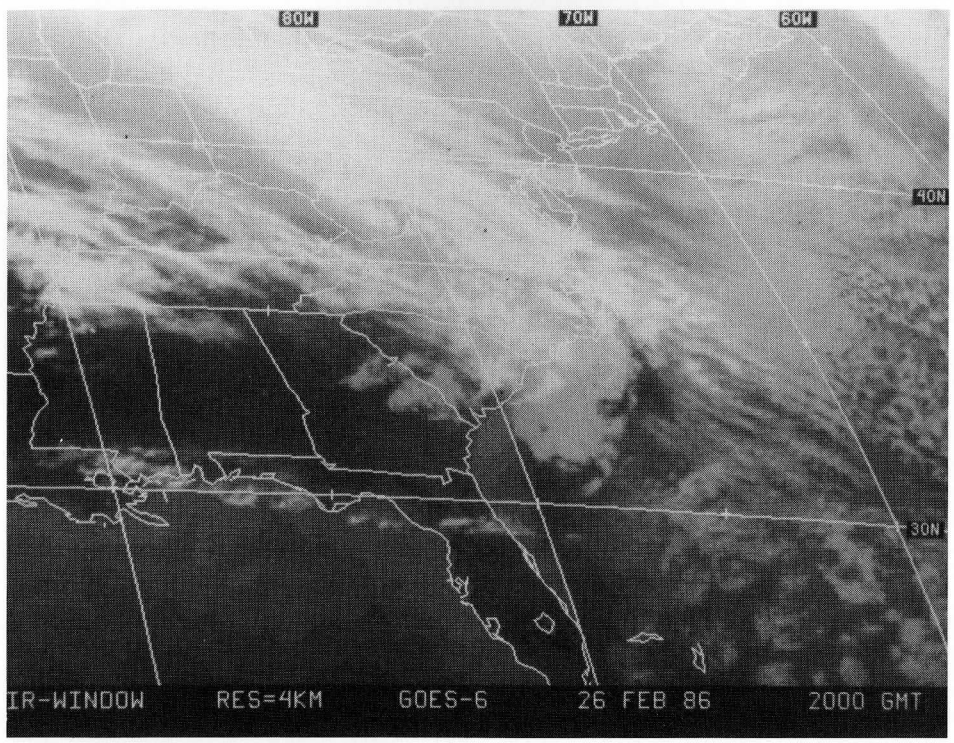
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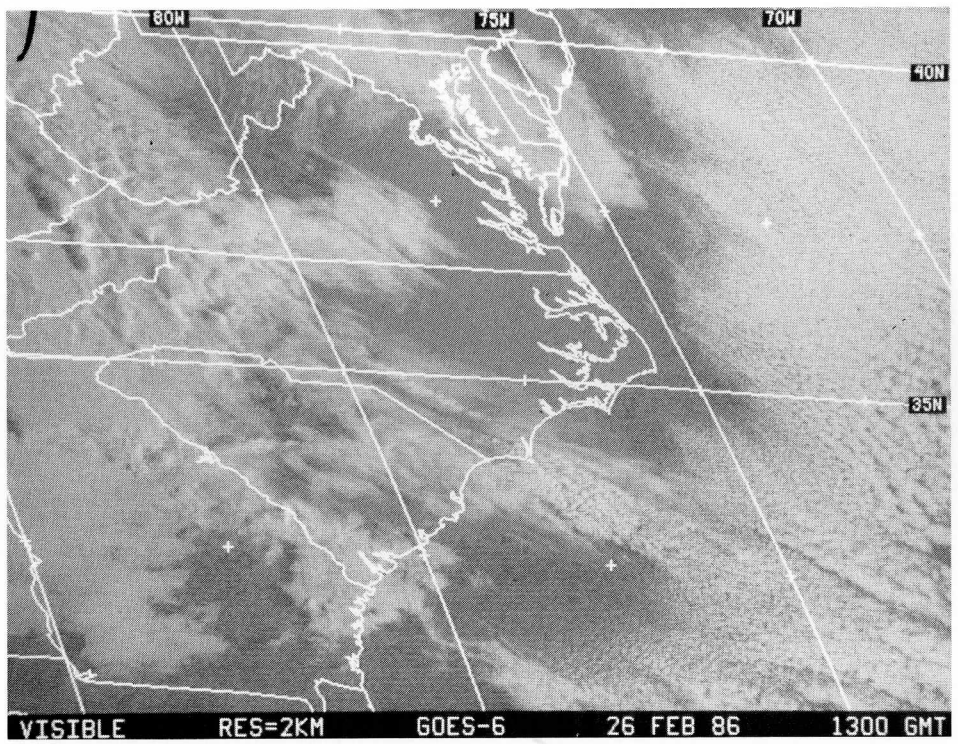
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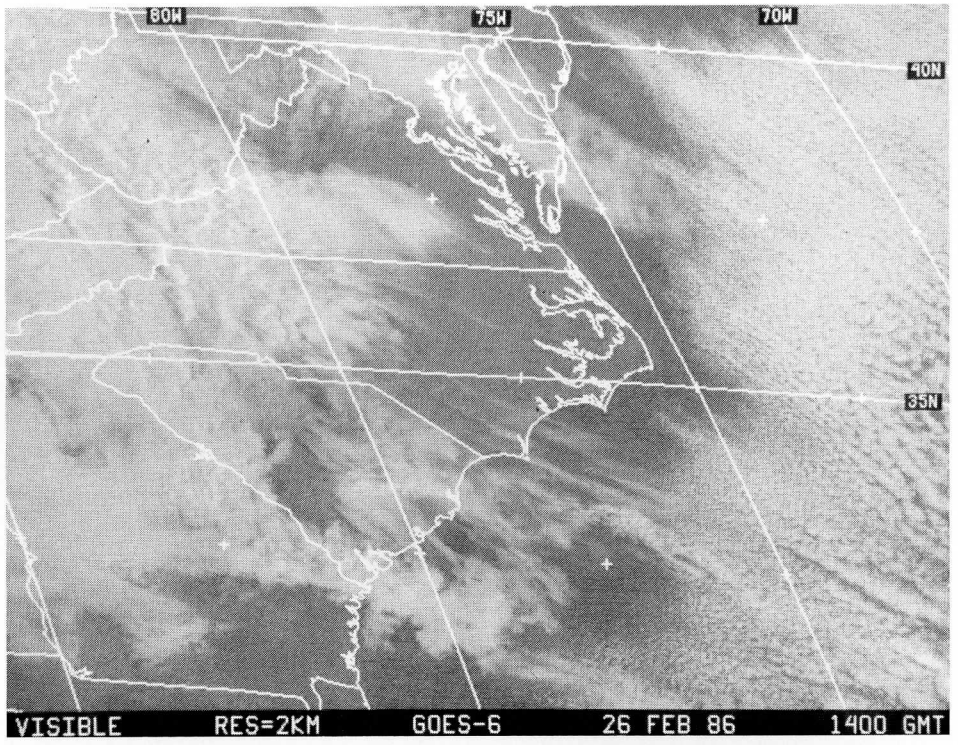
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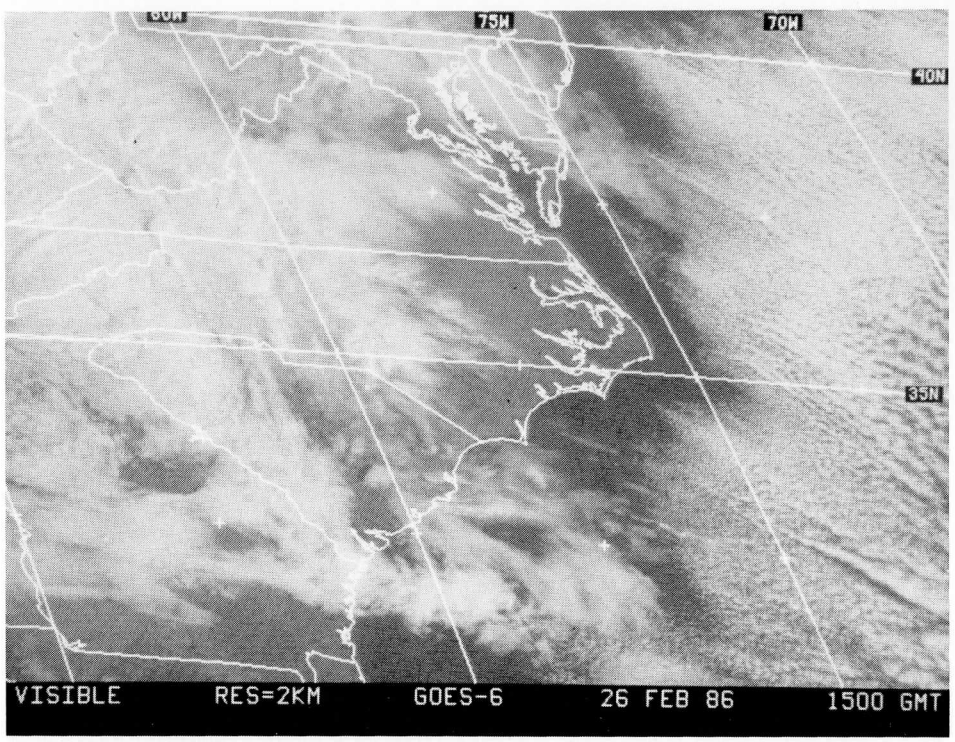
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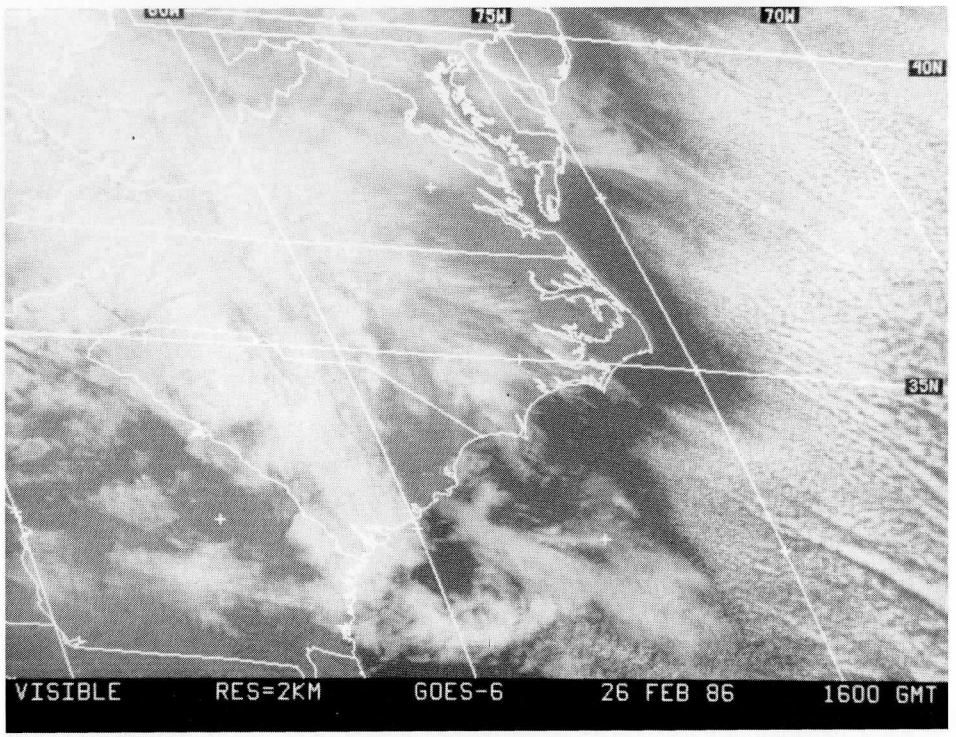
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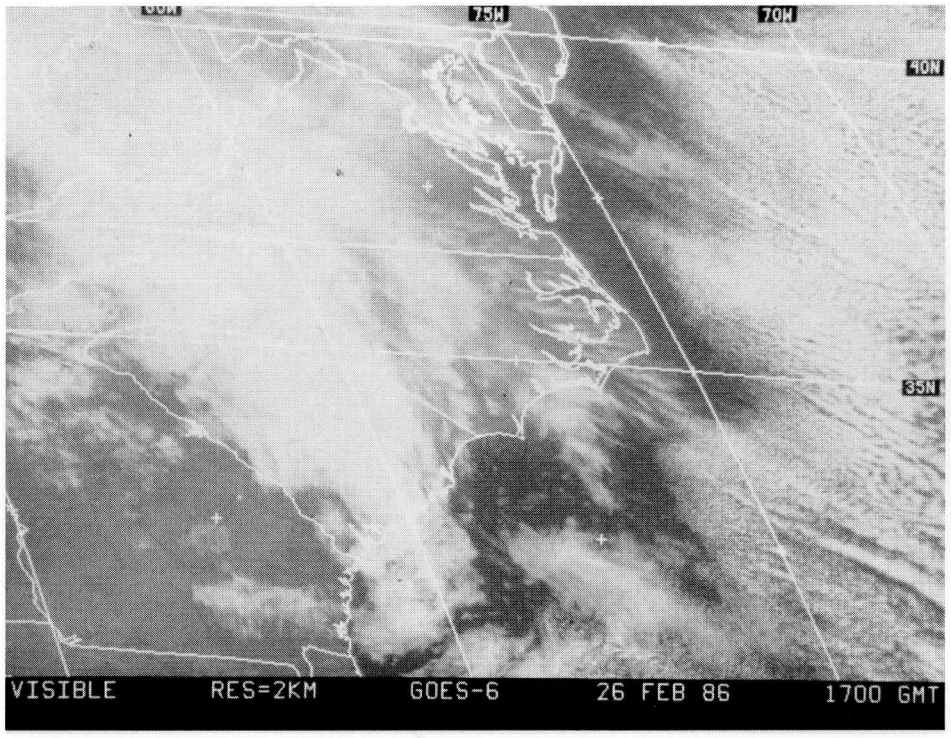
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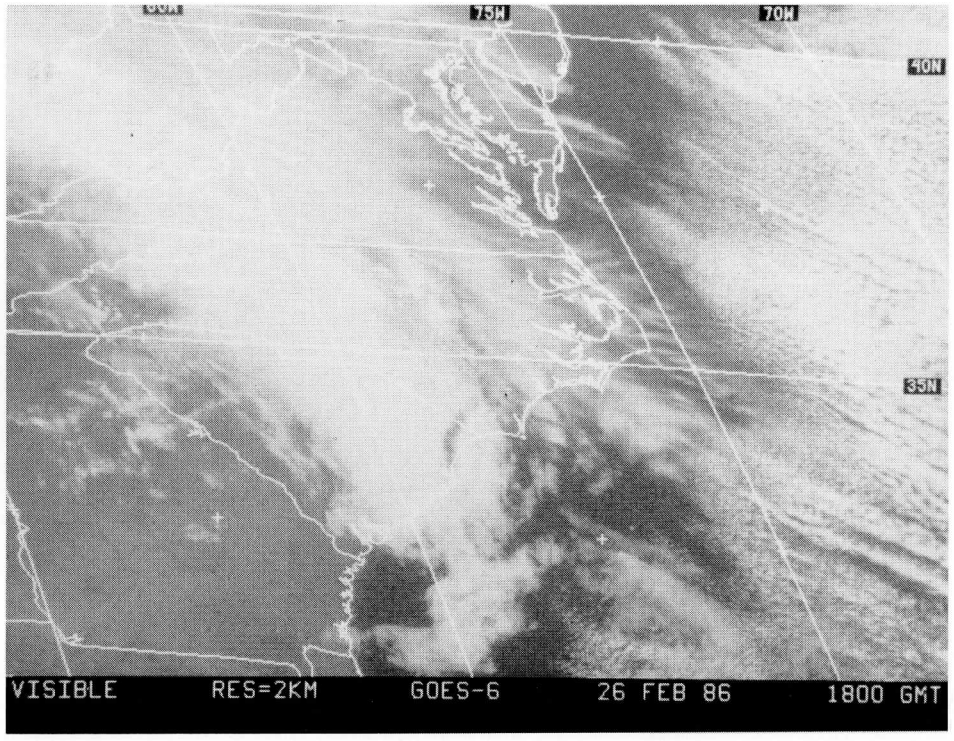
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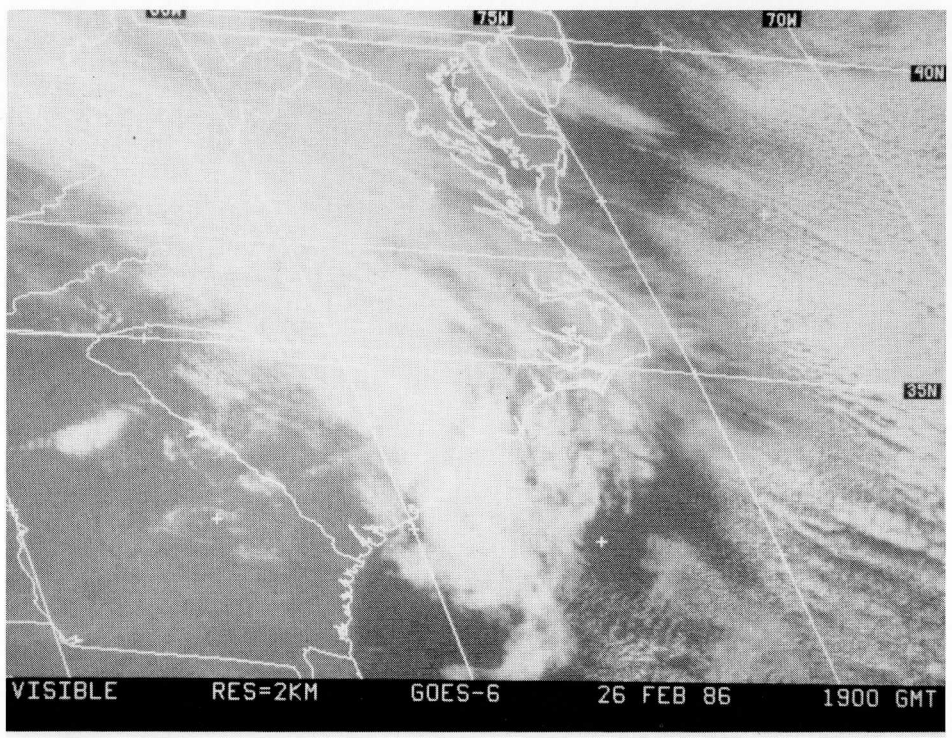
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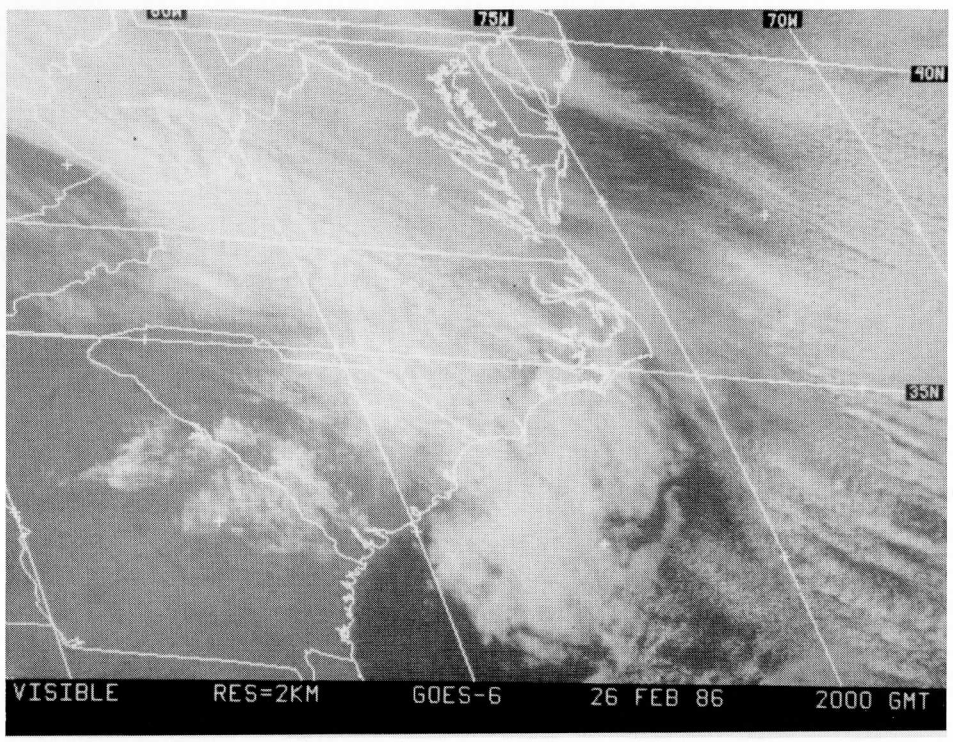
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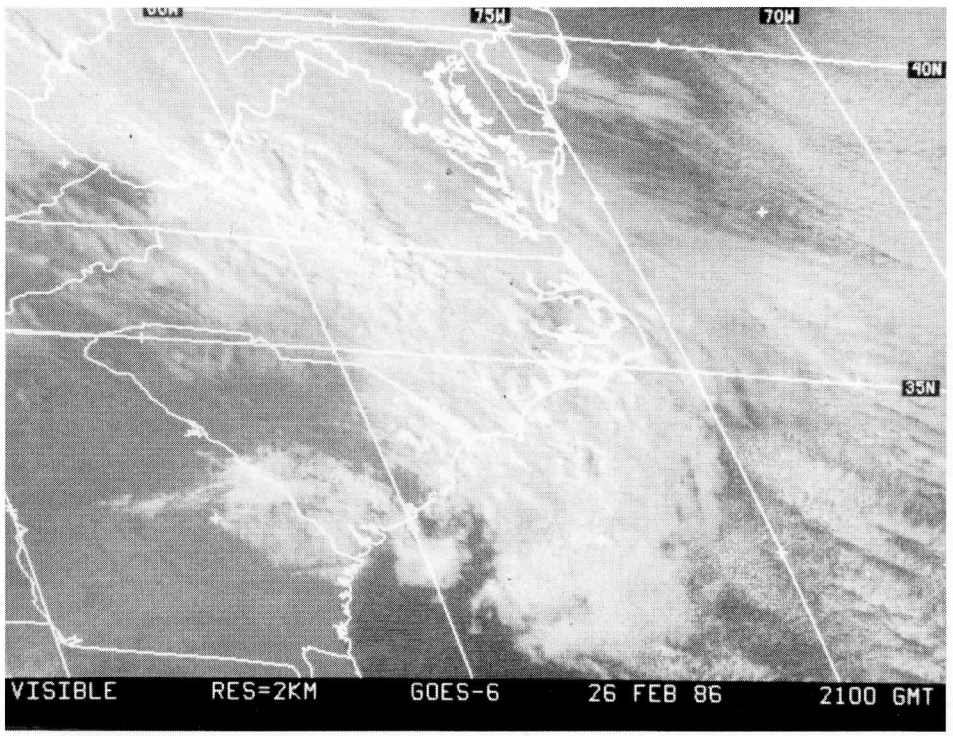
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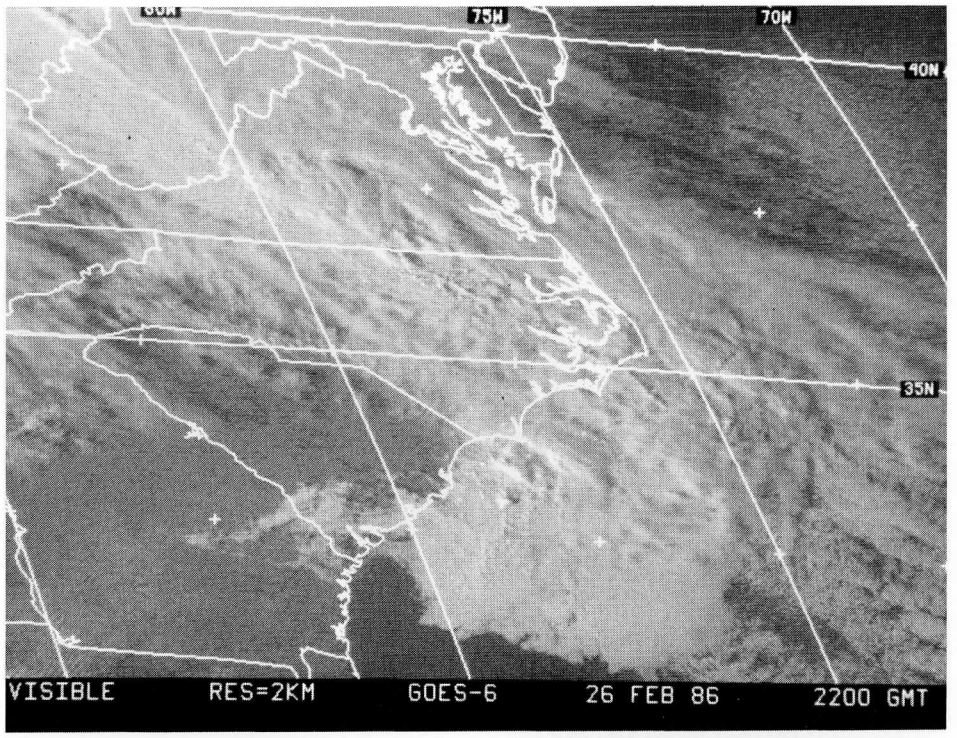
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END OF IOP

IOP #10 - Alberta Clipper / Cold Frontogenesis / Coastal Cyclogenesis
February 27 - February 28

Satellite Synopsis

Water Vapor

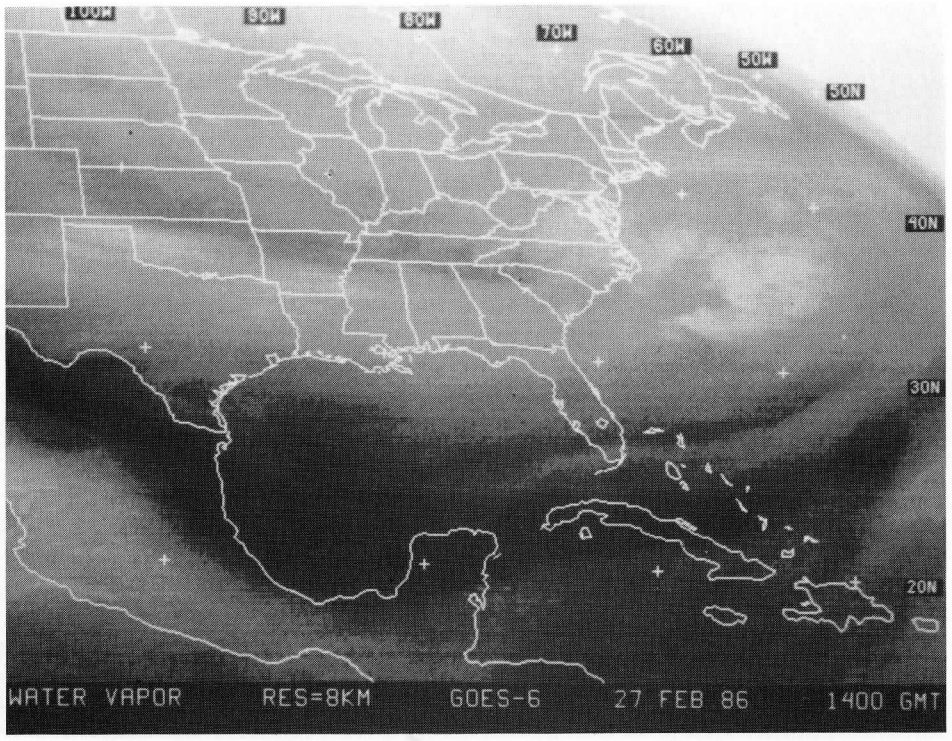
- At 12 GMT on the 27th a weak circulation was apparent in Virginia which moved offshore late on 27th, with a dry wedge developing north of Cape Hatteras.
- Good strong convection in PVA ahead of circulation.
- 28th, large circulation associated with the long wave trough is depicted well.

IR

- Circulation becomes more evident/organized on the 27th and wraps up nicely offshore on the 28th.
- Big thunderstorms well off Carolinas on 28th associated with the front.

Visible

- Drying is evident behind front and expands over Georgia and North Carolina.
- Wave clouds in western North Carolina.
- Secondary convergence lines in cold air with some limited convection.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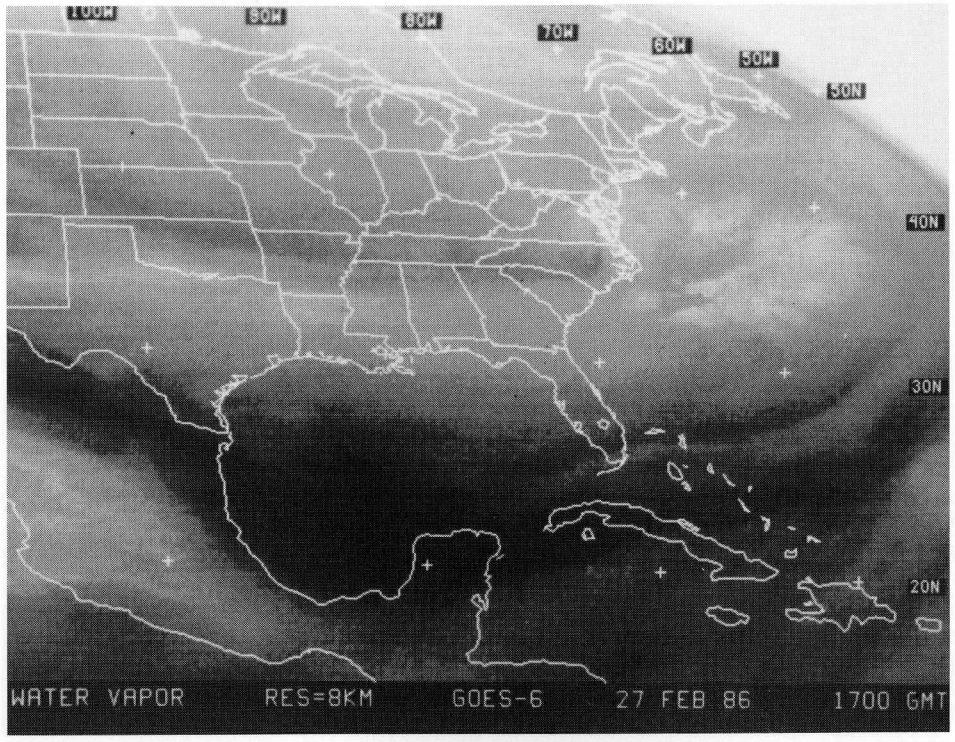
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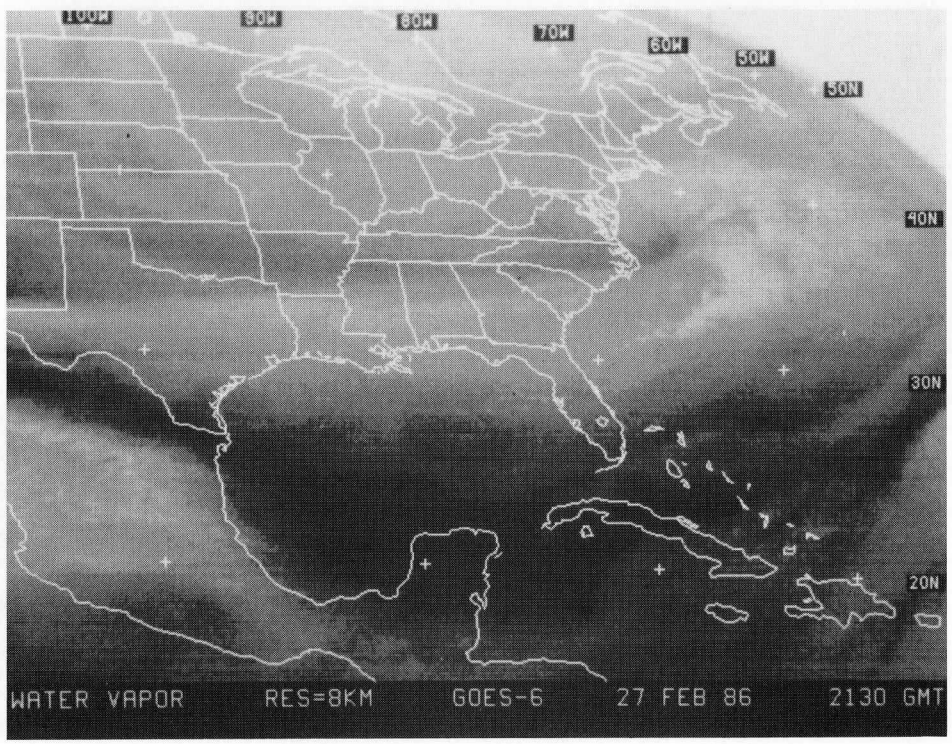
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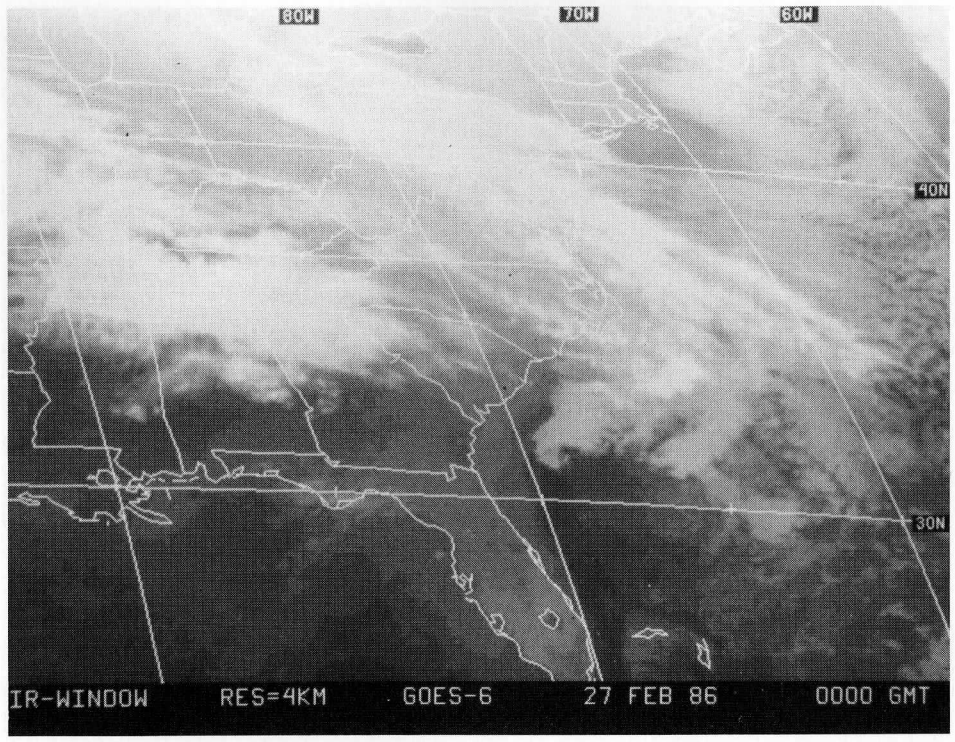
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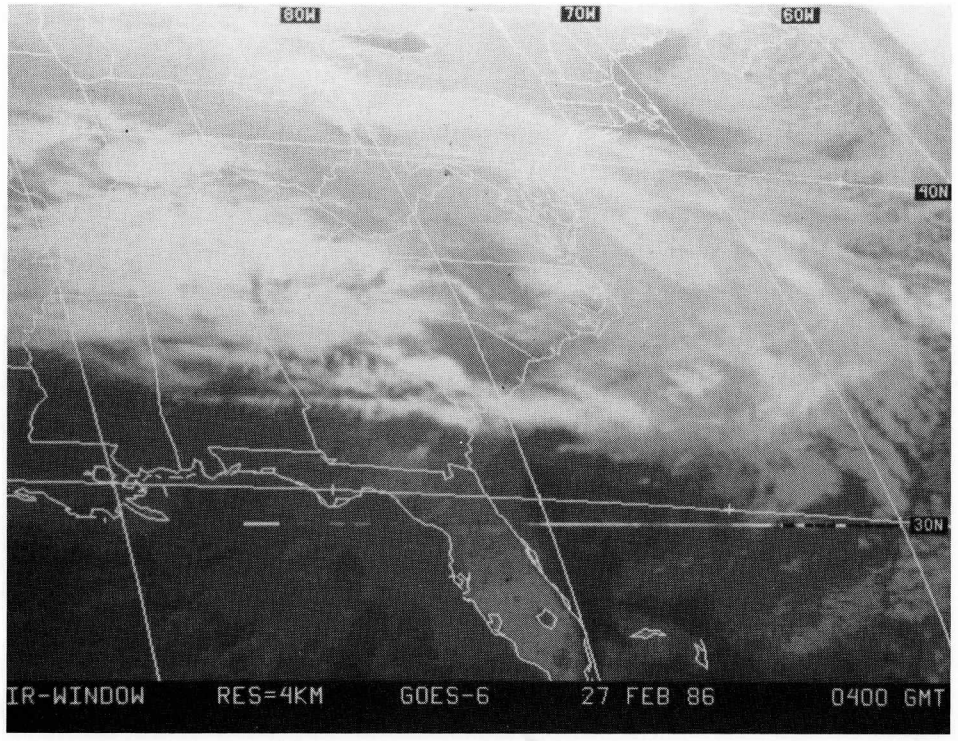
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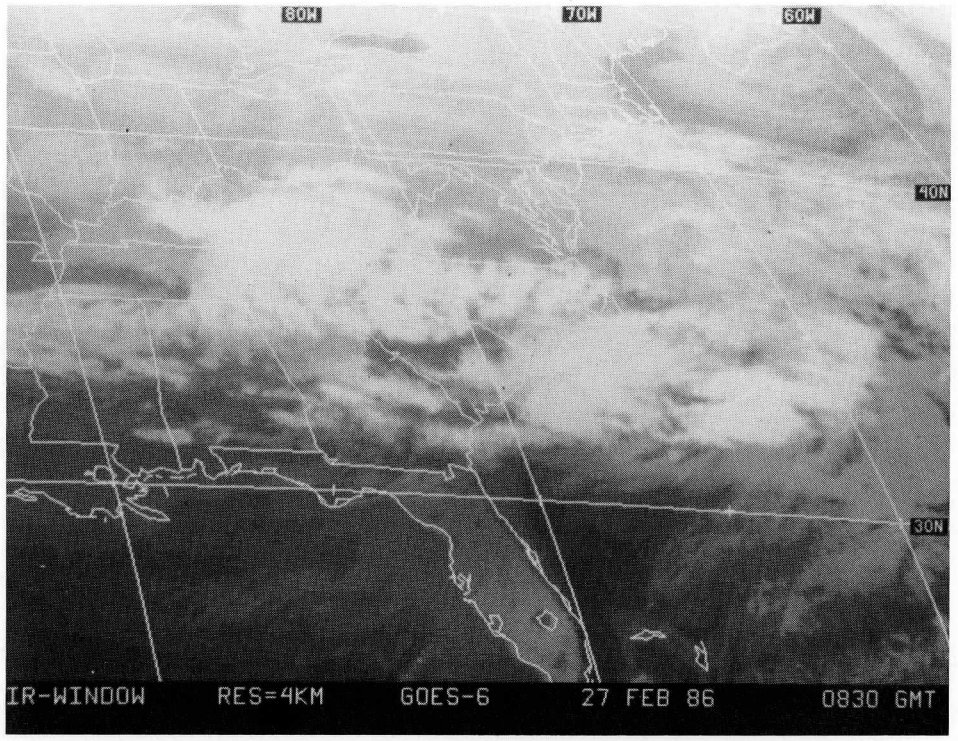
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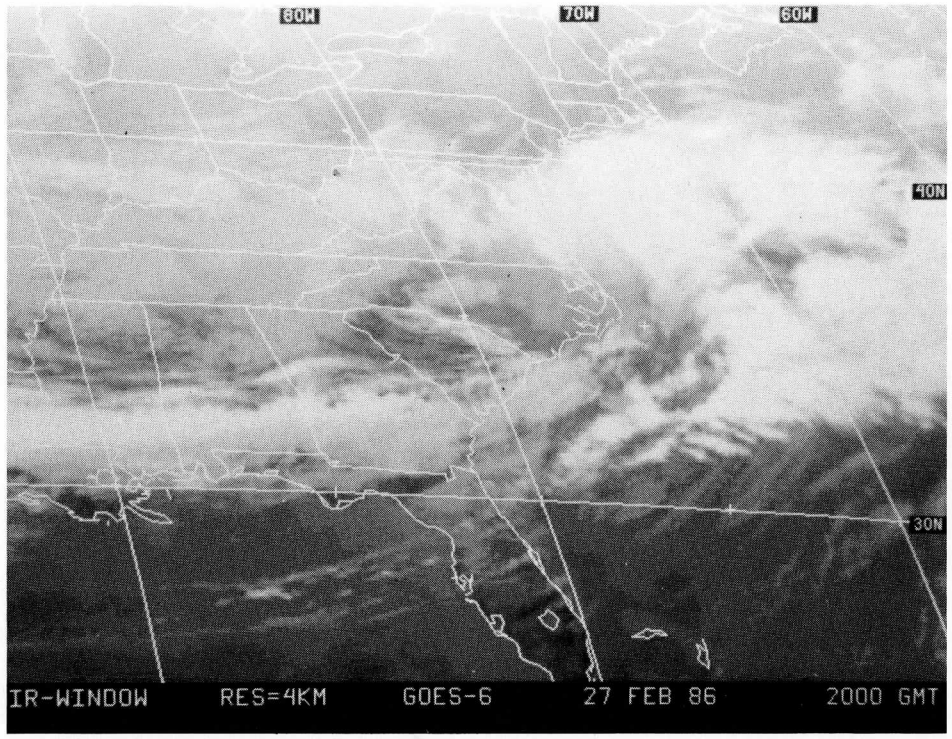
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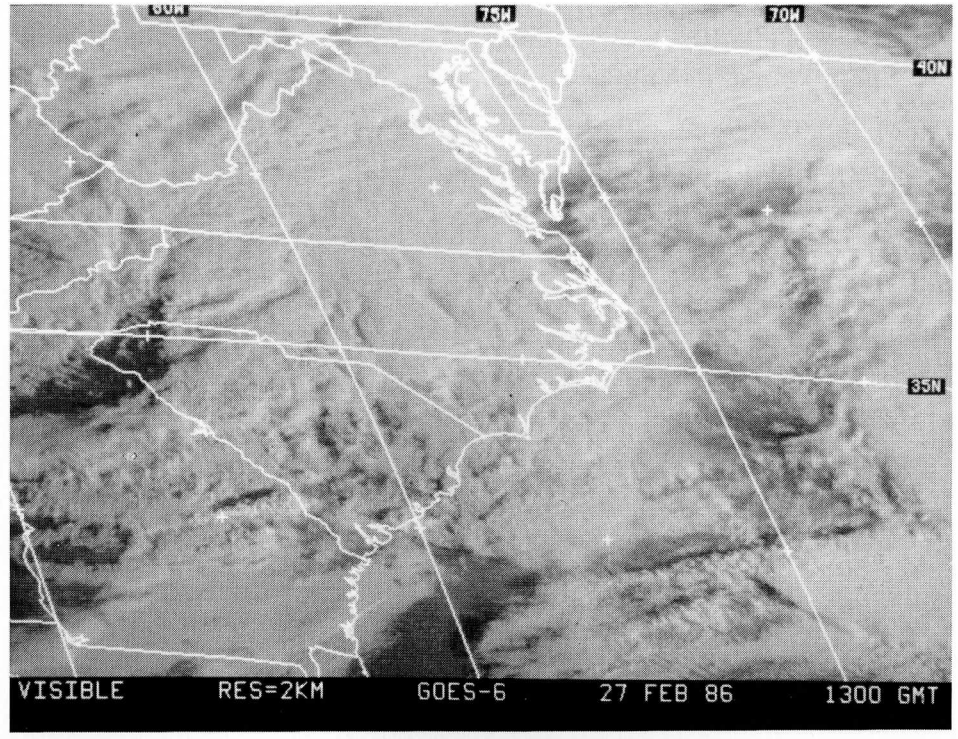
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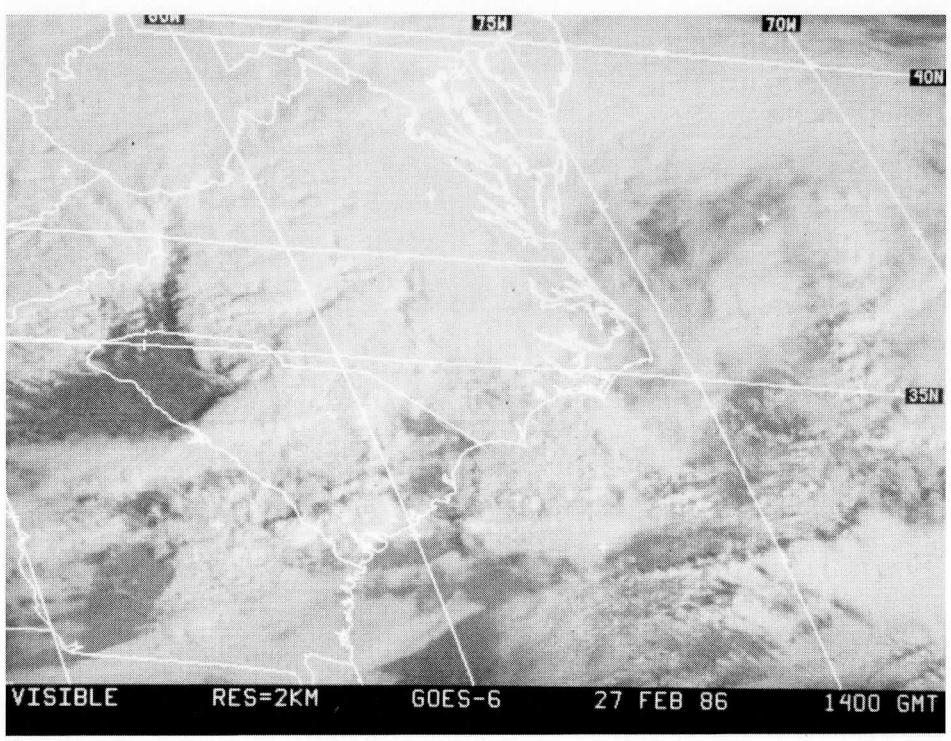
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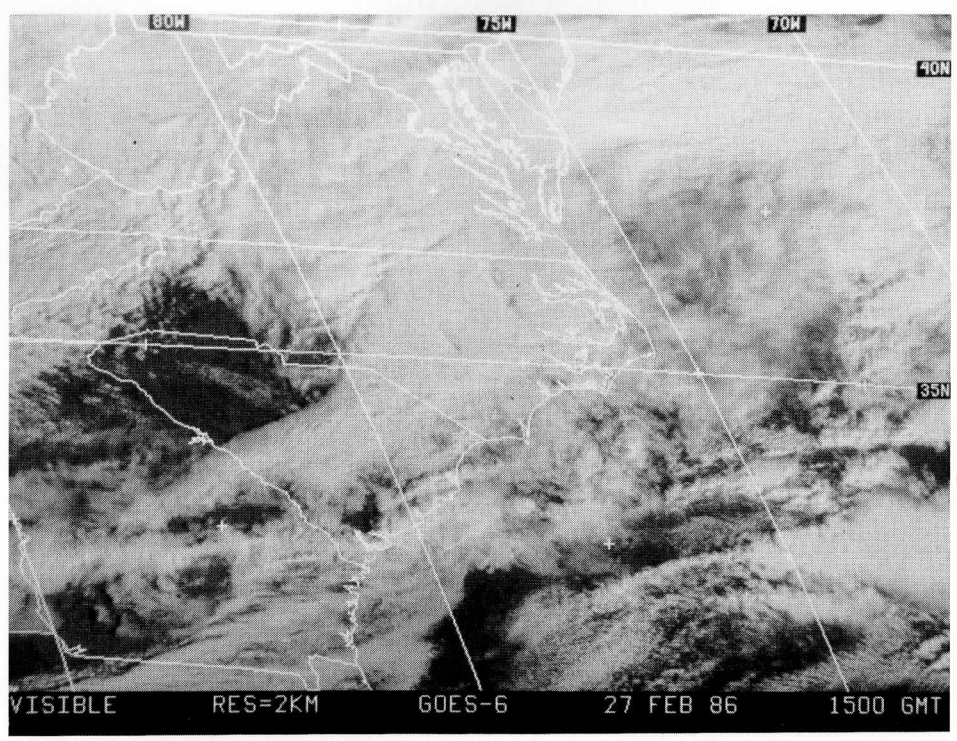
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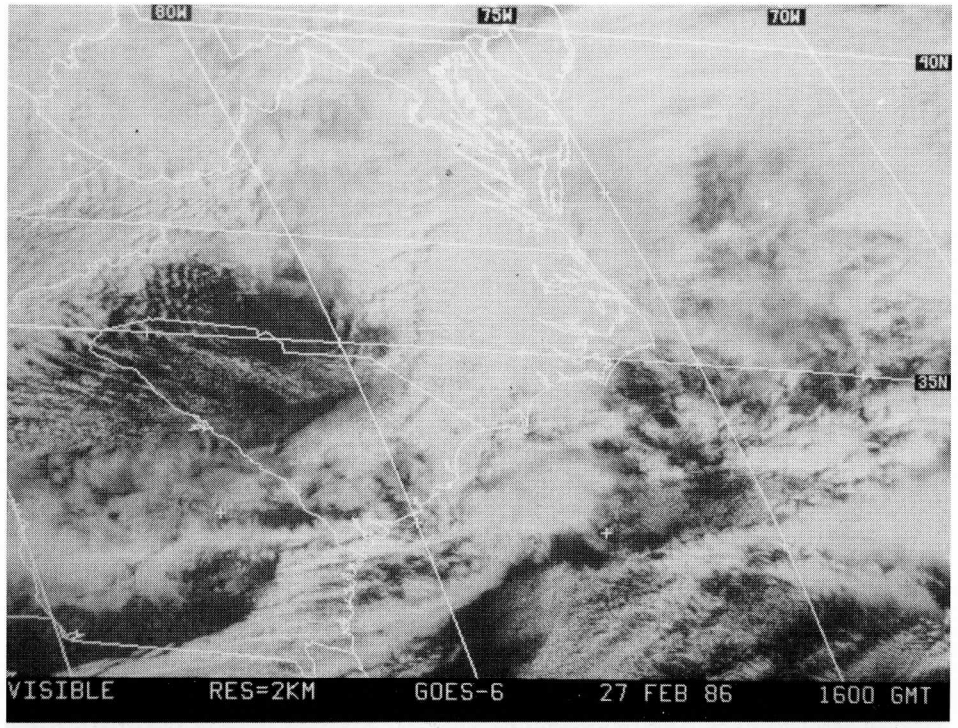
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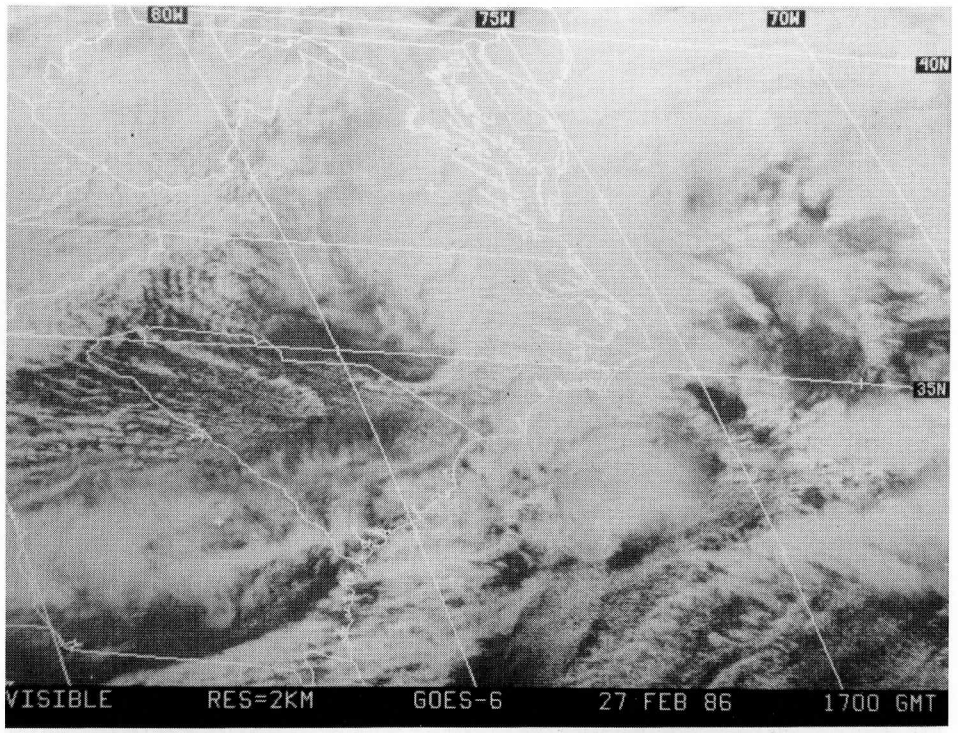
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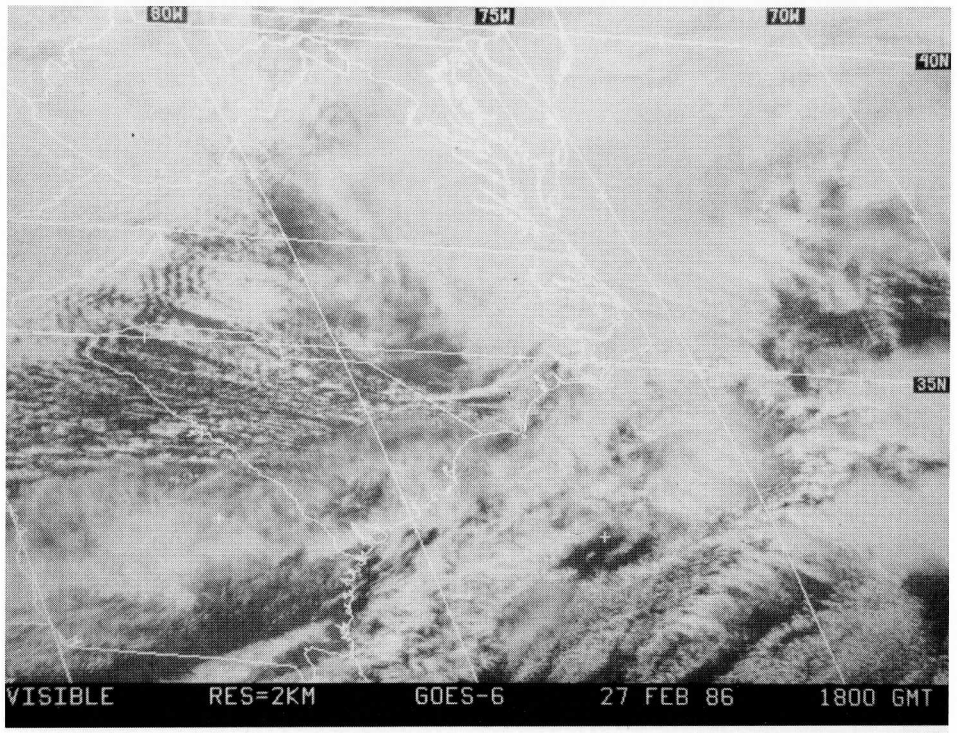
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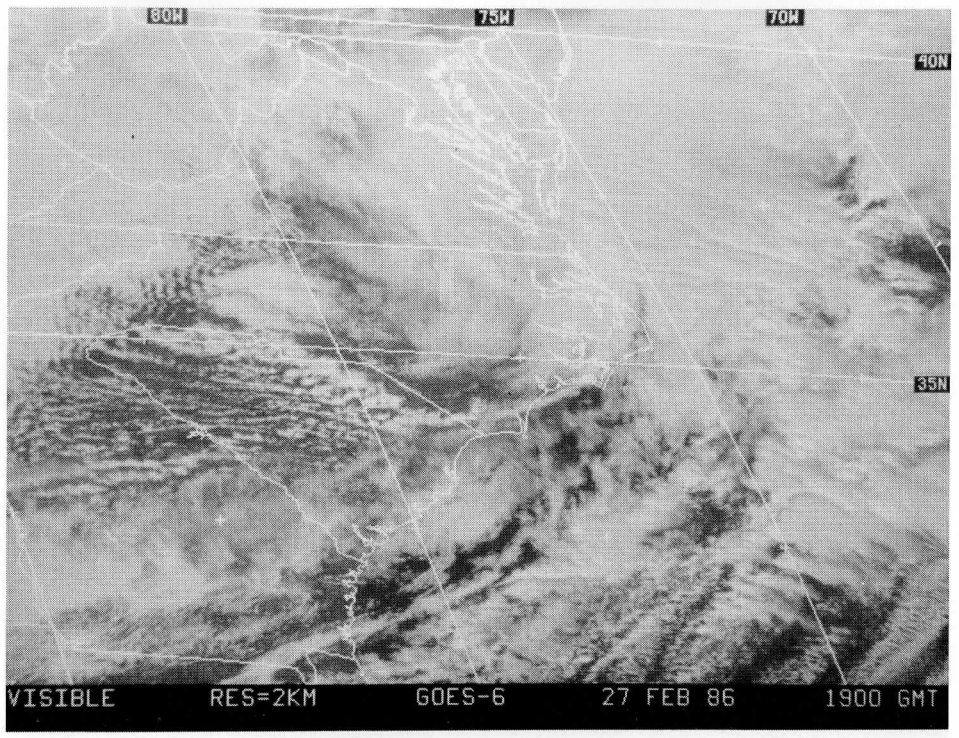
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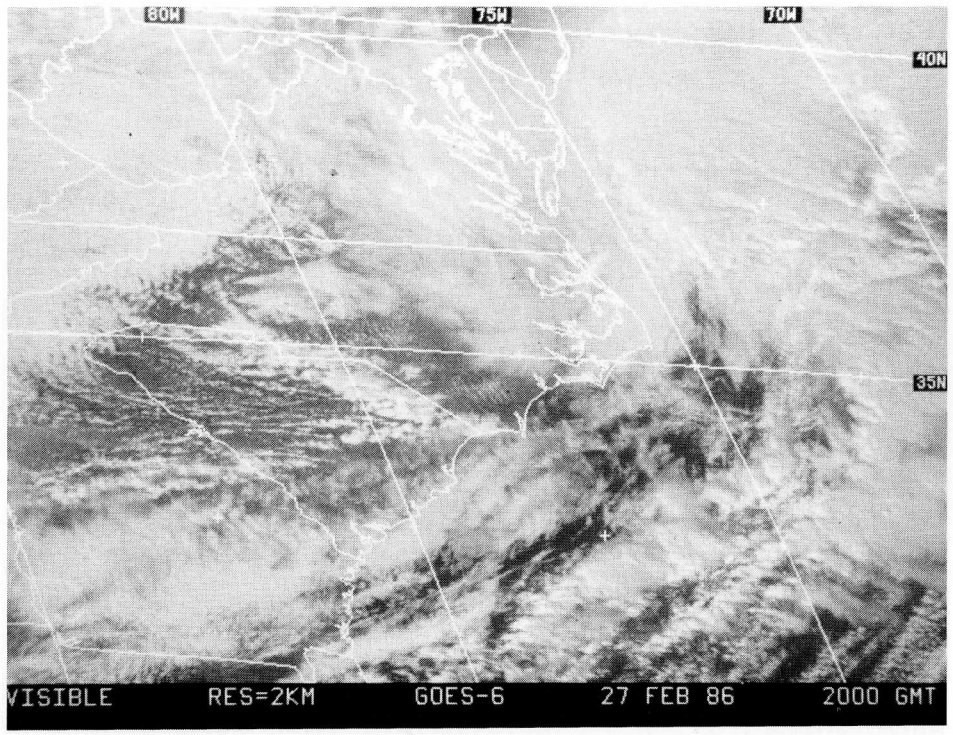
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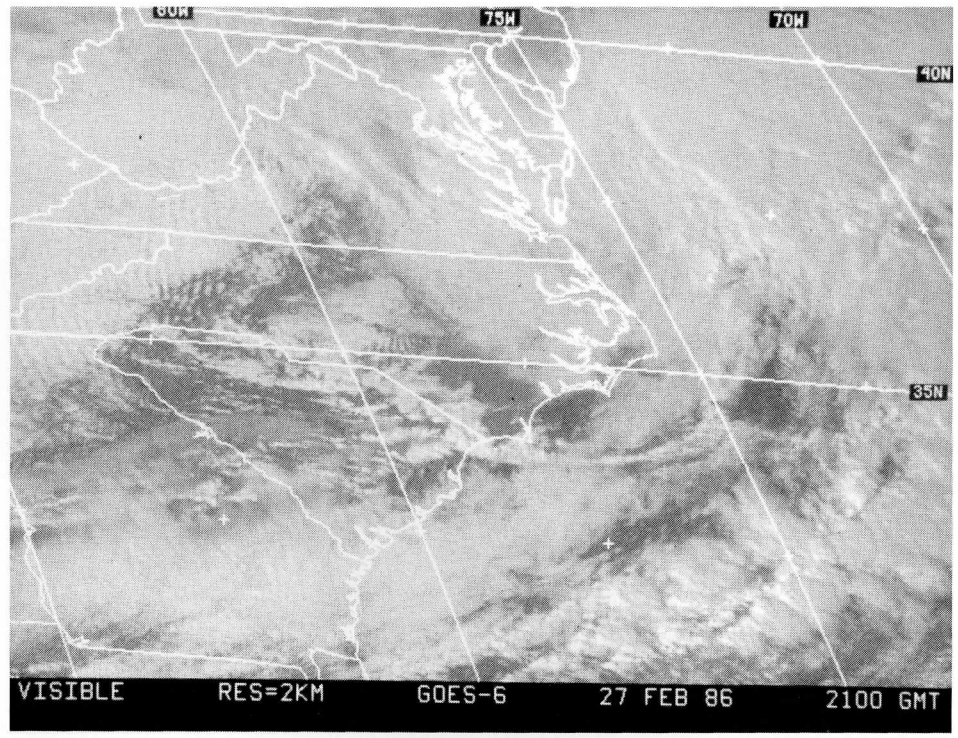
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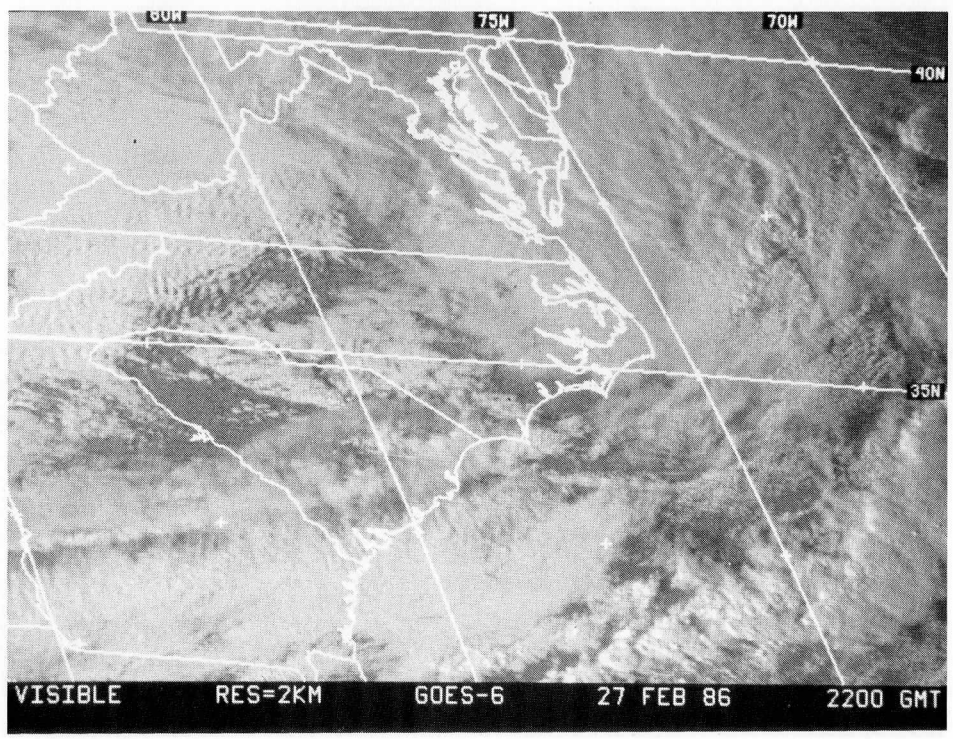
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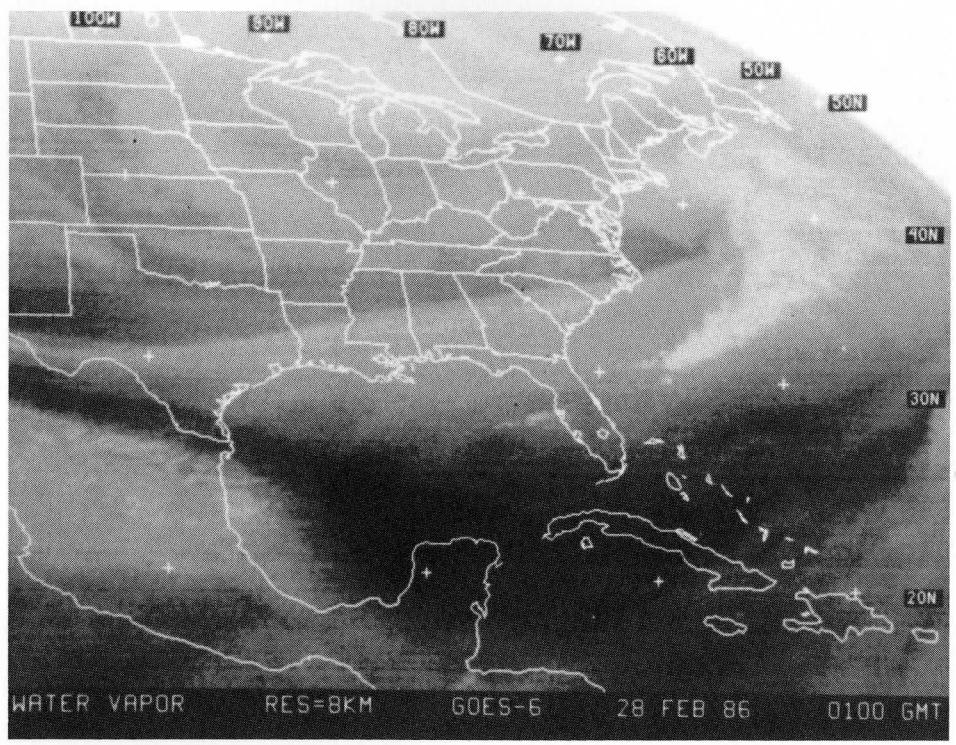
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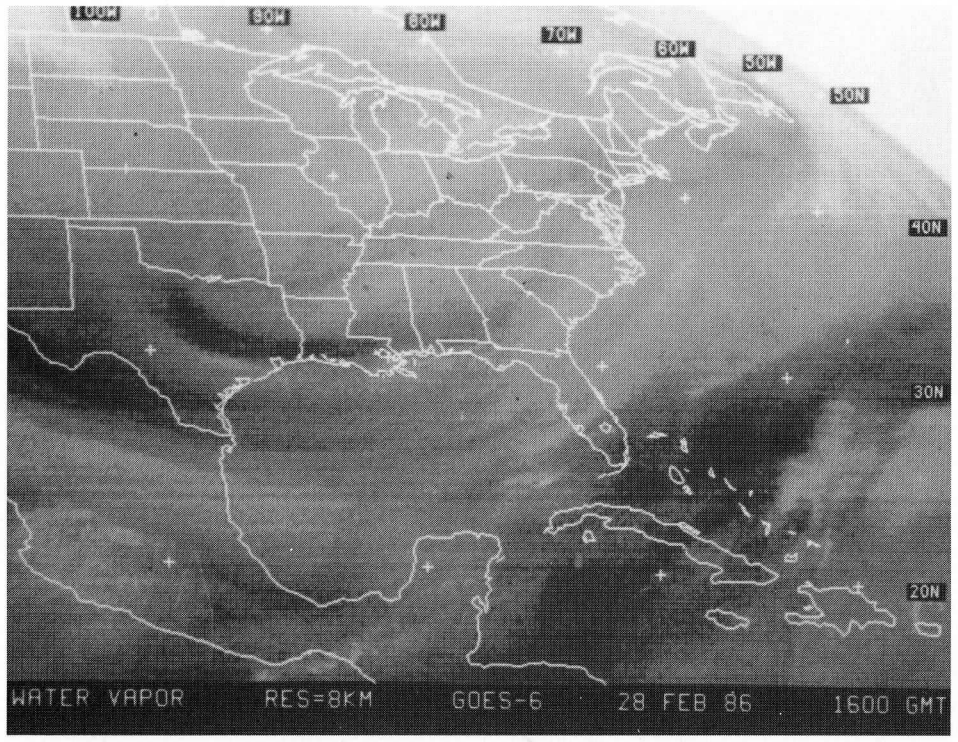
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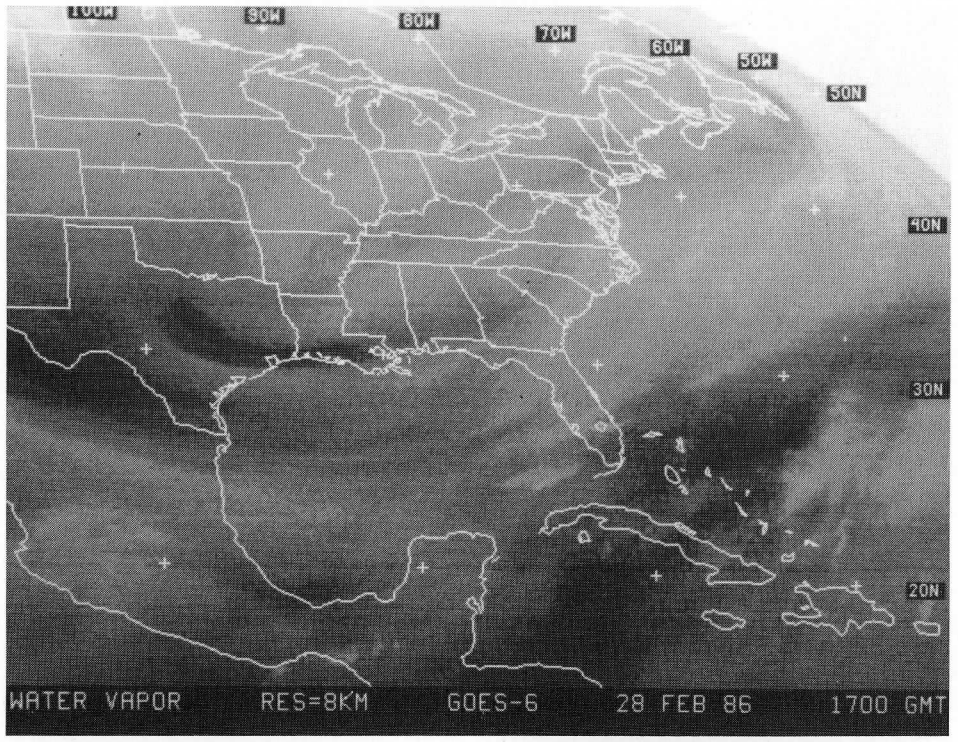
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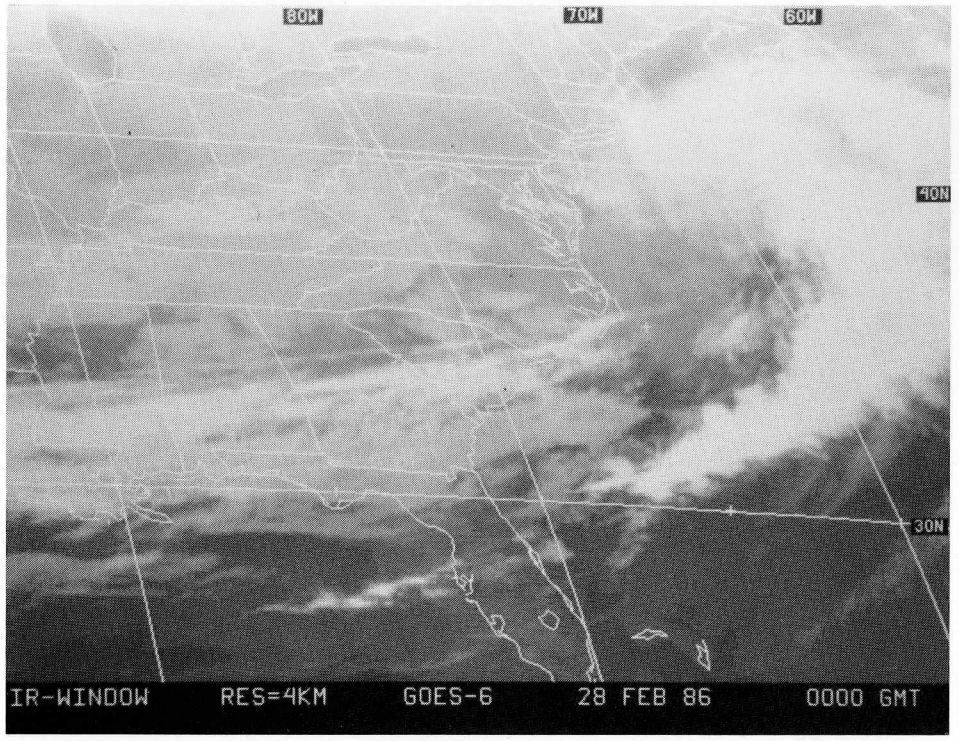
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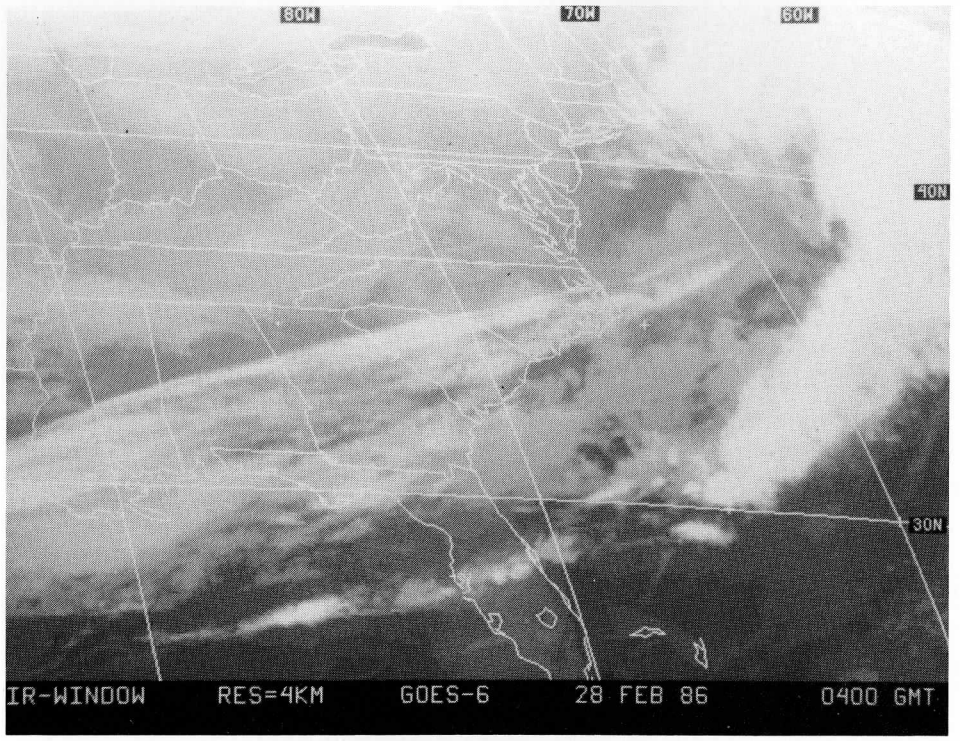
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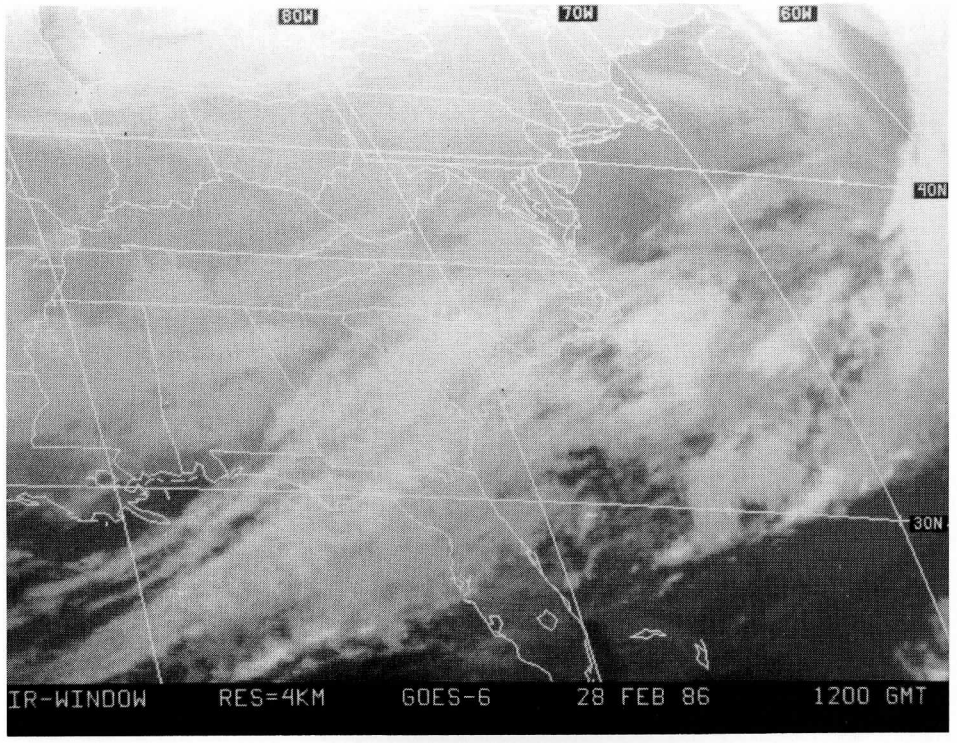
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END OF IOP

IOP #11 - Offshore Cyclogenesis
February 28 - March 2

Satellite Synopsis

Water Vapor

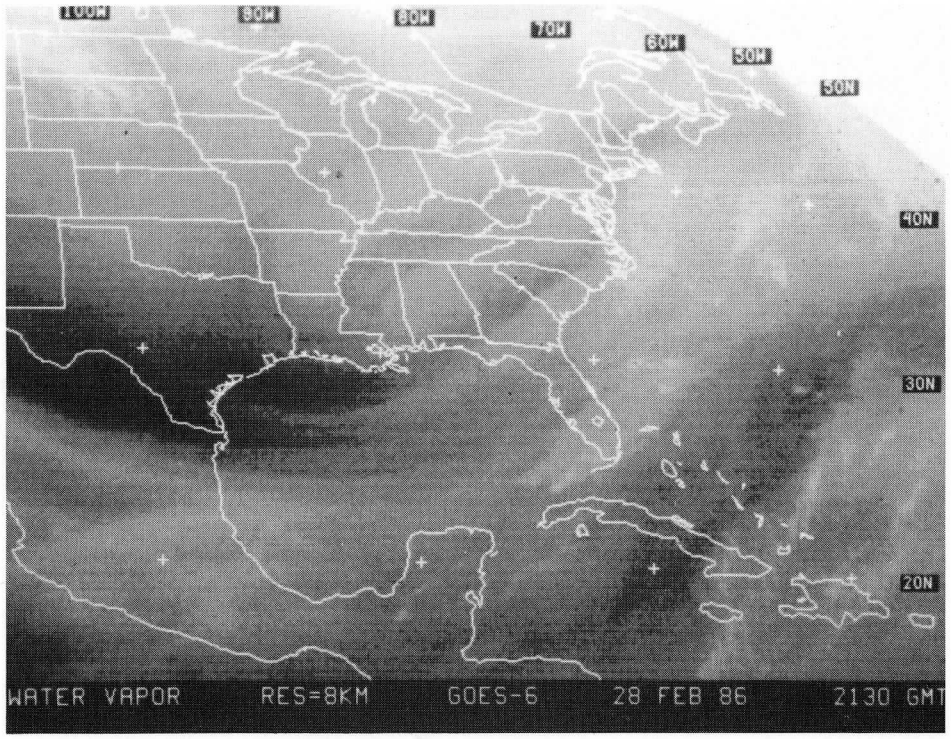
- On the 28th a long wave trough was depicted in the moisture pattern with a center in northeast Arkansas.
- By the 1st, the center was in northeast Georgia with a negative tilt apparent.
- Strong subsidence south of Florida on the 1st.
- Several spiral dry bands appear on the 1st. The main dry band surges north on the east side of the circulation center on the 2nd. The circulation spins up and drifts northeast.
- The digging trough through the period is well depicted.

IR

- Banding of low level clouds with cyclonic curvature on the 1st in Gulf of Mexico.
- Strong banding/streets with cold air push off shore of Georgia and Florida on the 2nd.
- Weak short wave/circulation in Indiana and Ohio late on the 2nd.

Visible

- 28th, low level wave clouds over Georgia.
- 28th, low level cloud structure, patchy areas, well offshore.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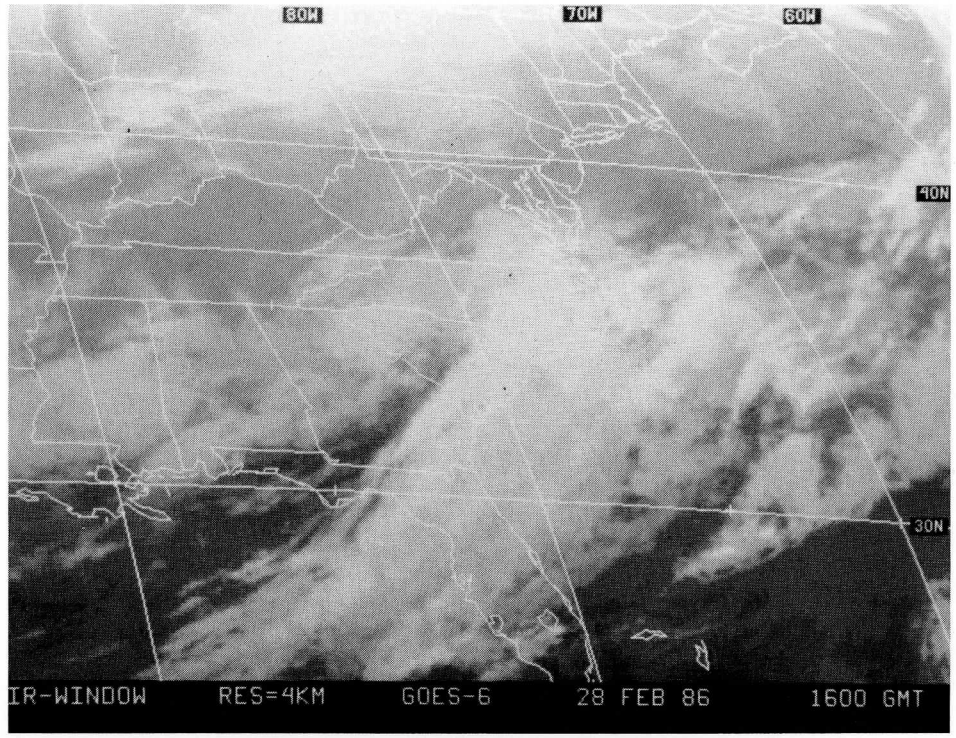
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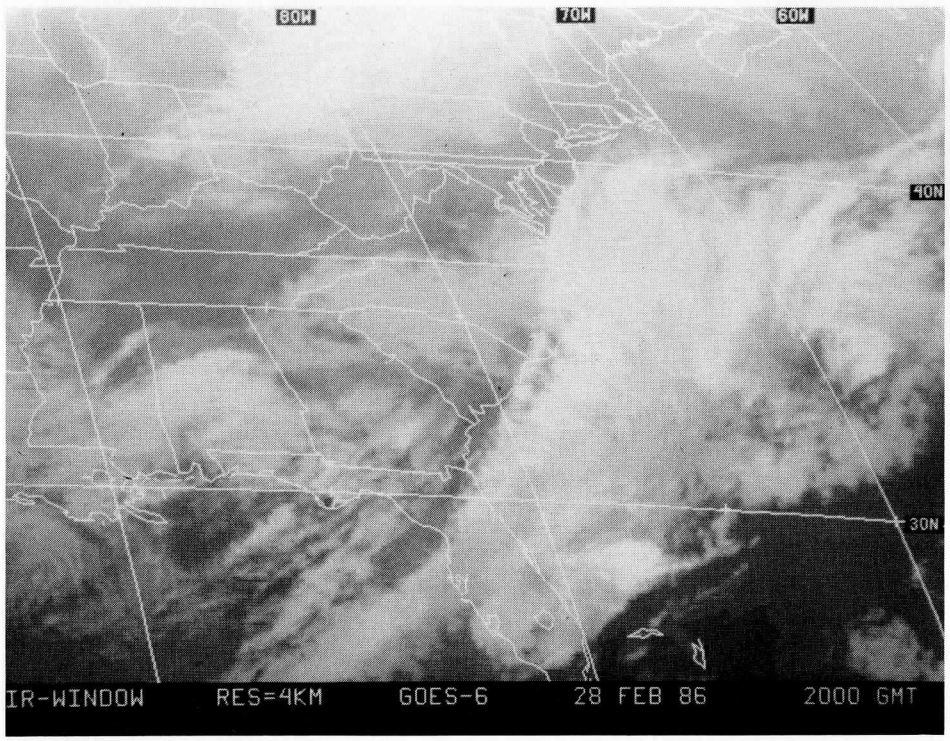
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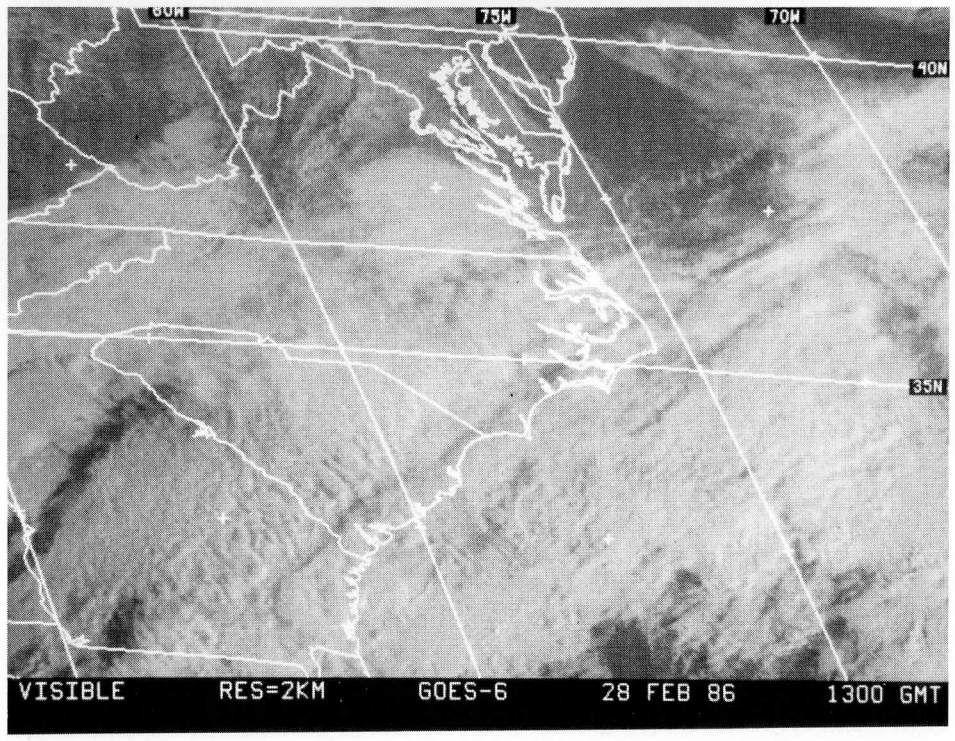
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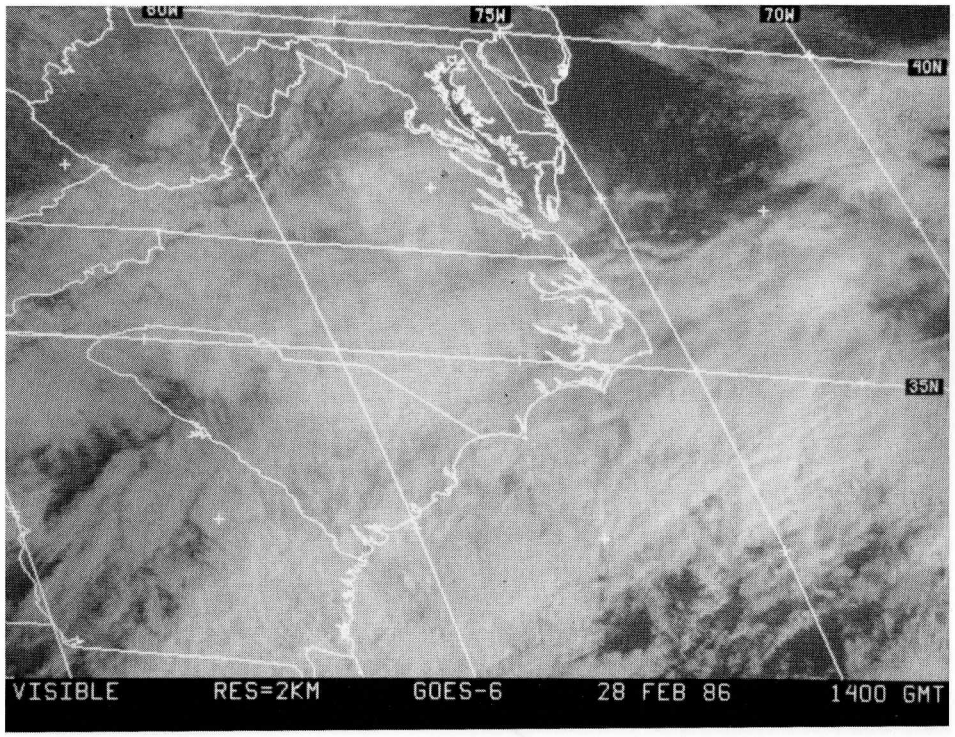
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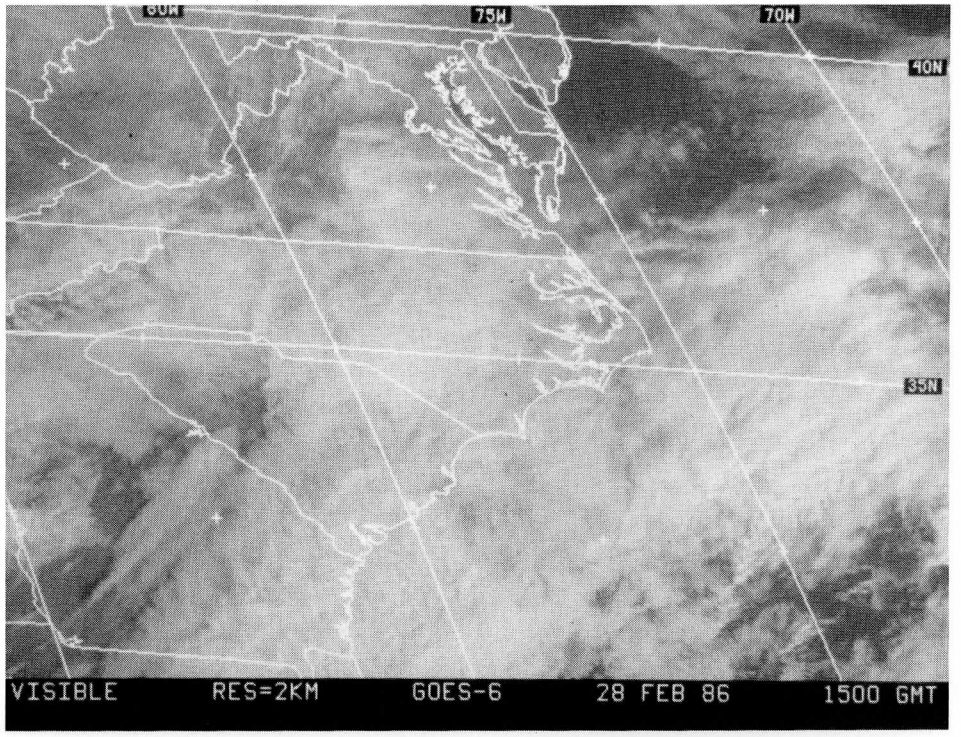
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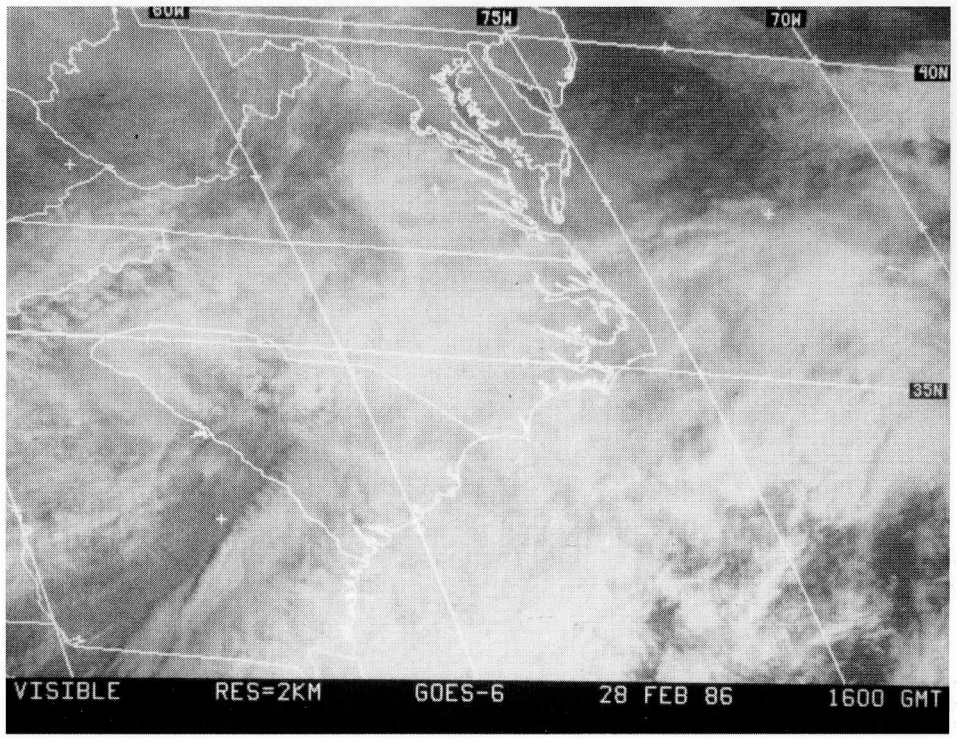
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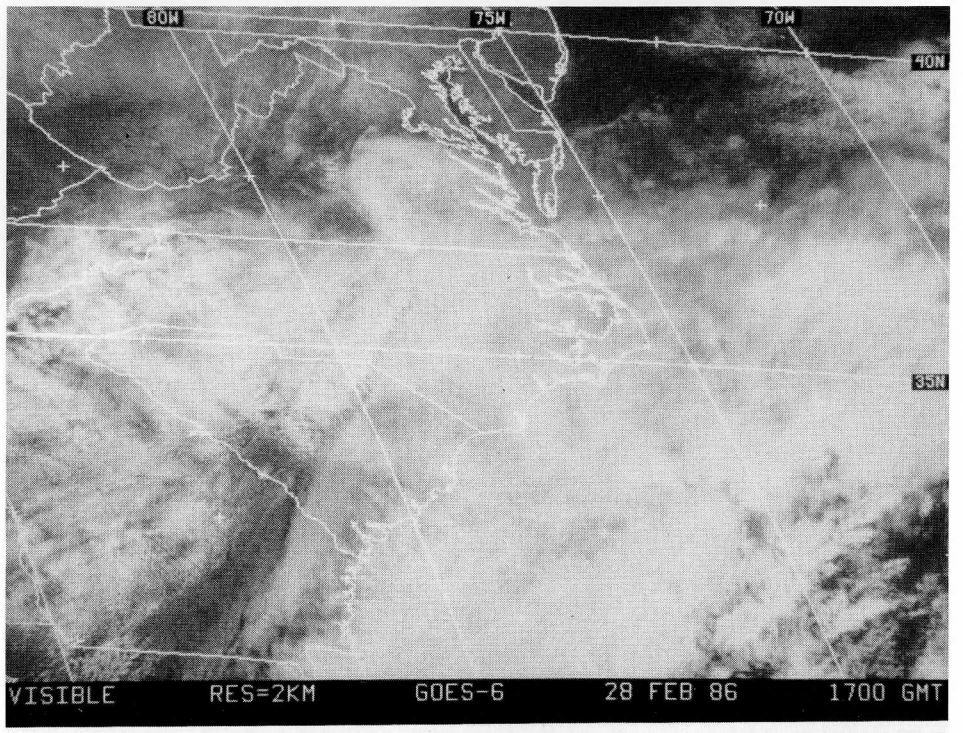
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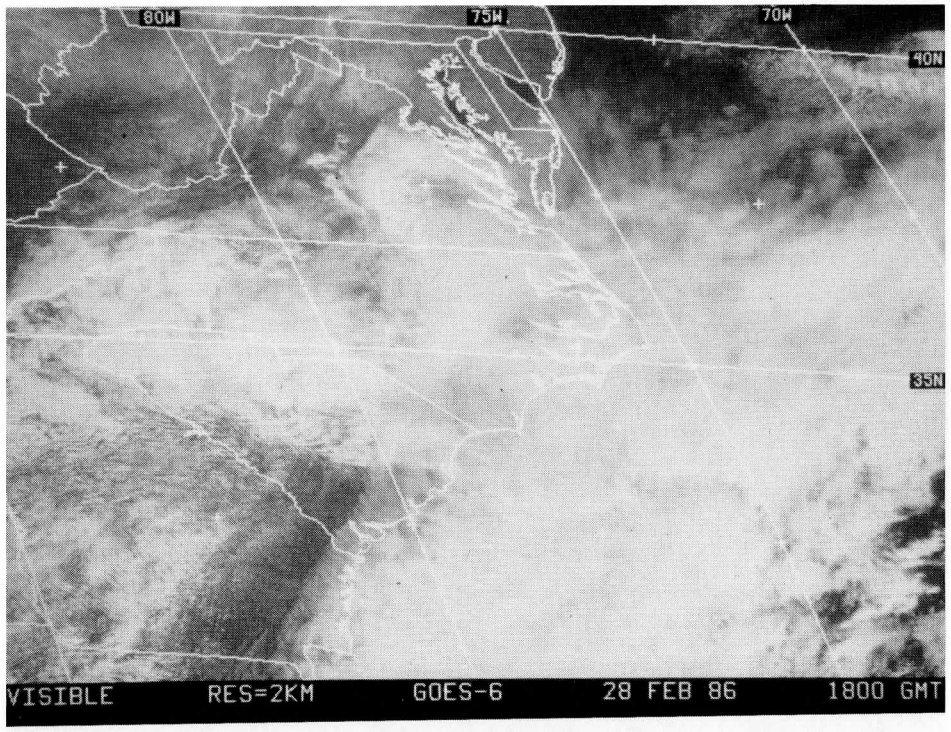
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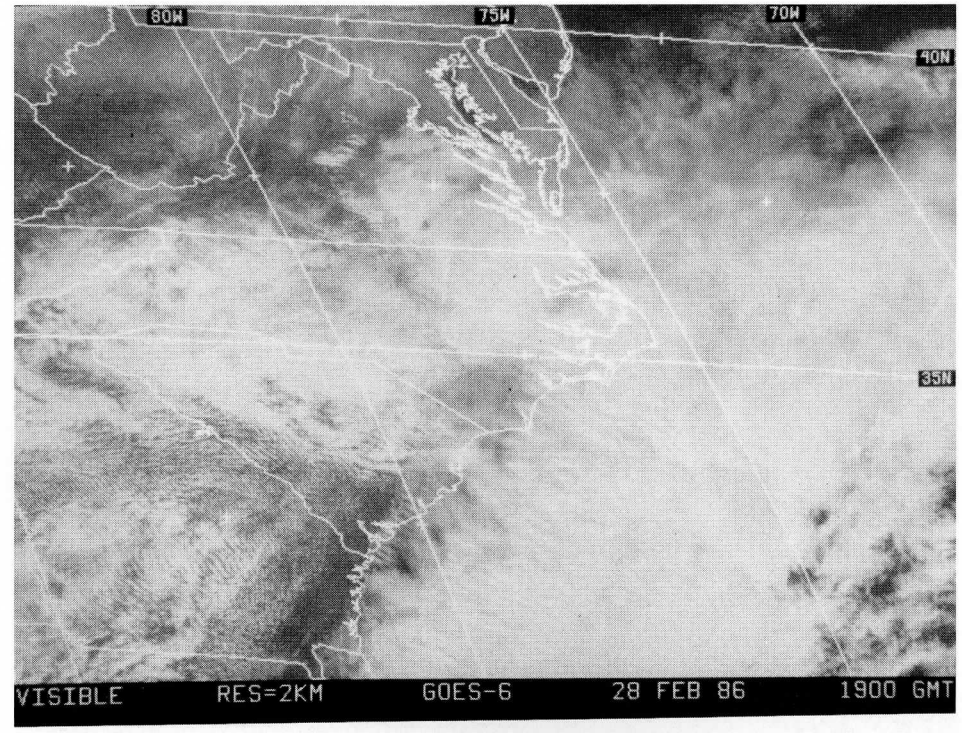
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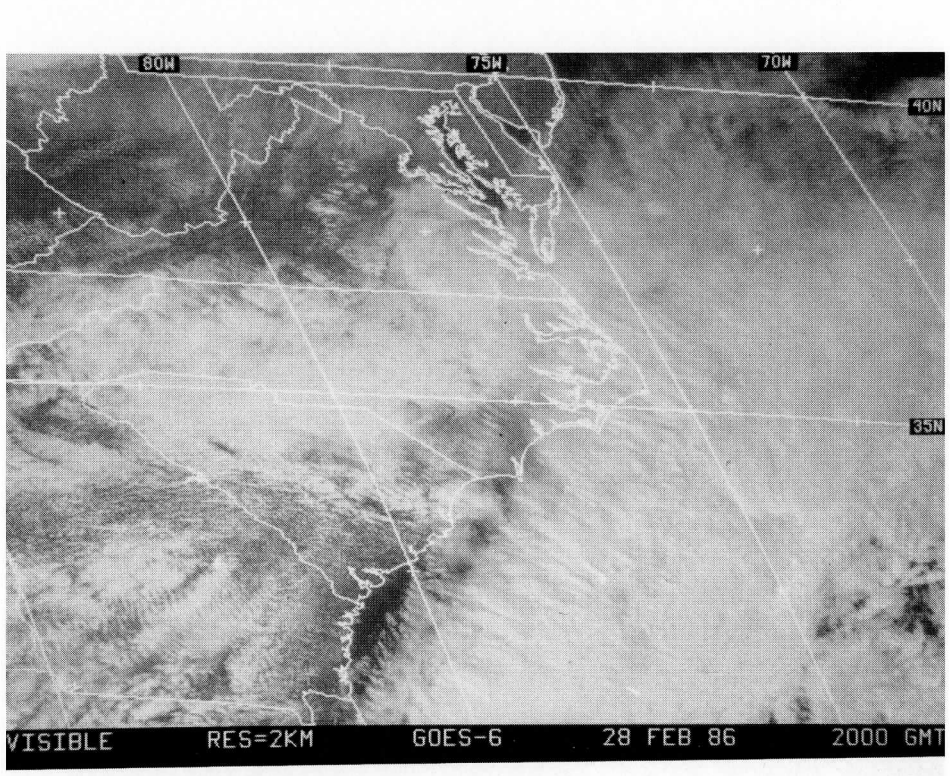
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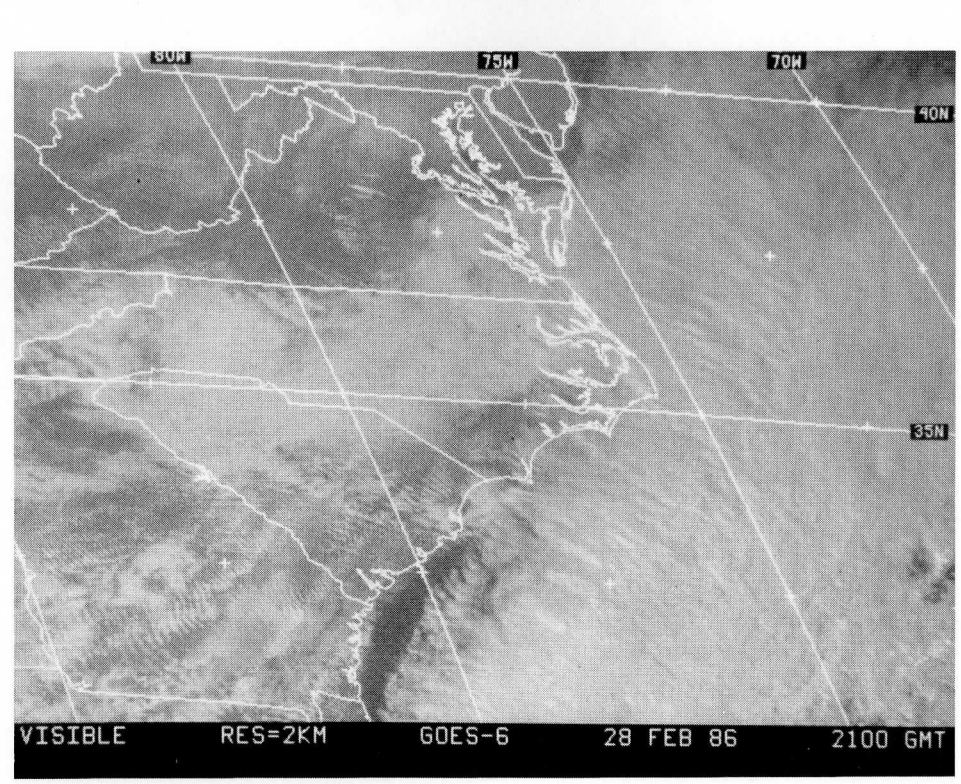
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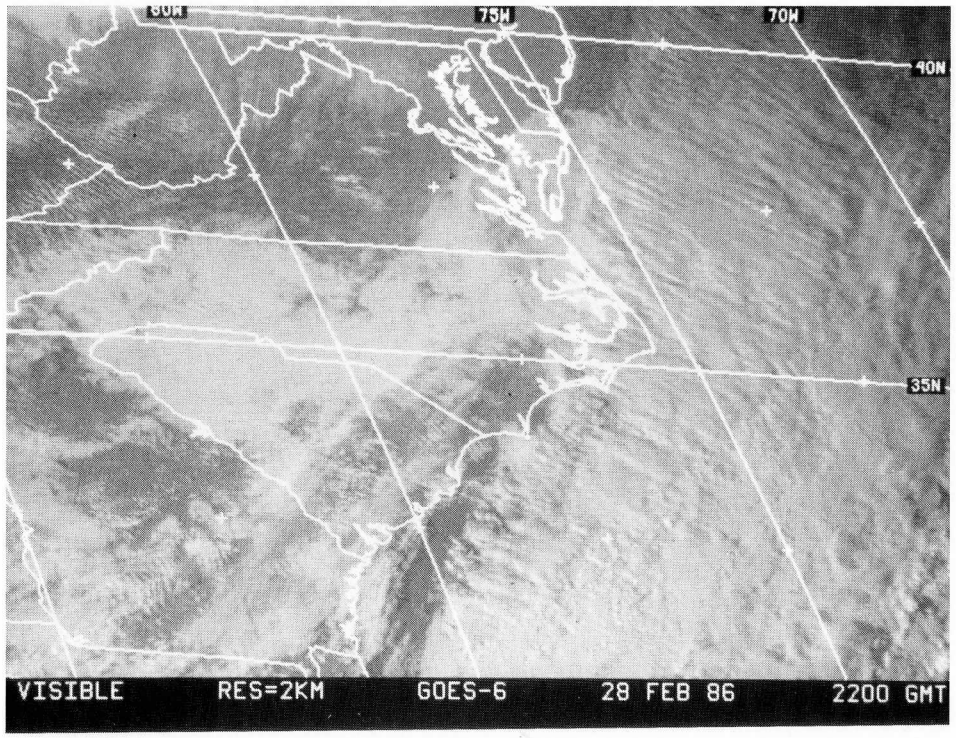
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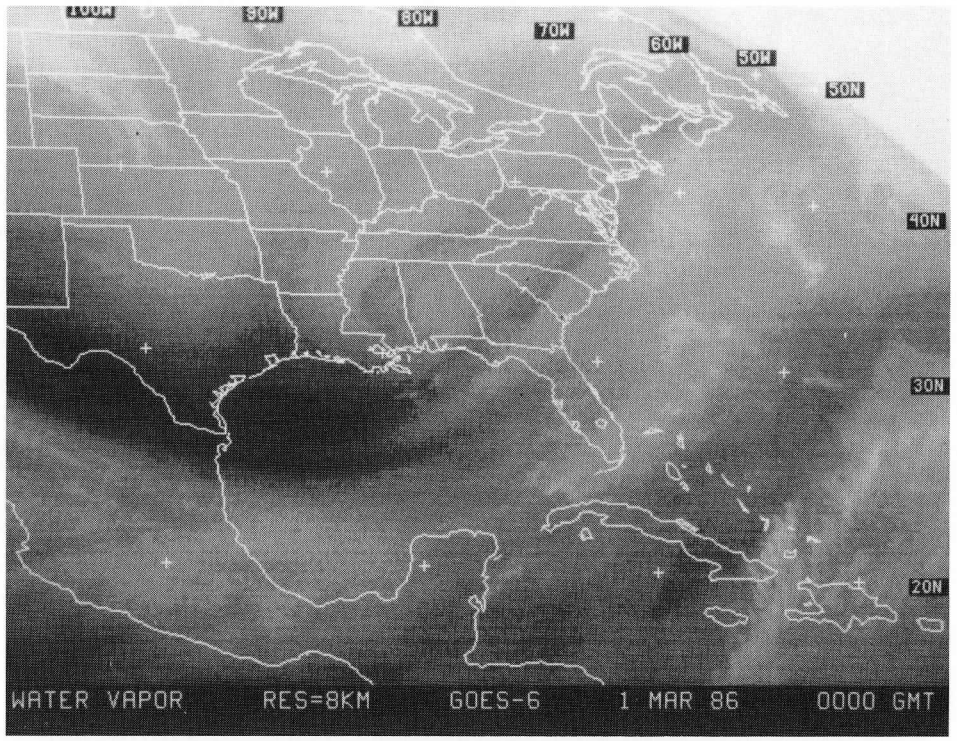
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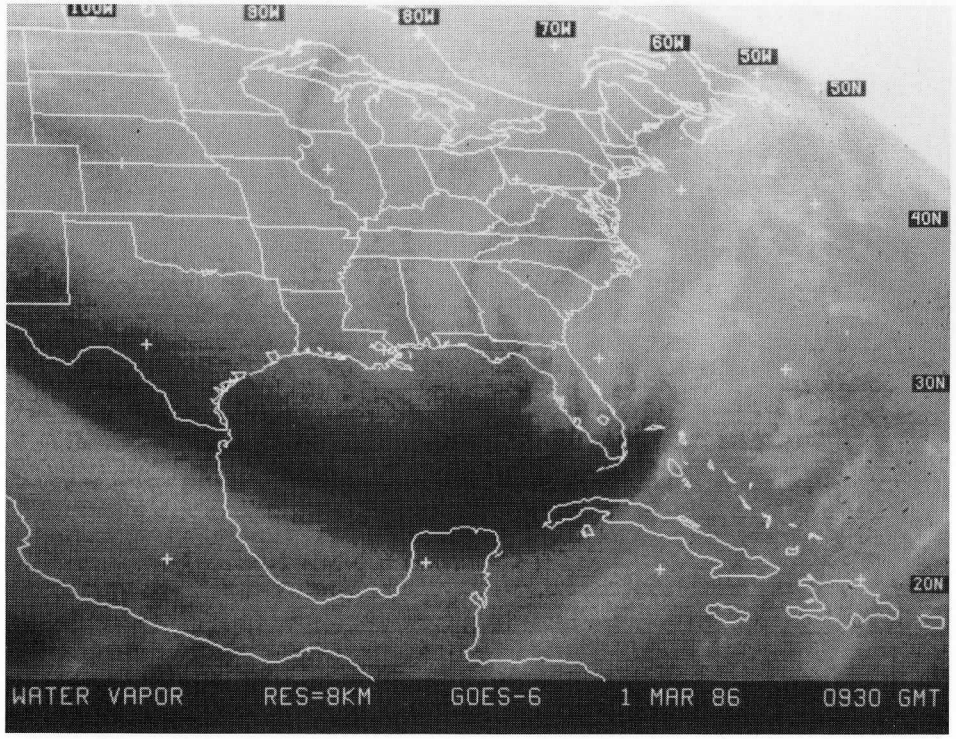
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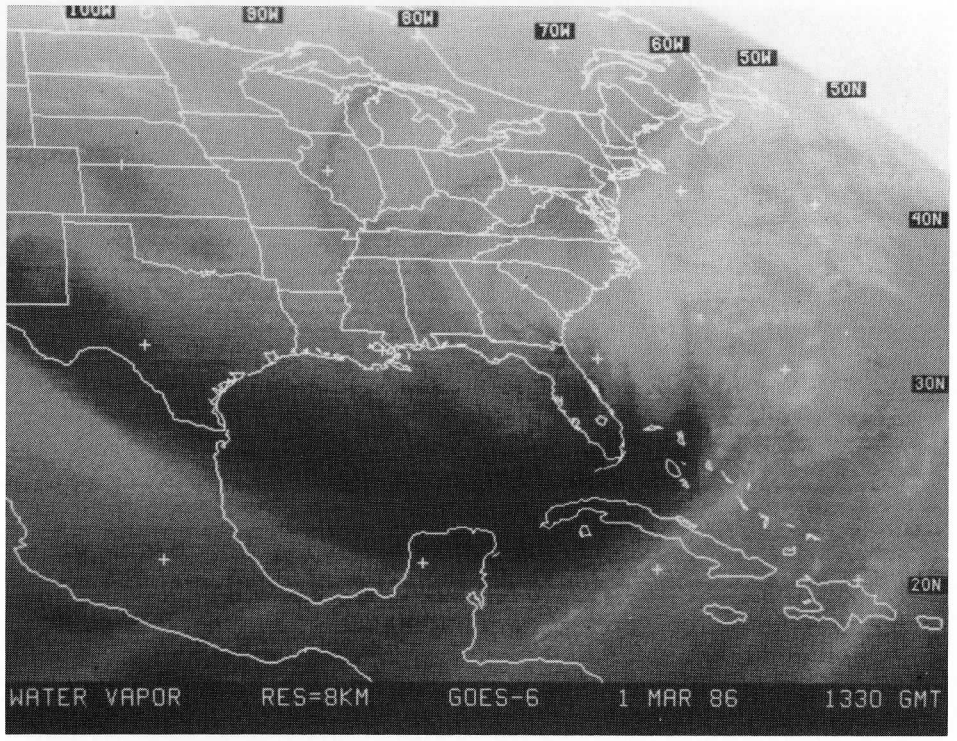
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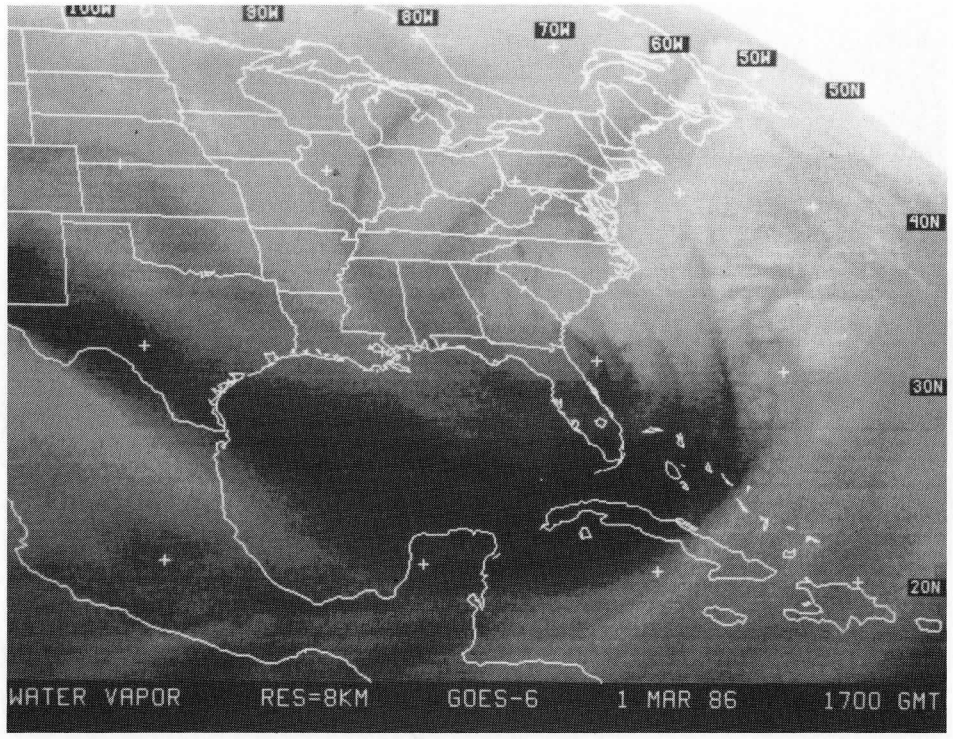
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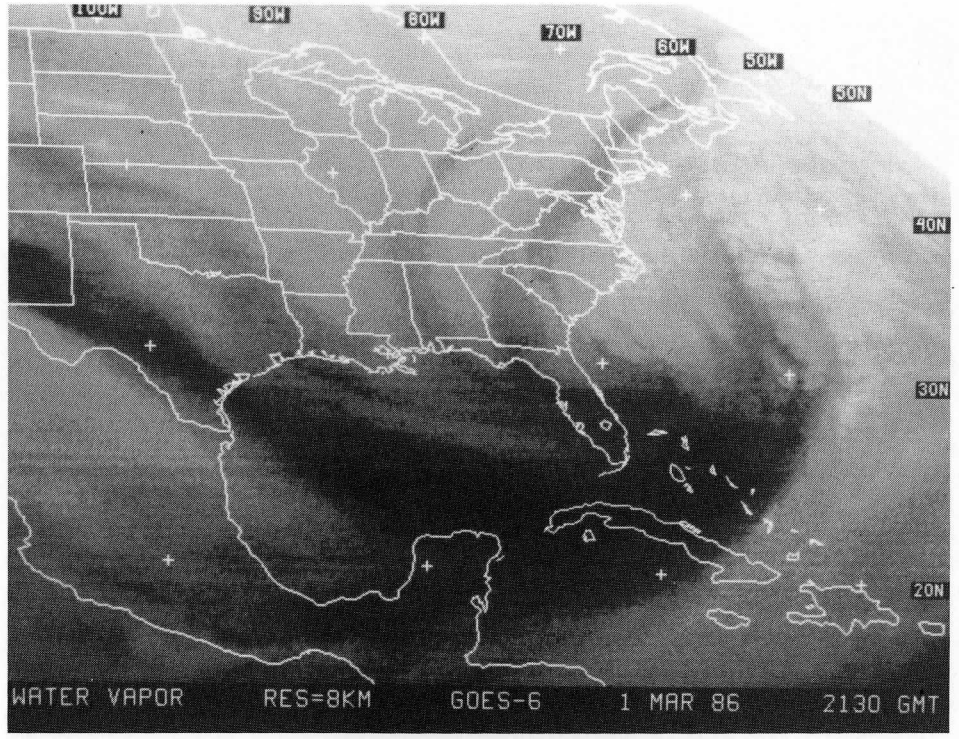
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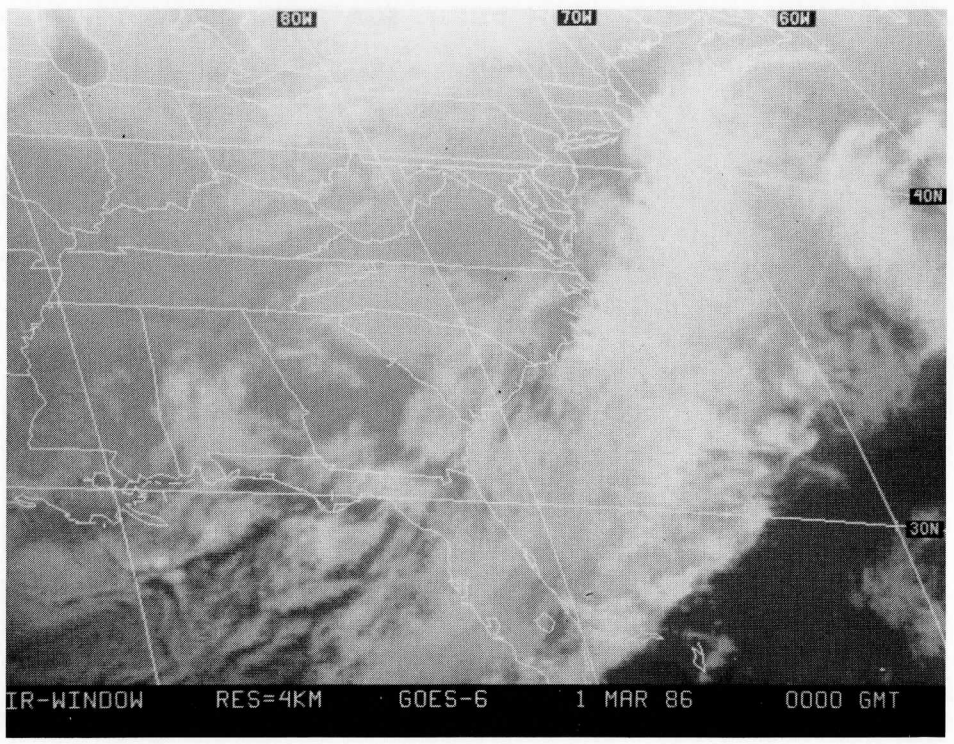
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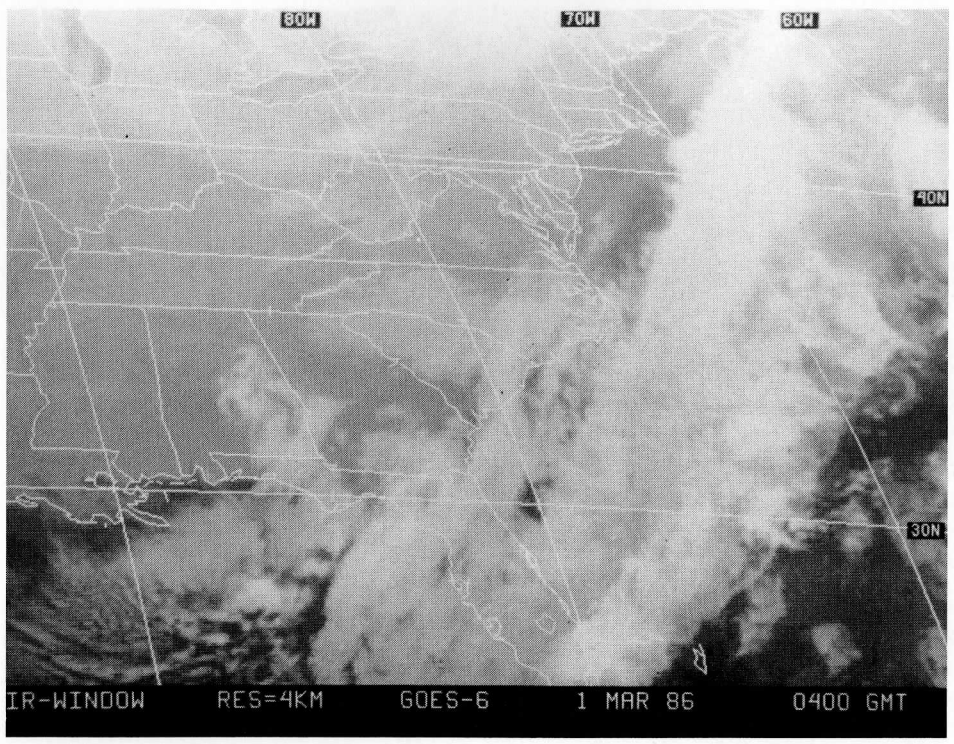
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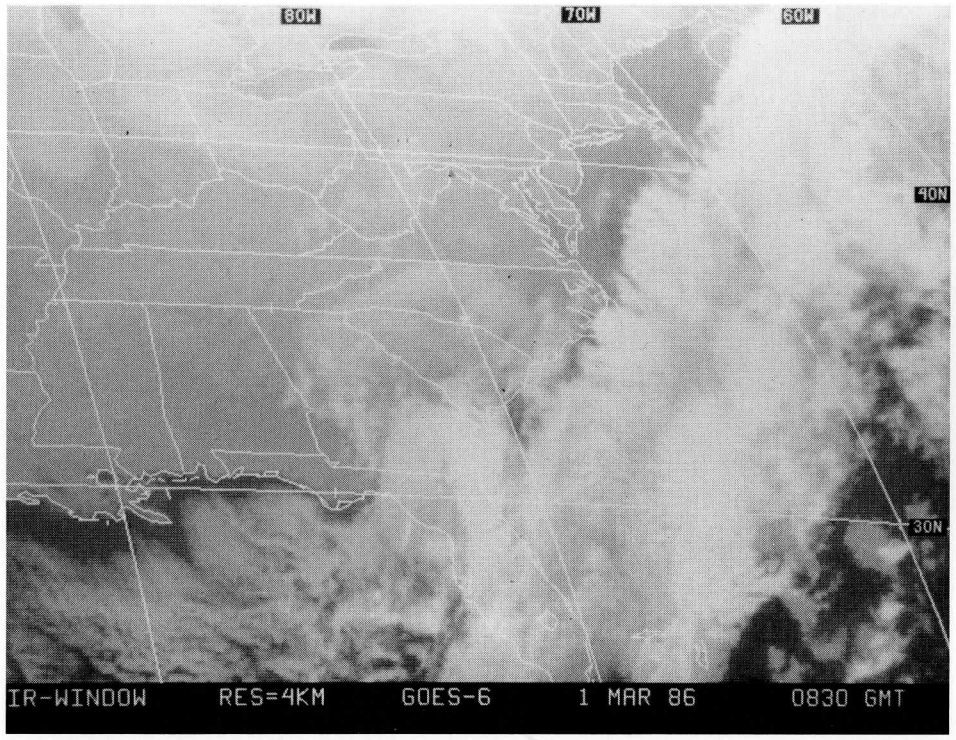
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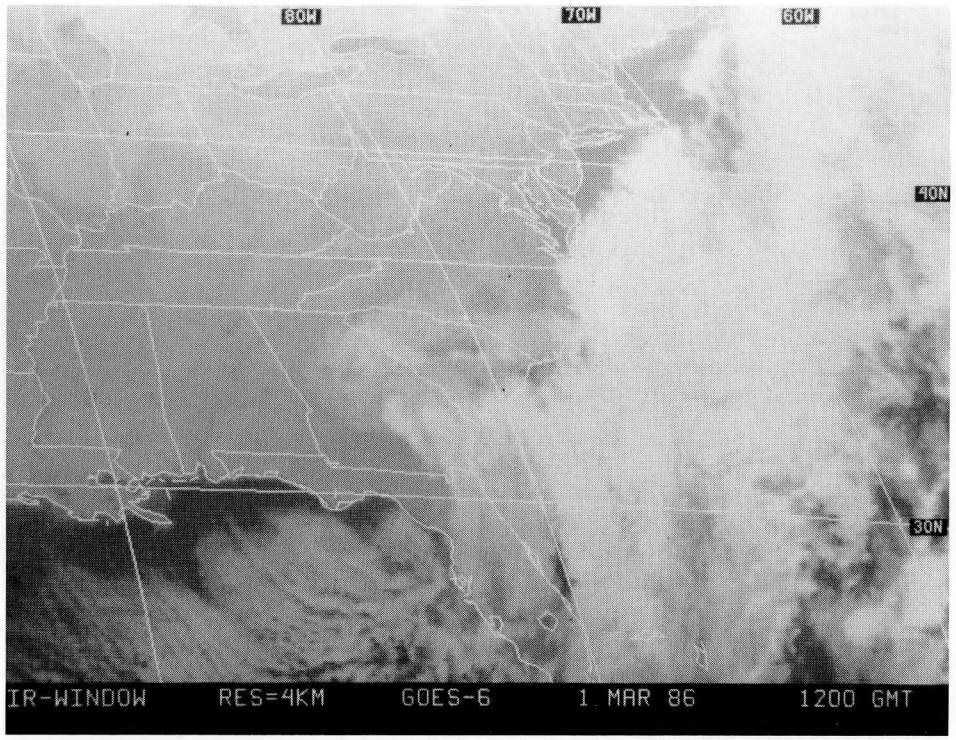
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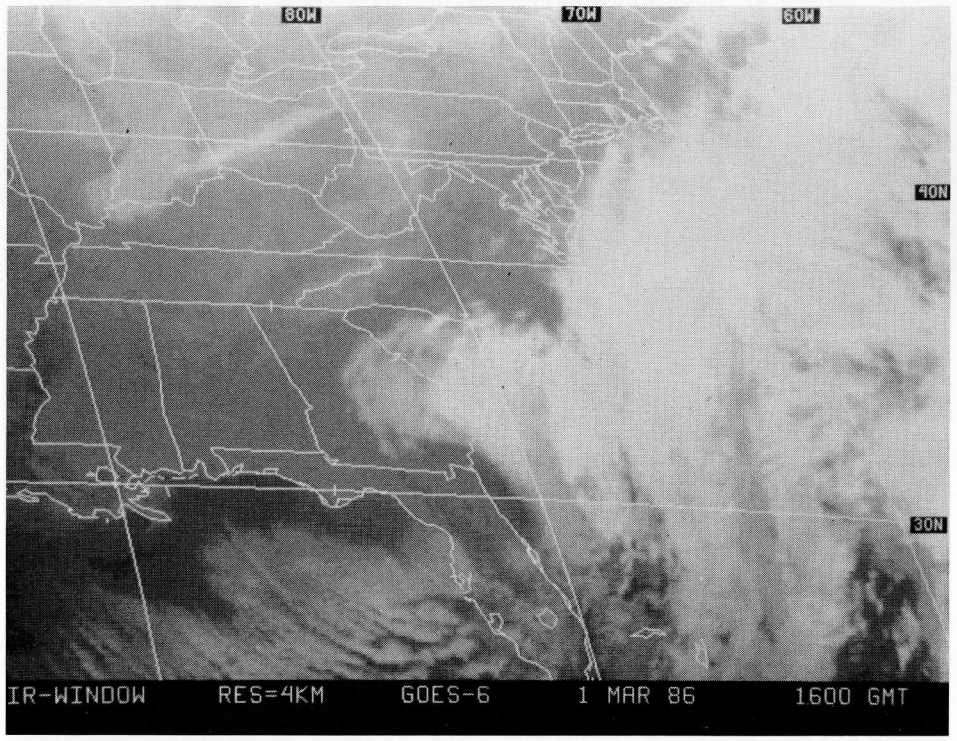
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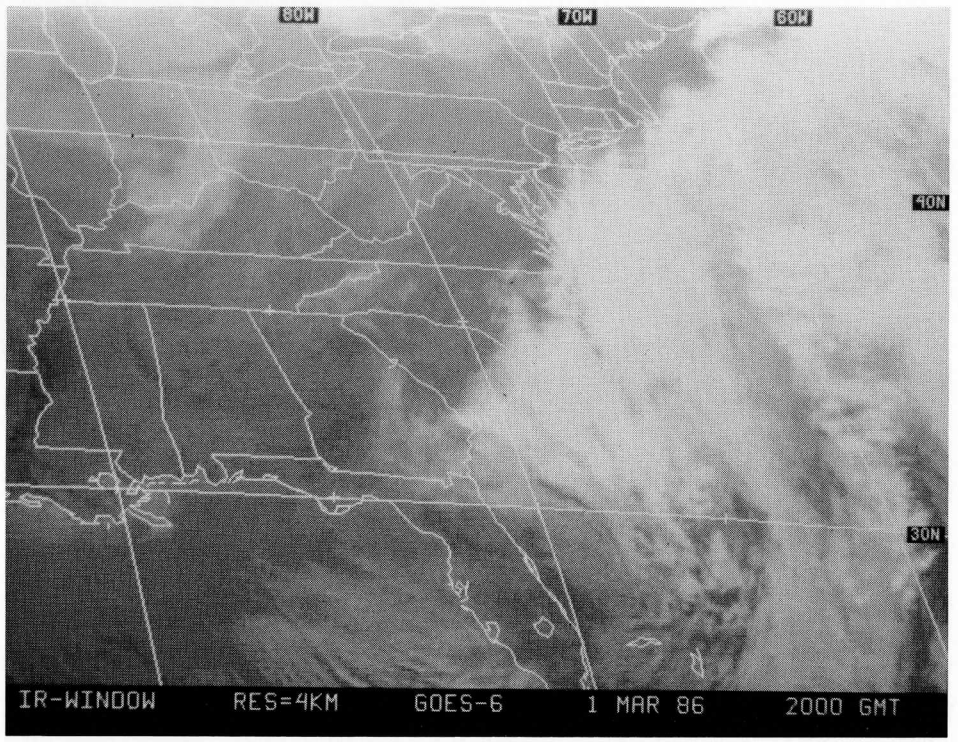
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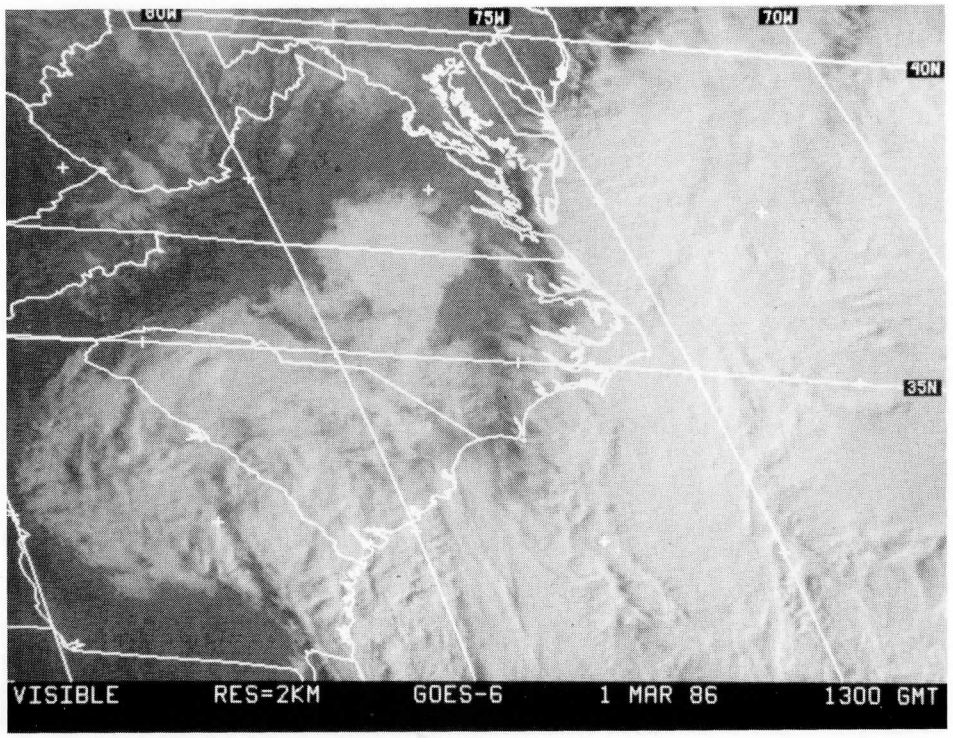
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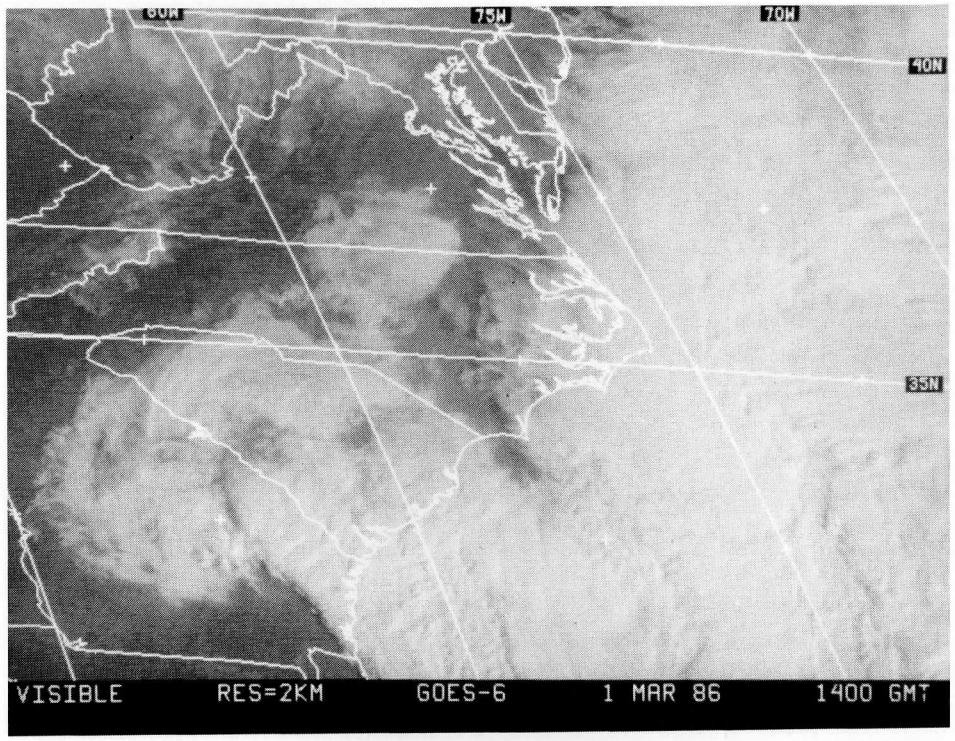
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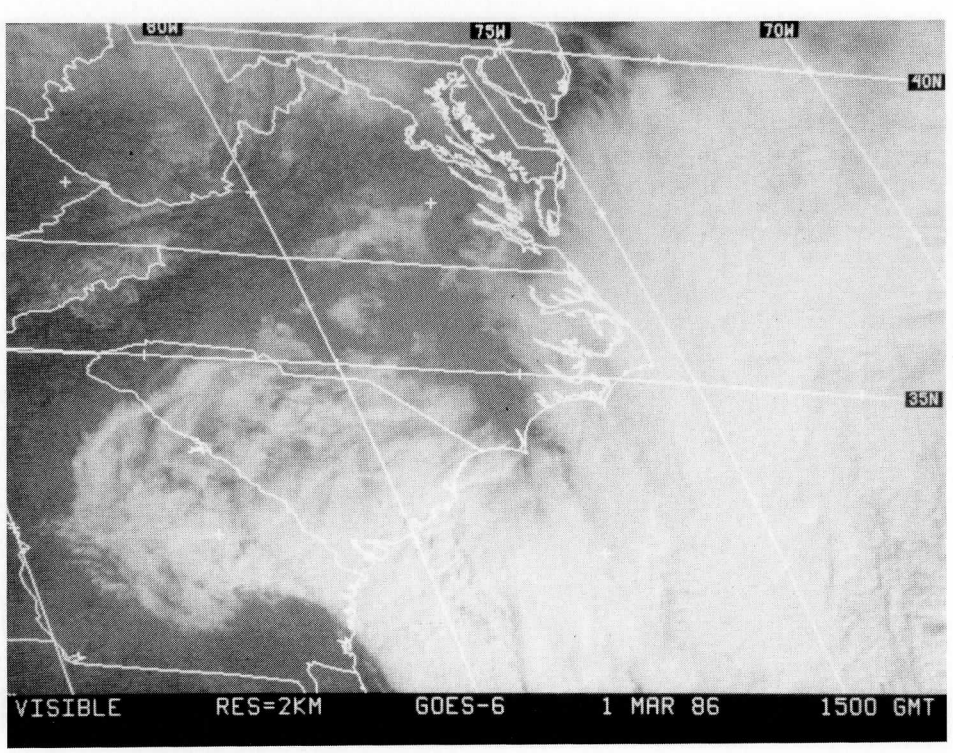
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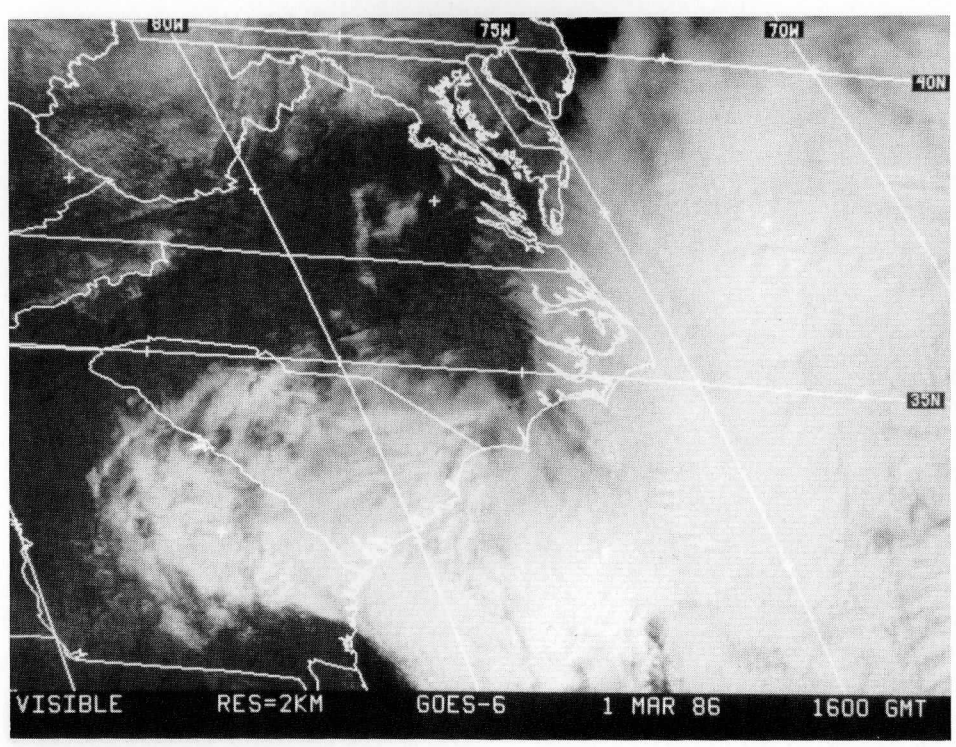
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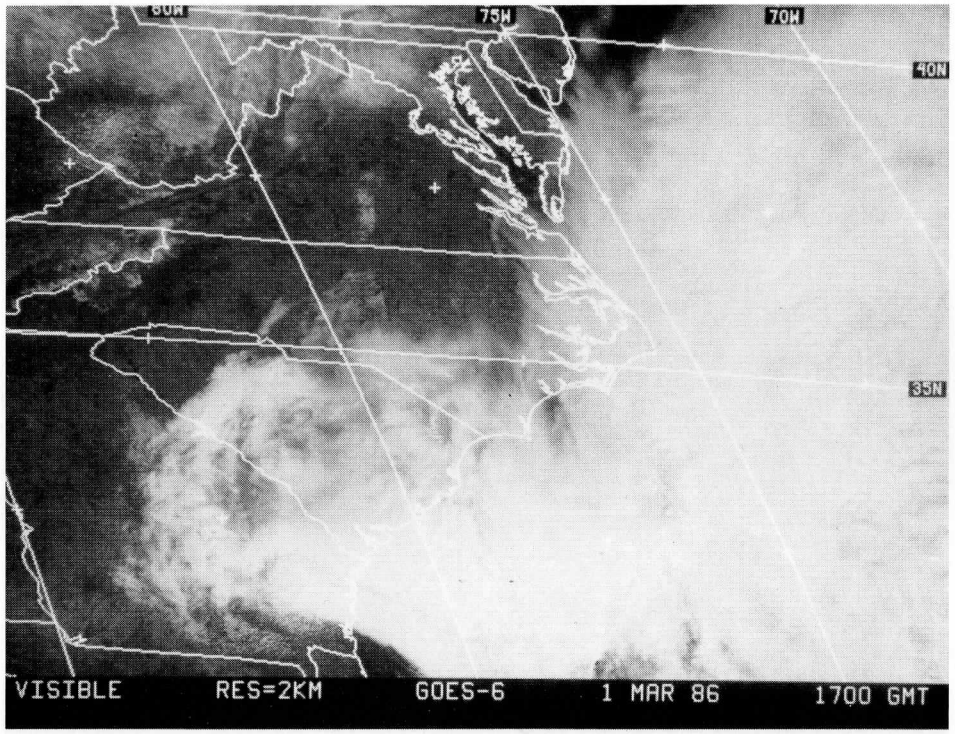
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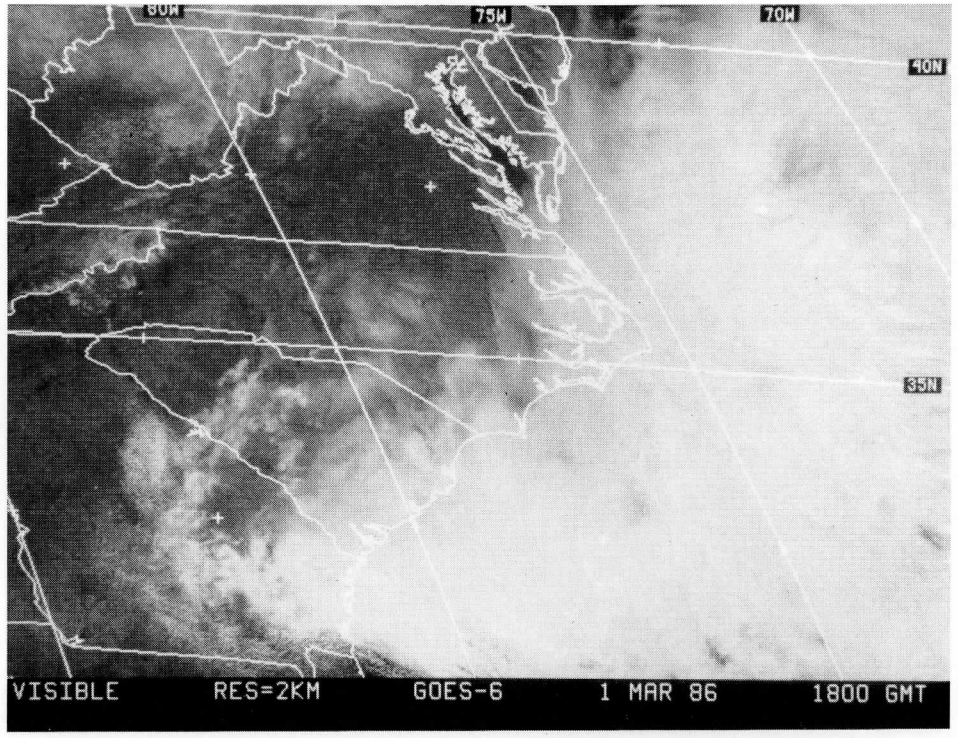
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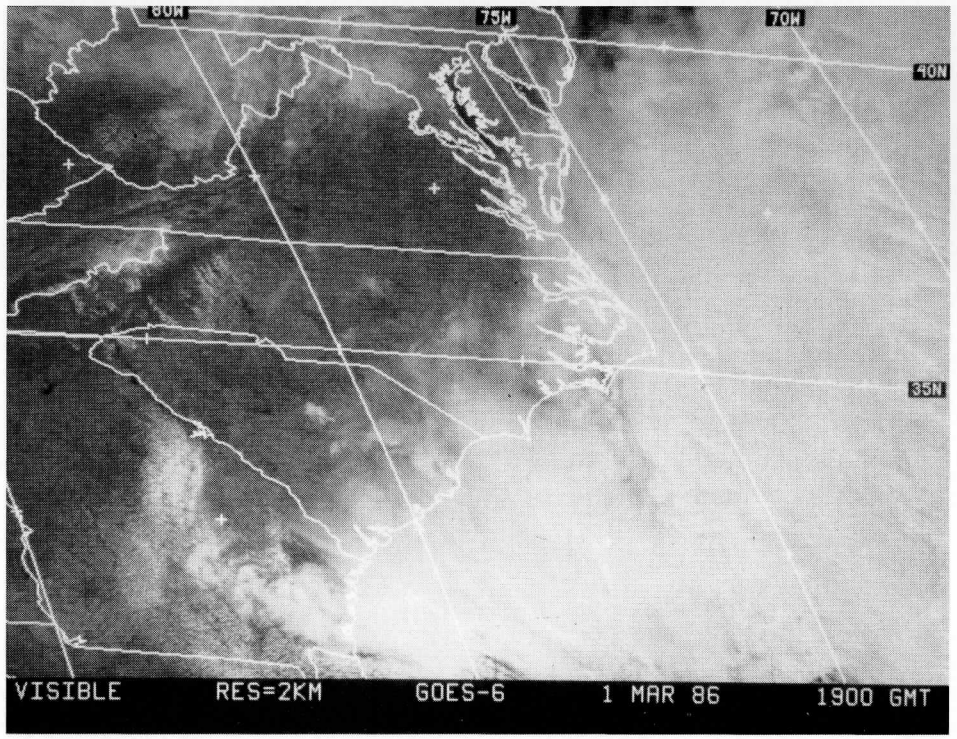
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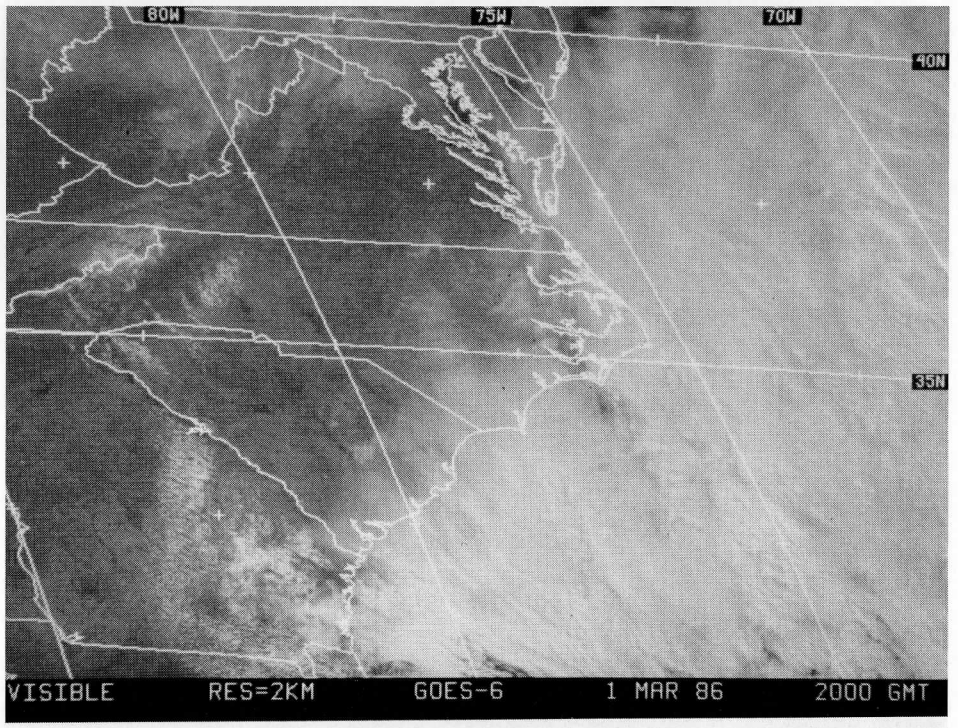
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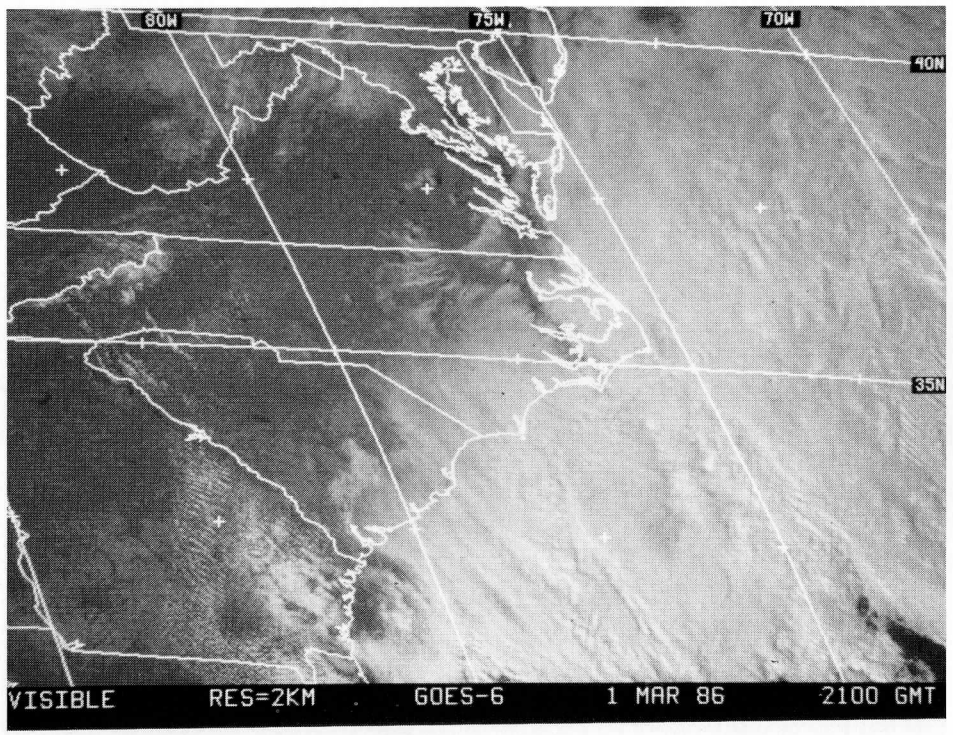
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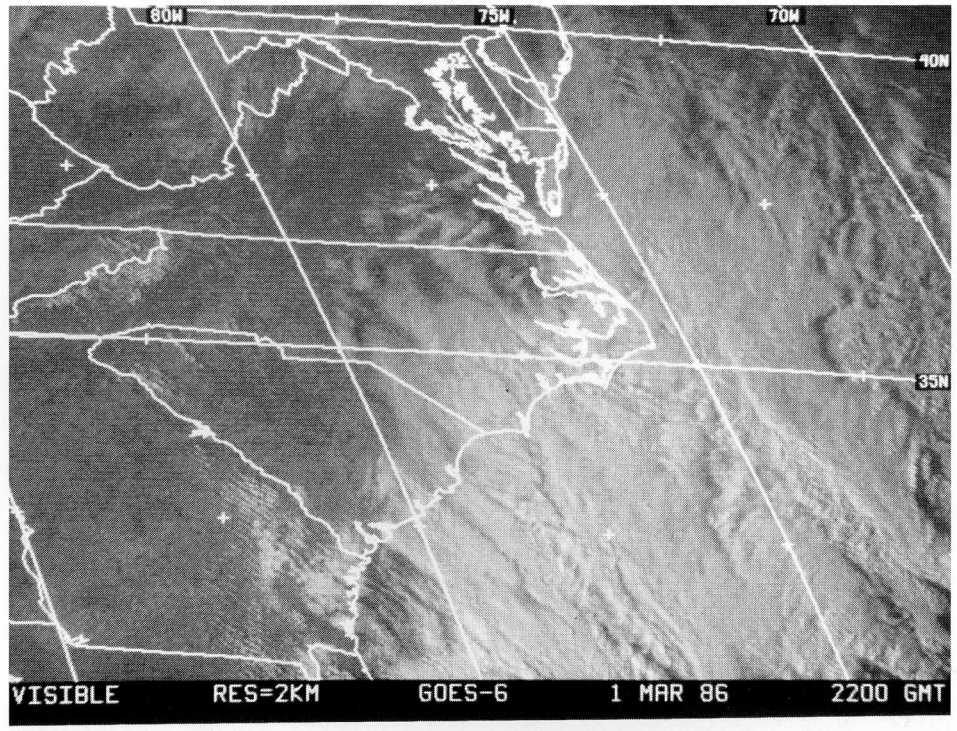
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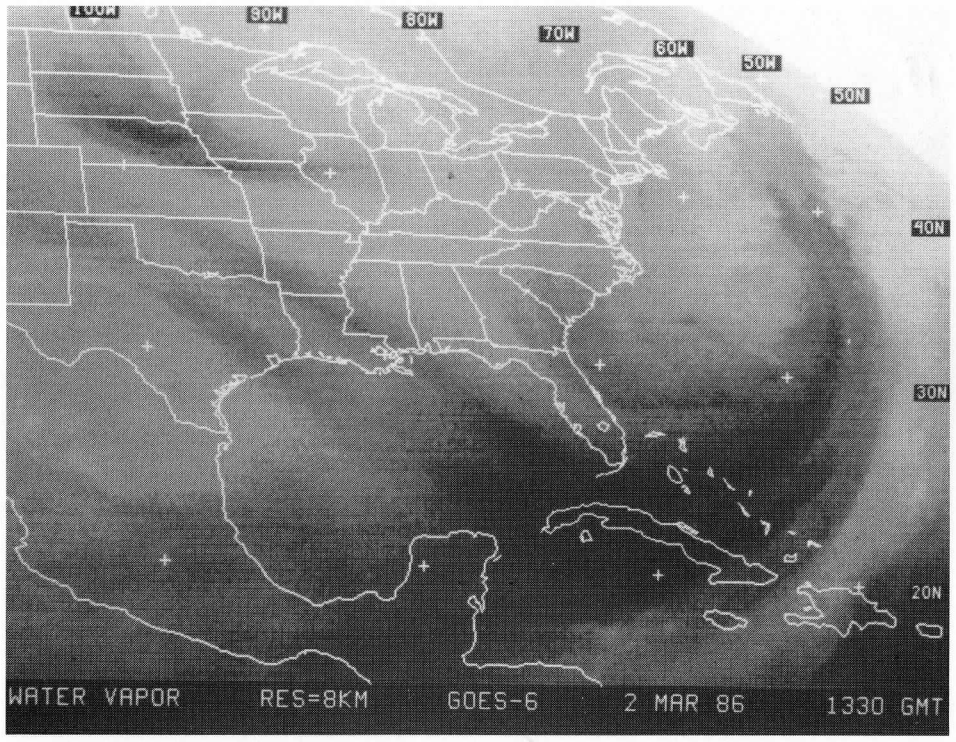
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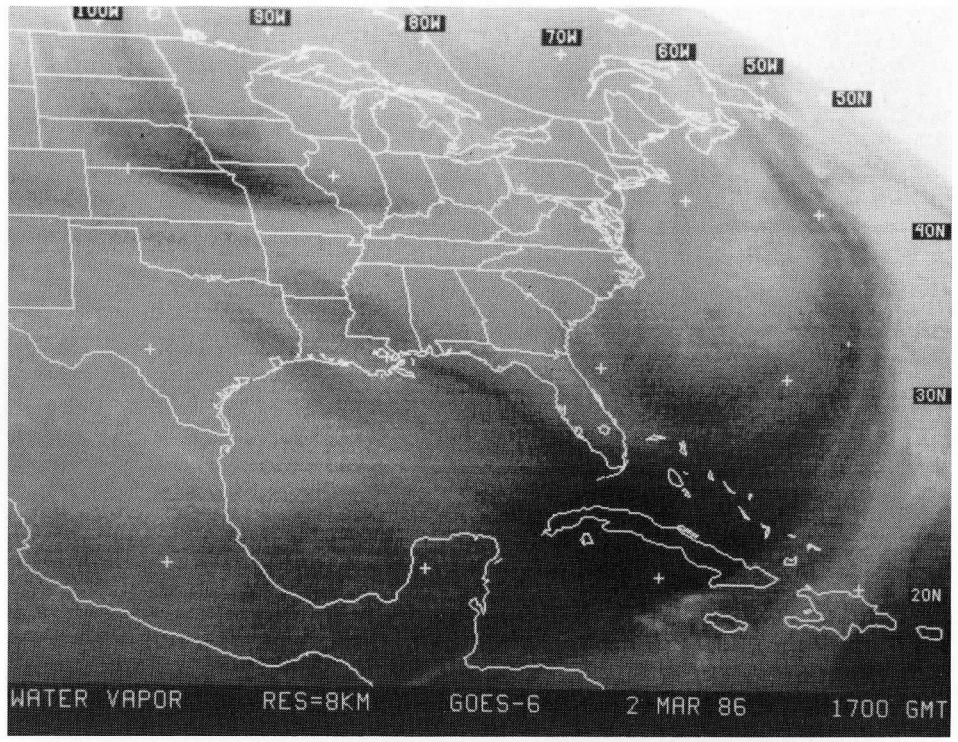
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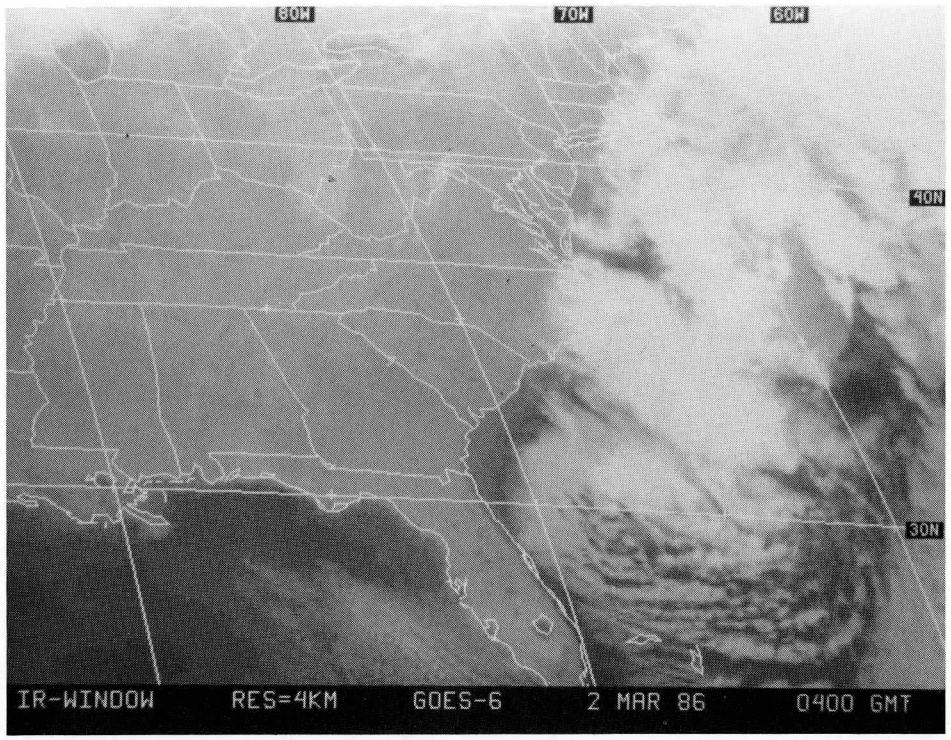
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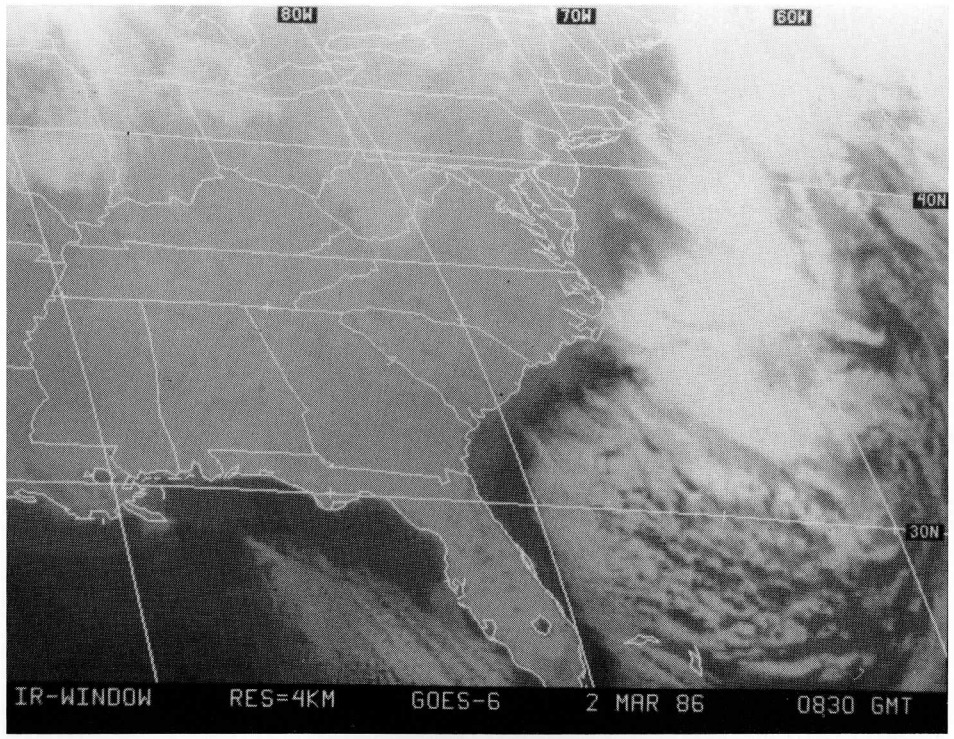
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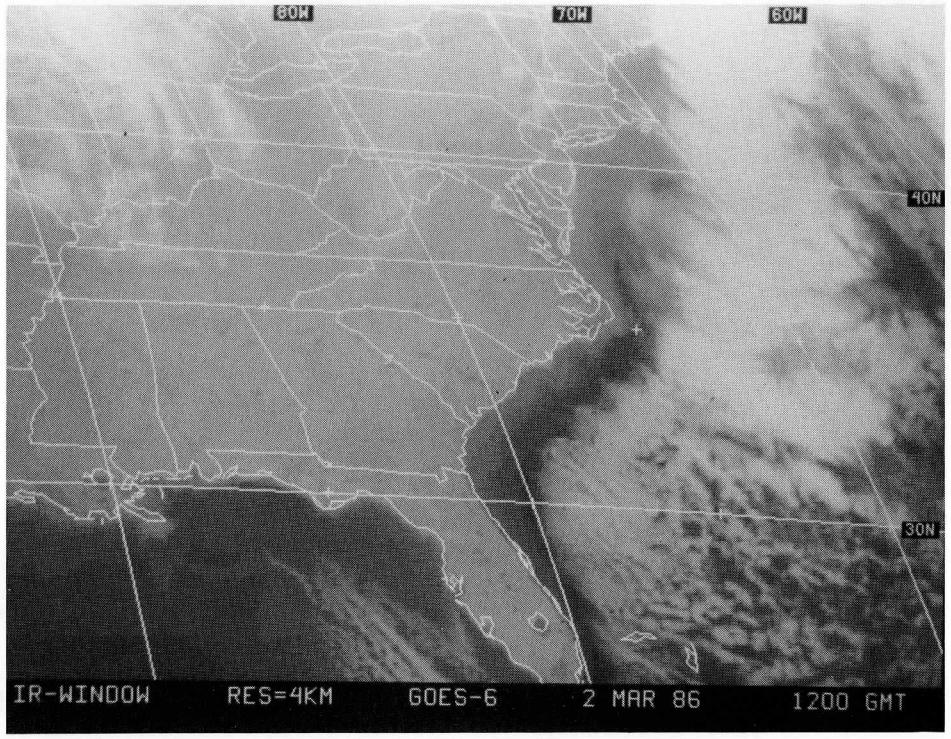
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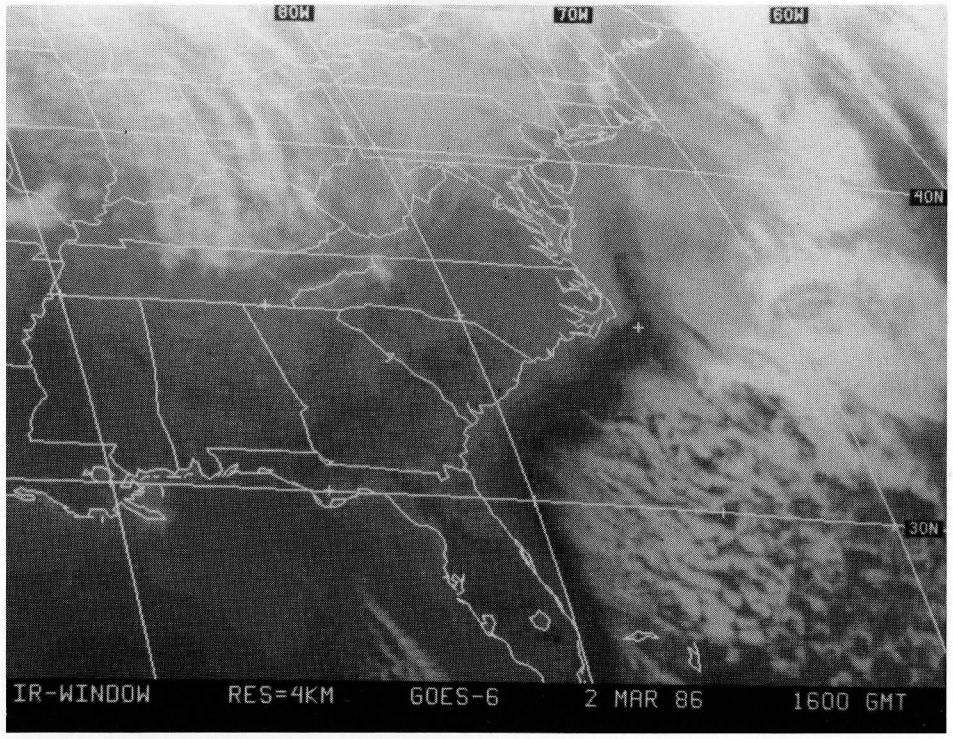
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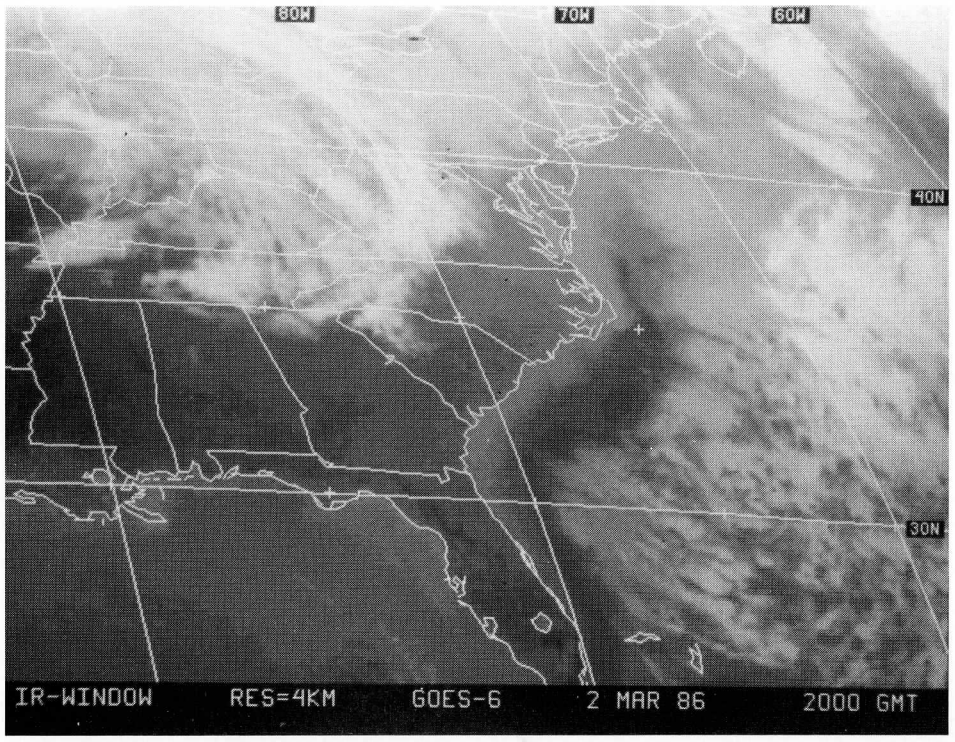
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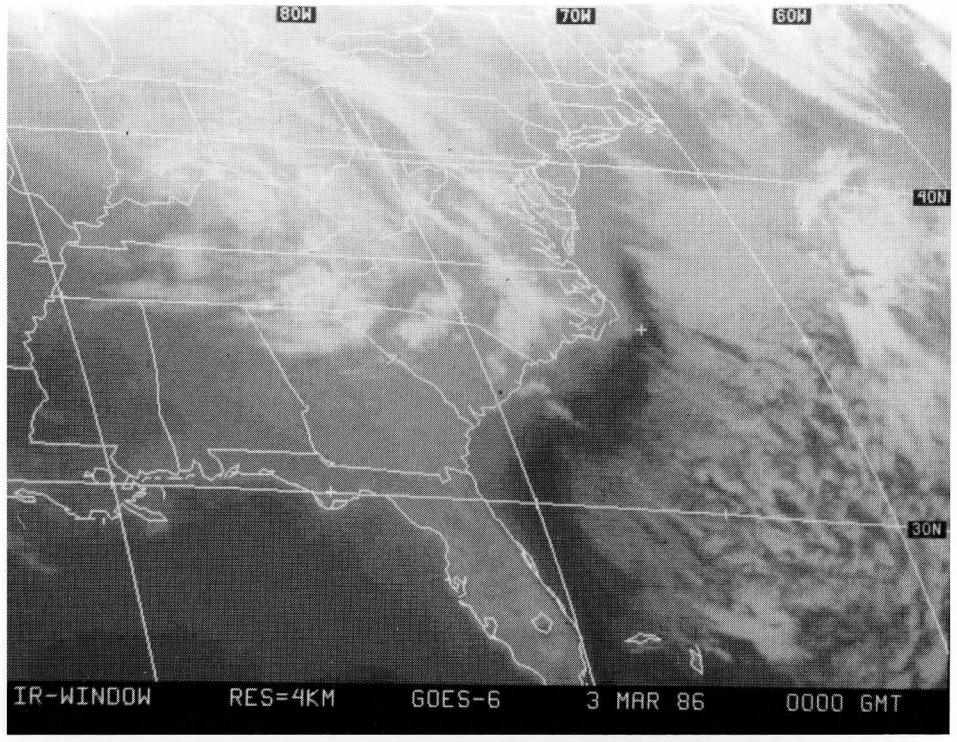
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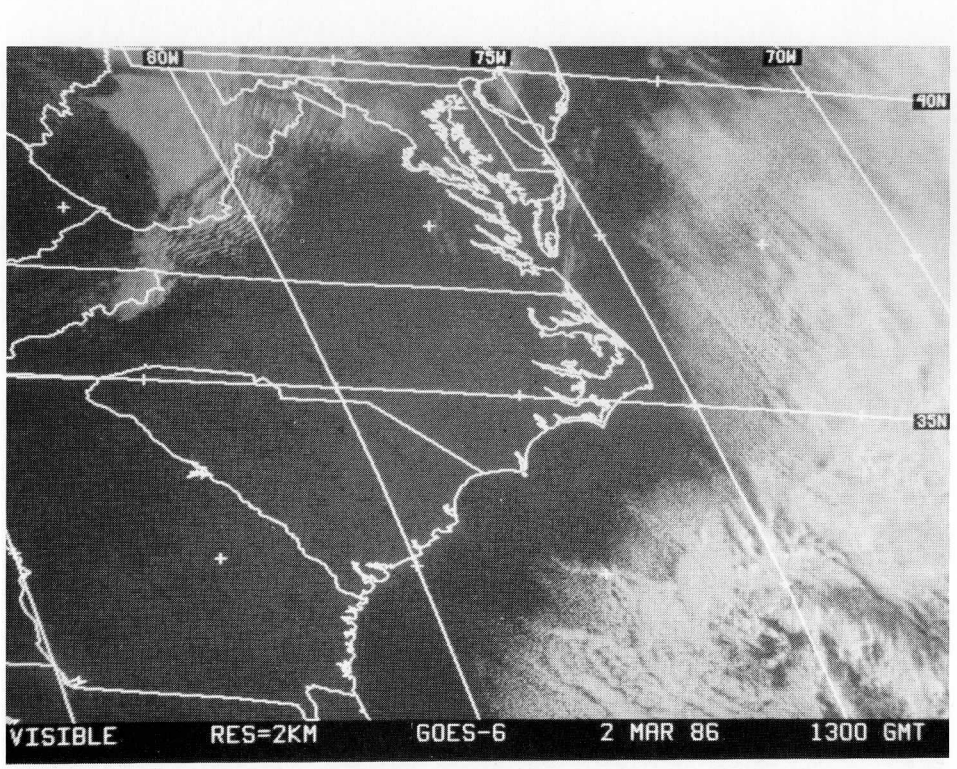
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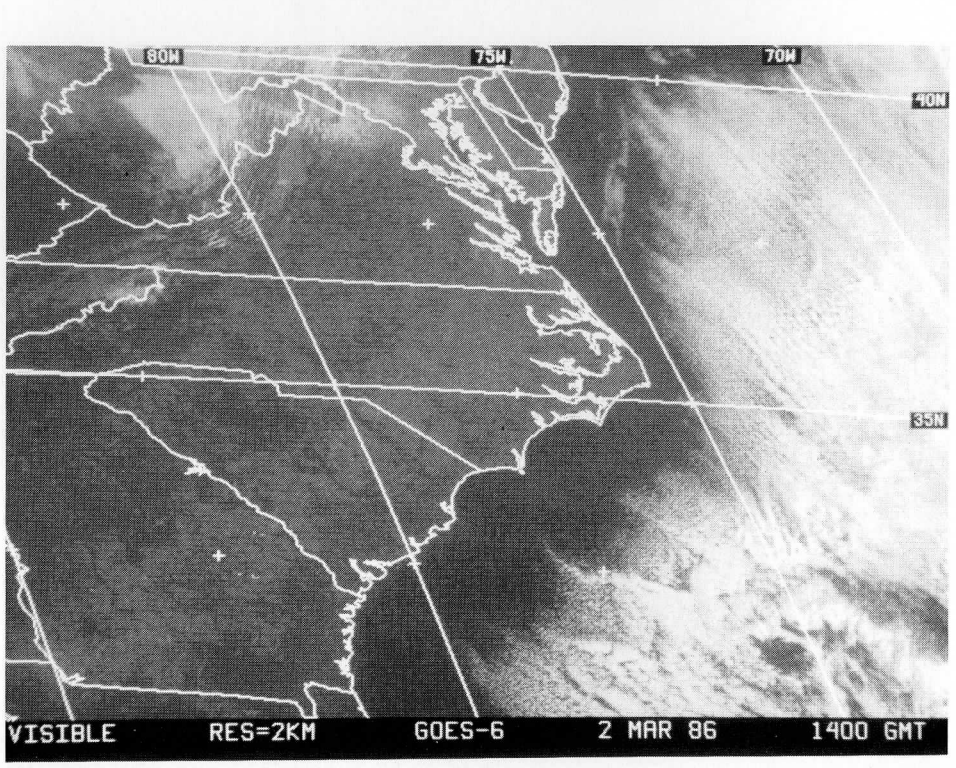
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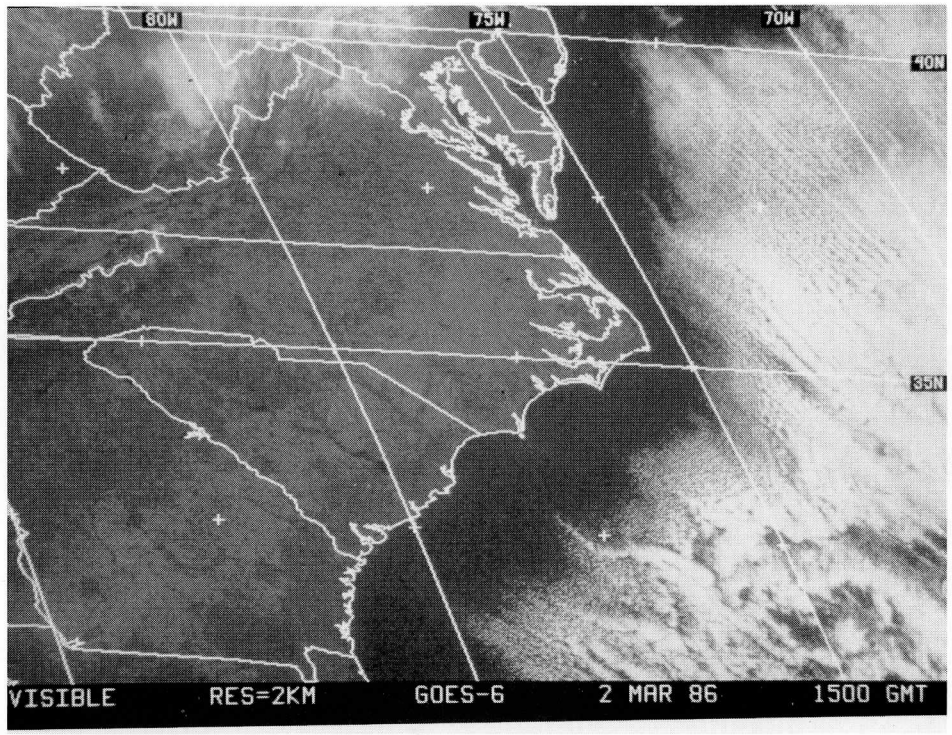
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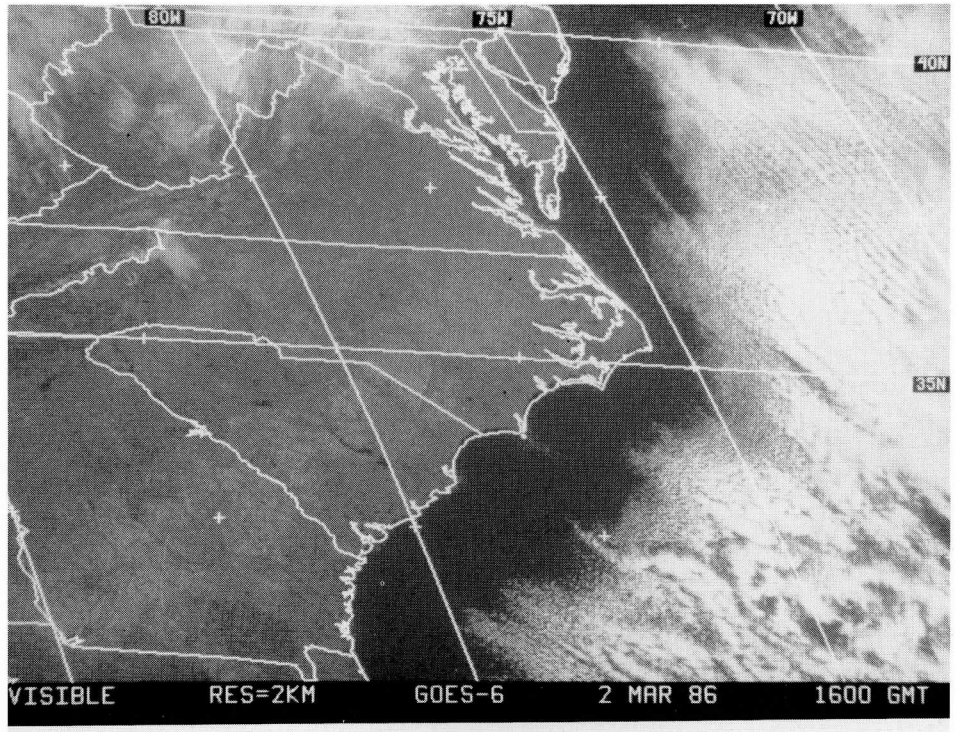
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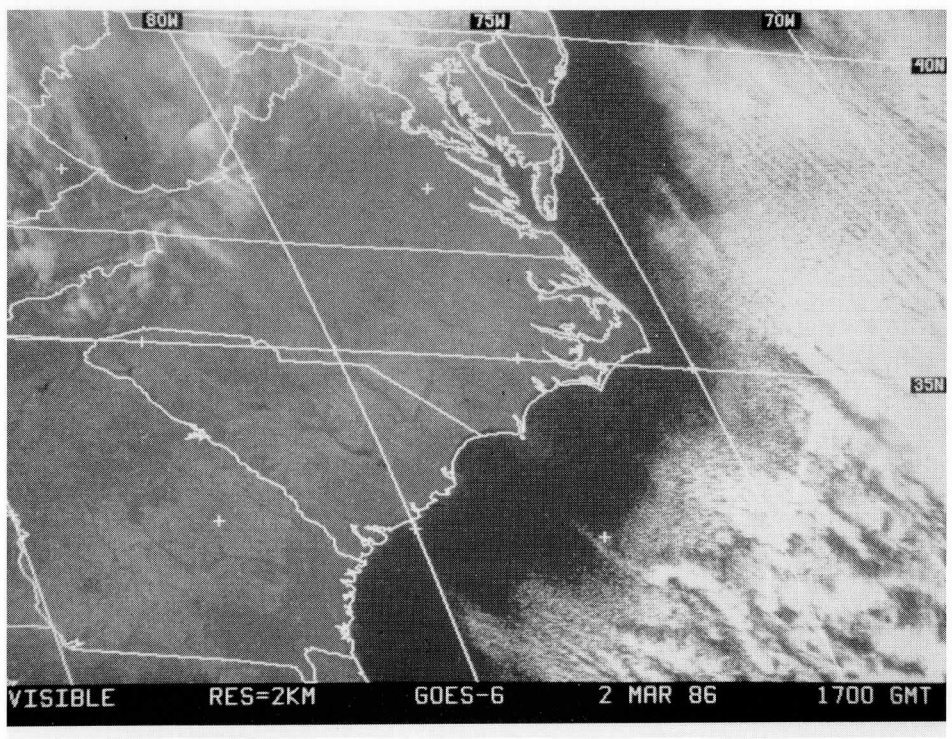
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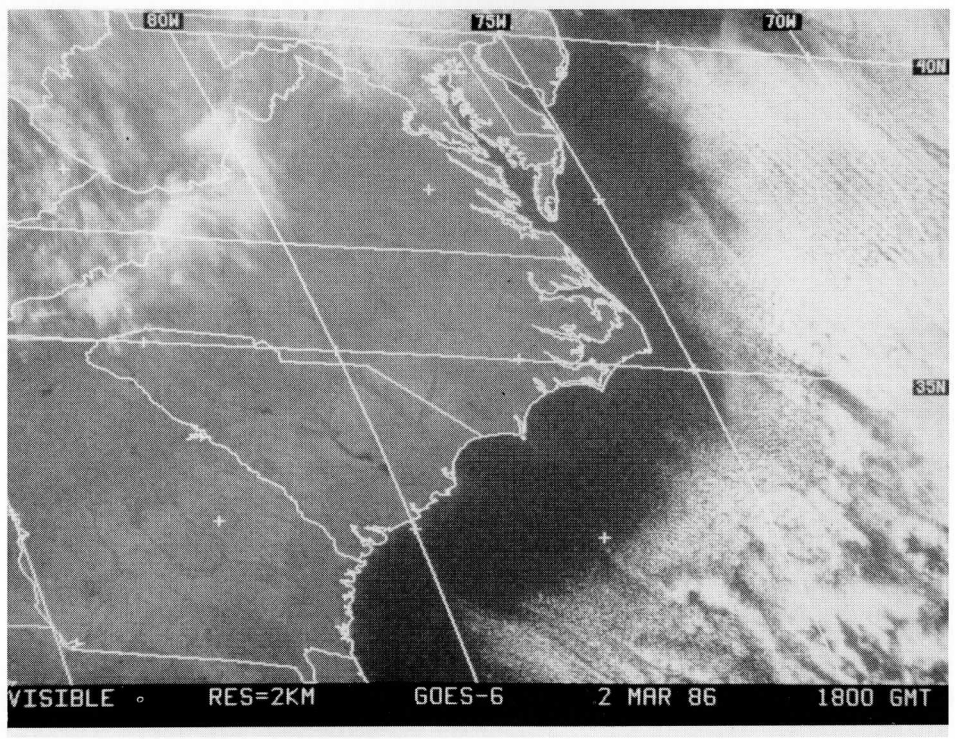
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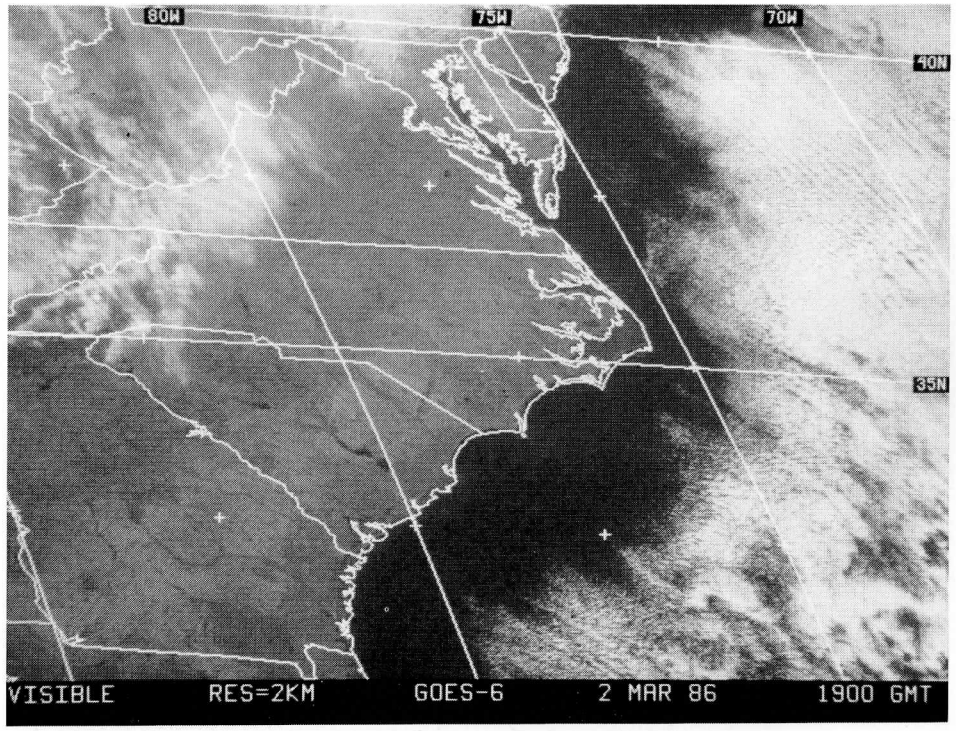
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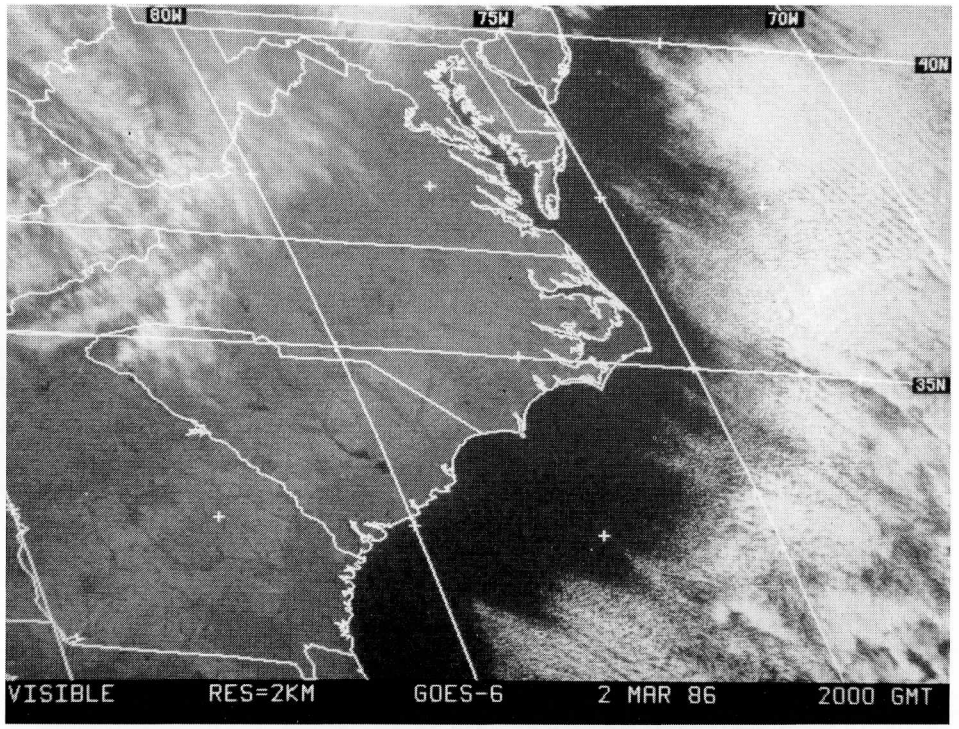
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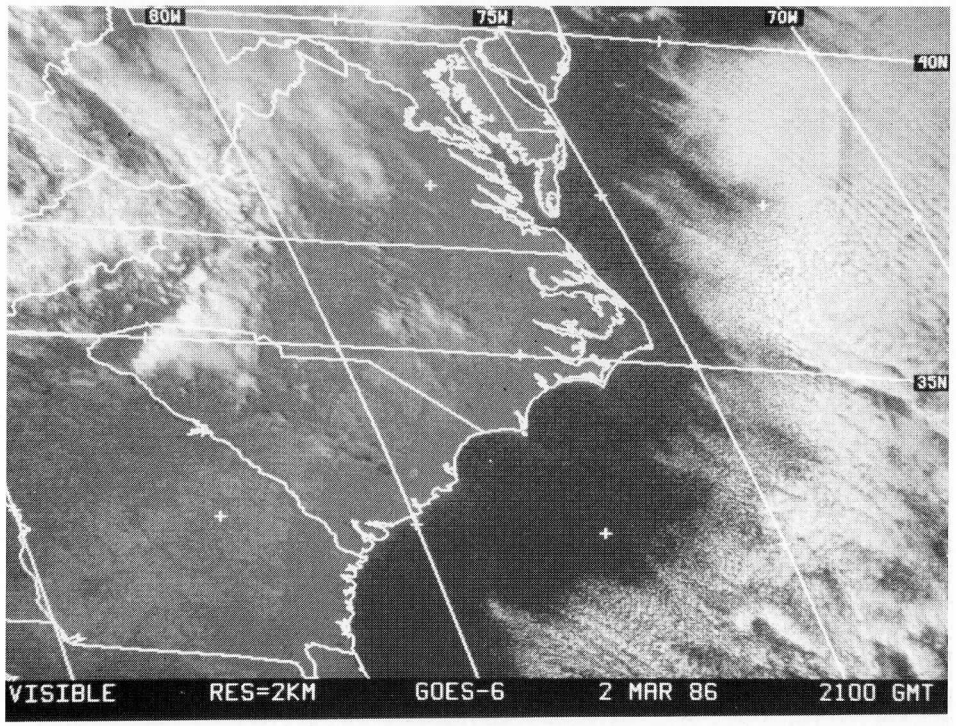
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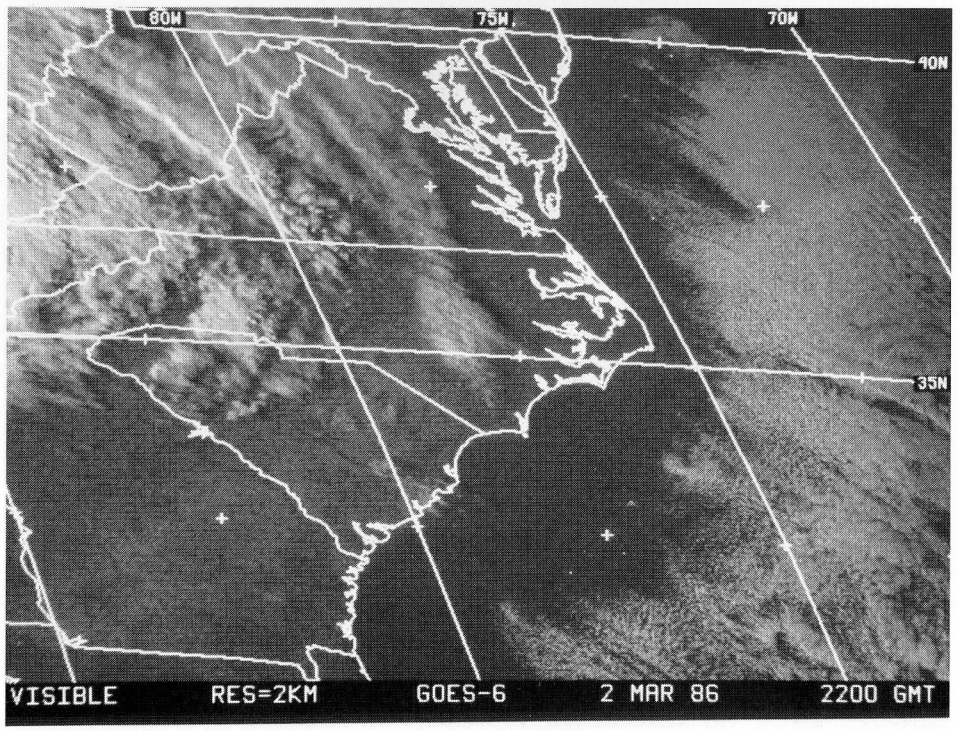
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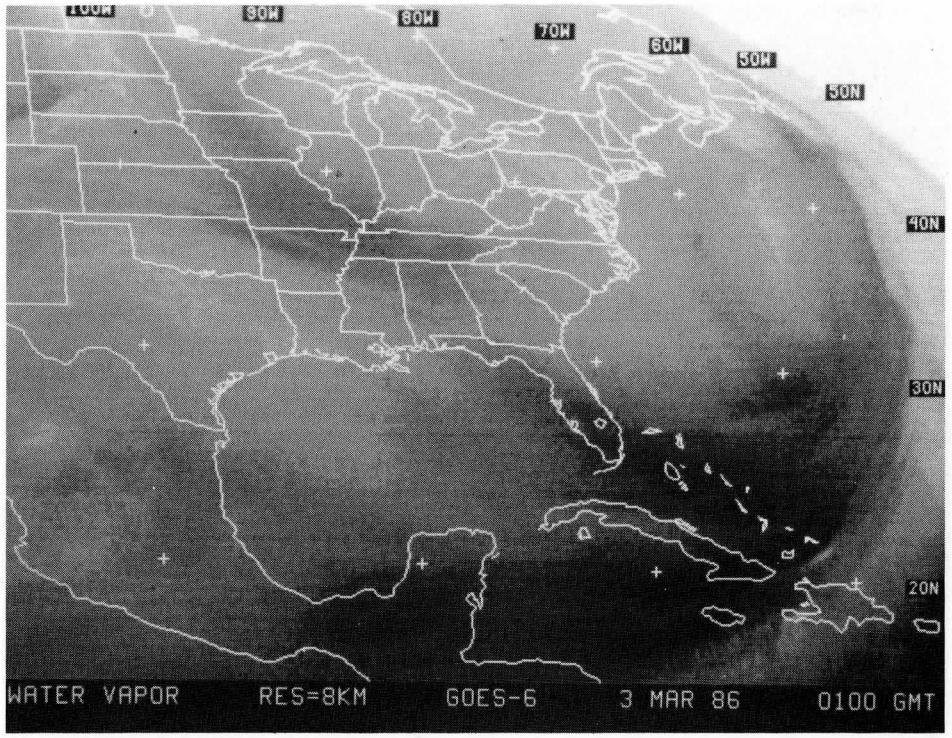
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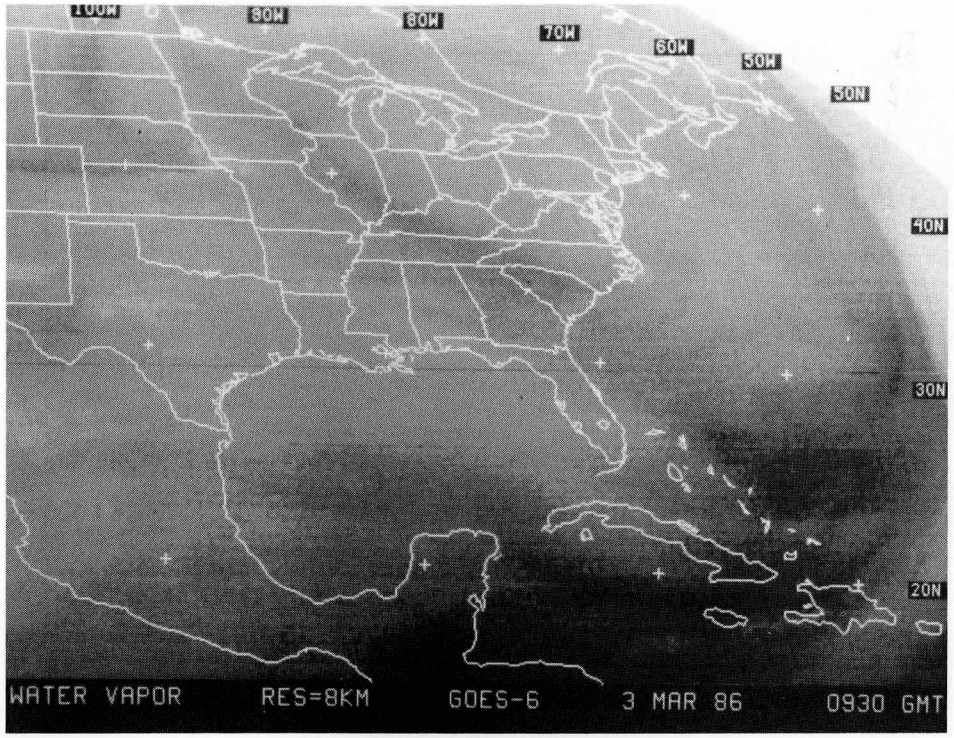
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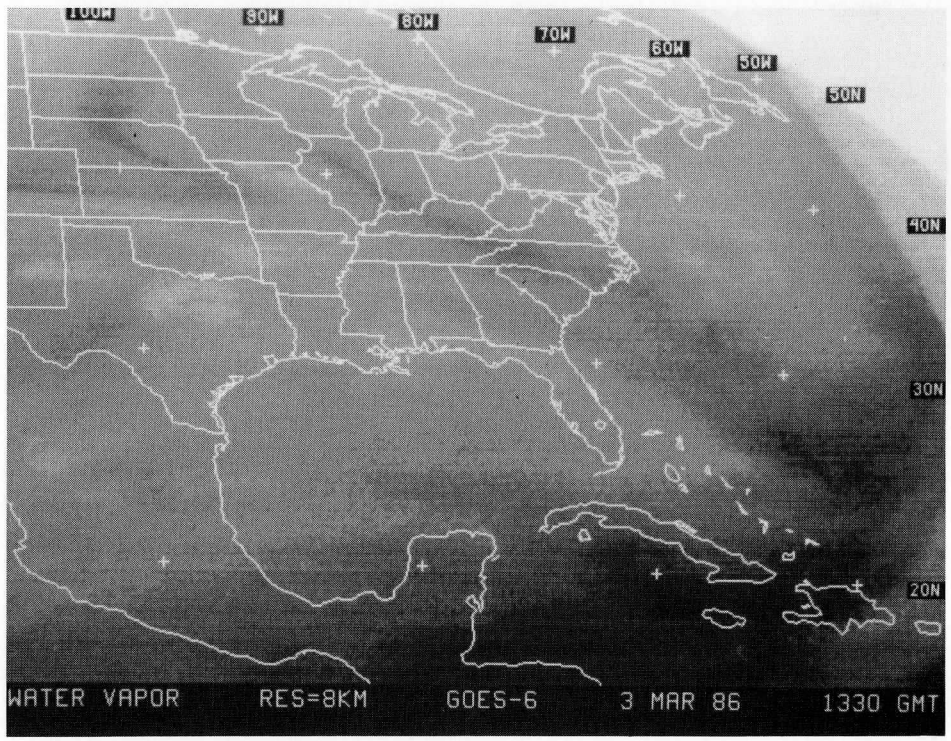
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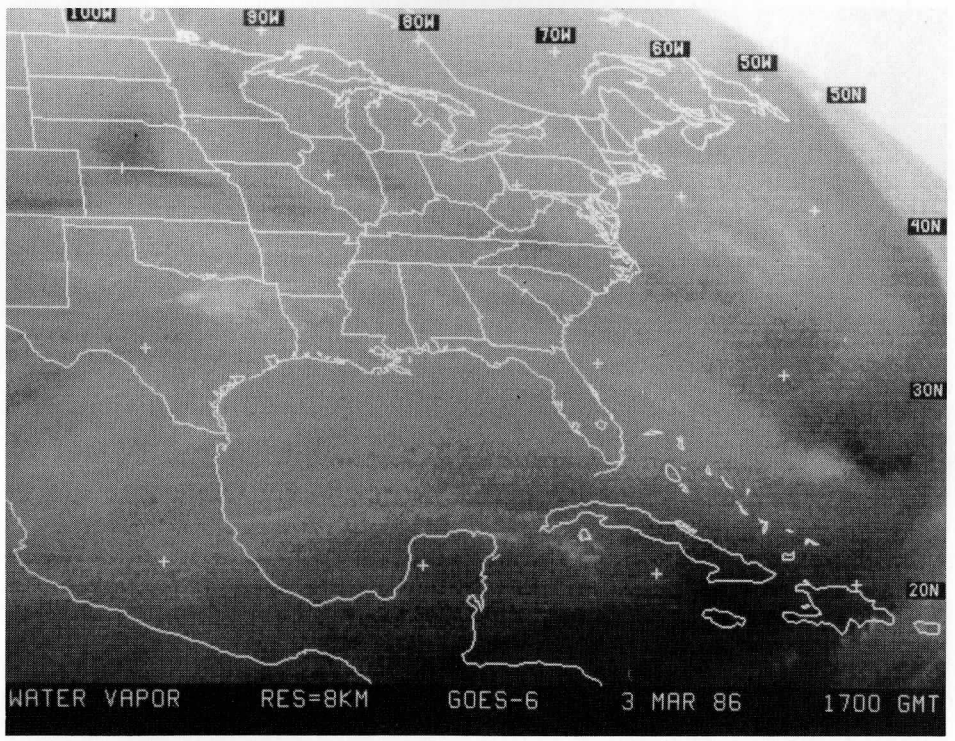
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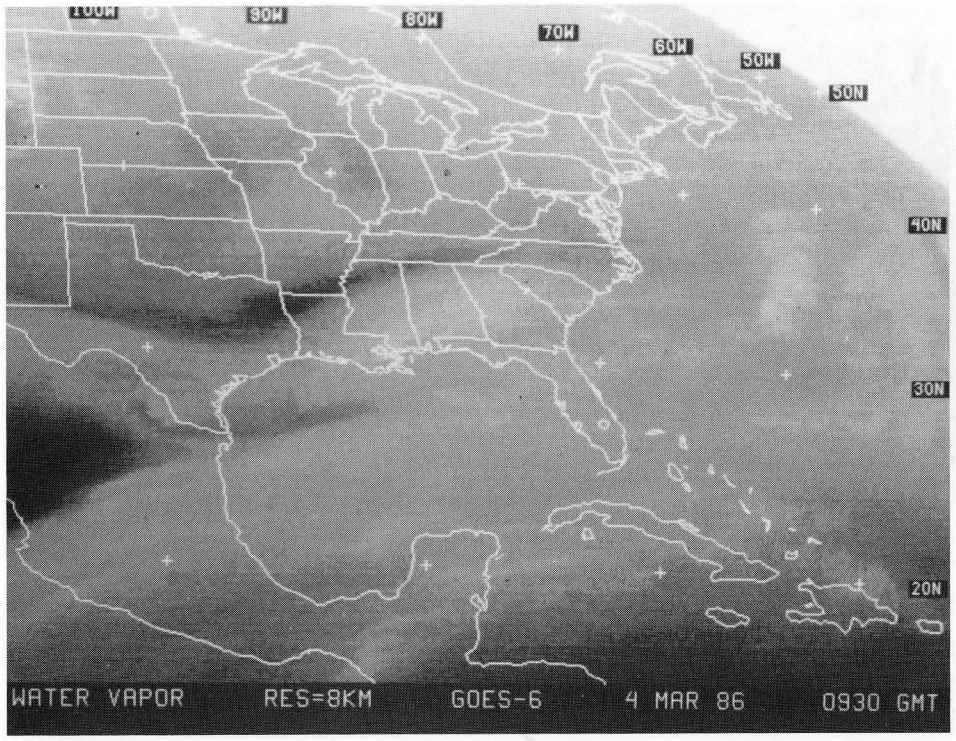
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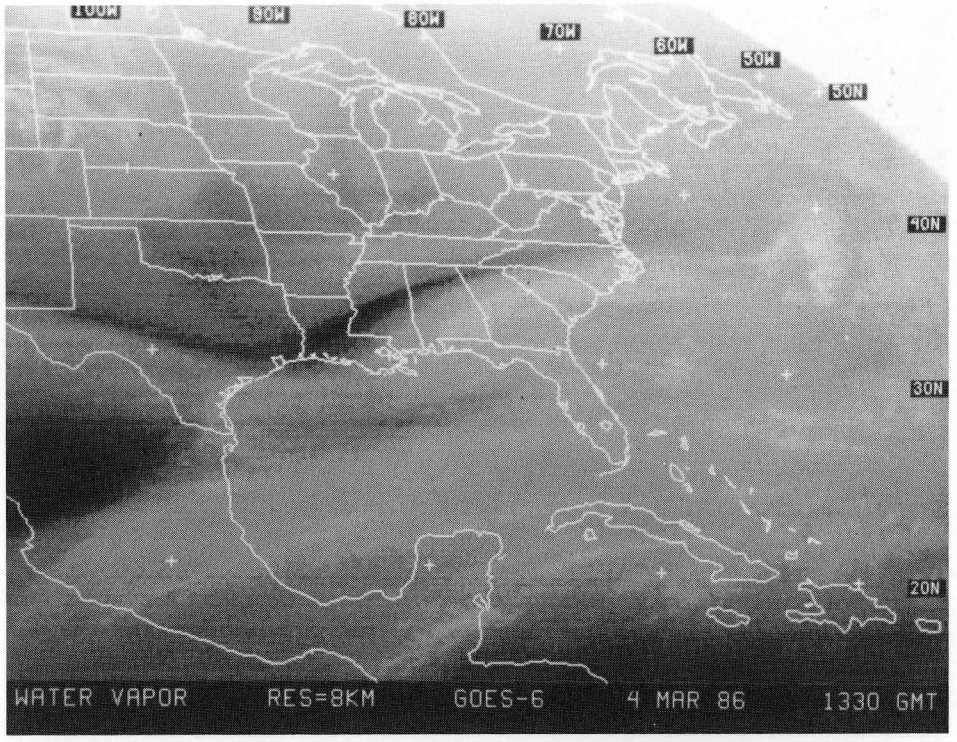
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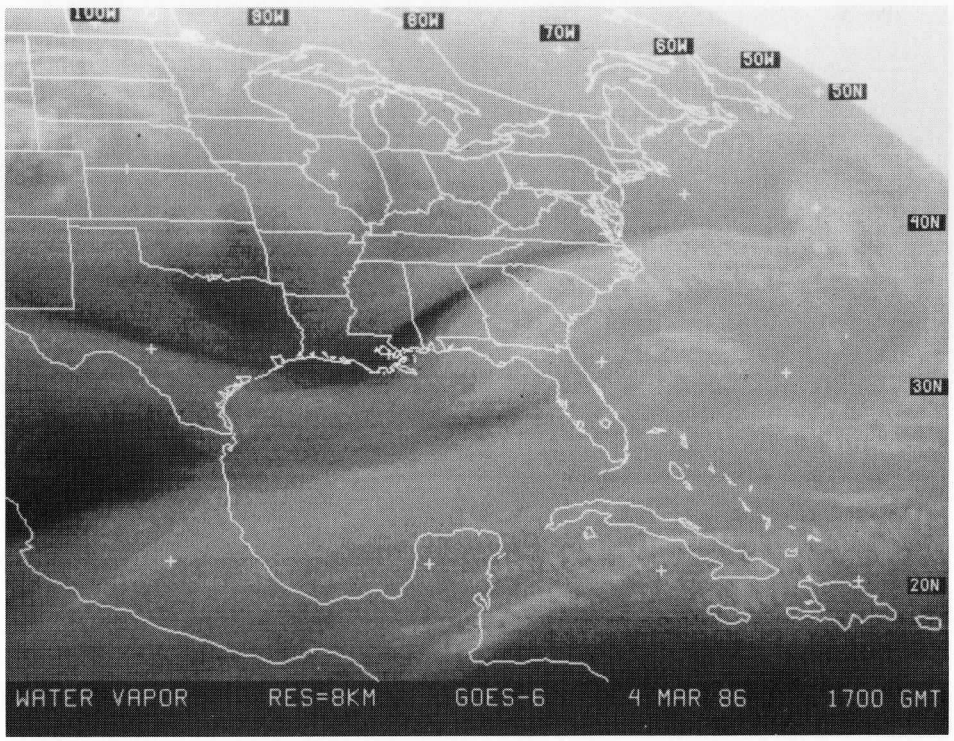
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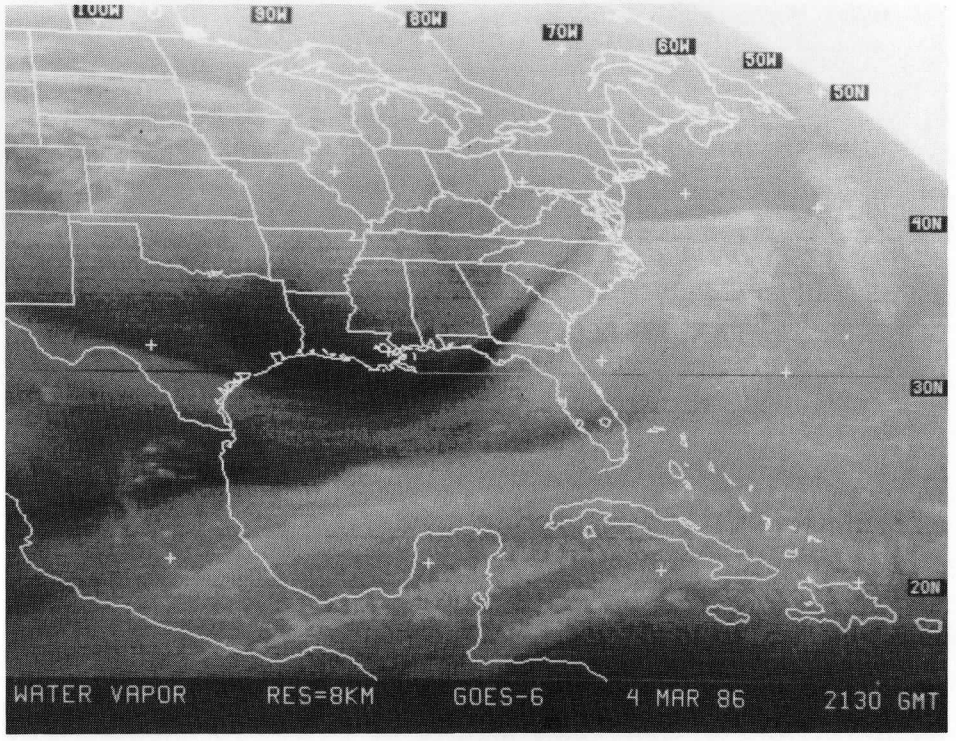
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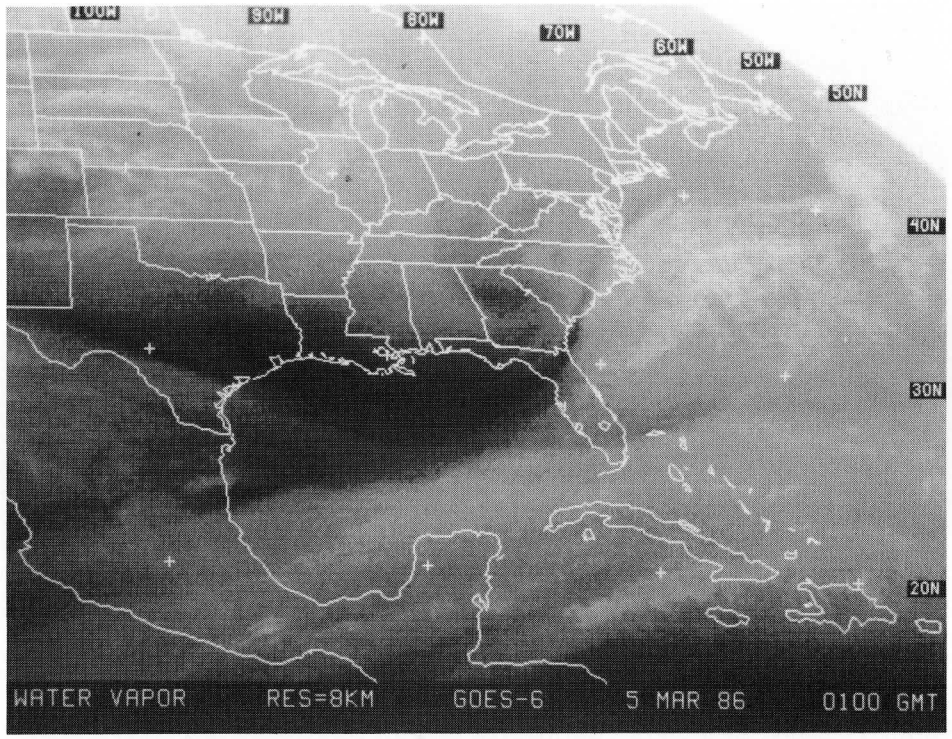
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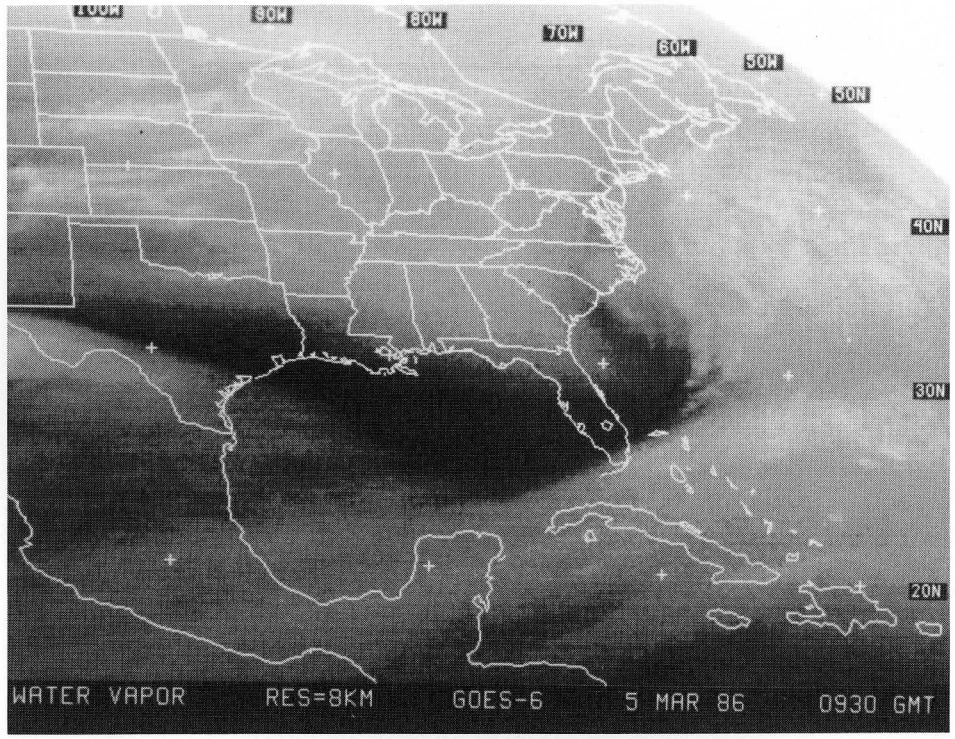
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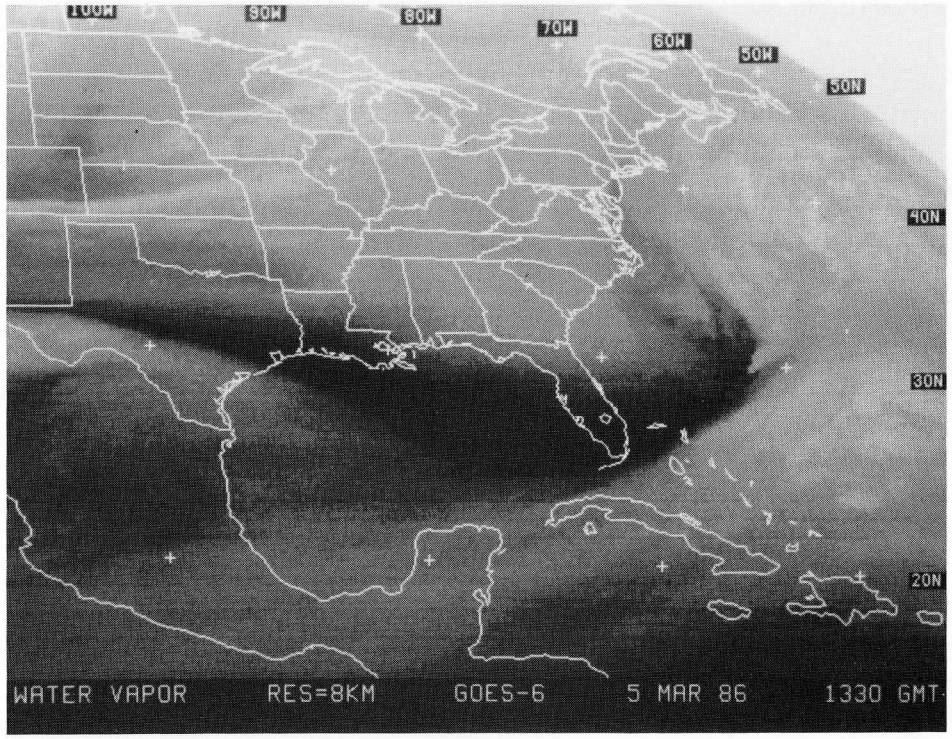
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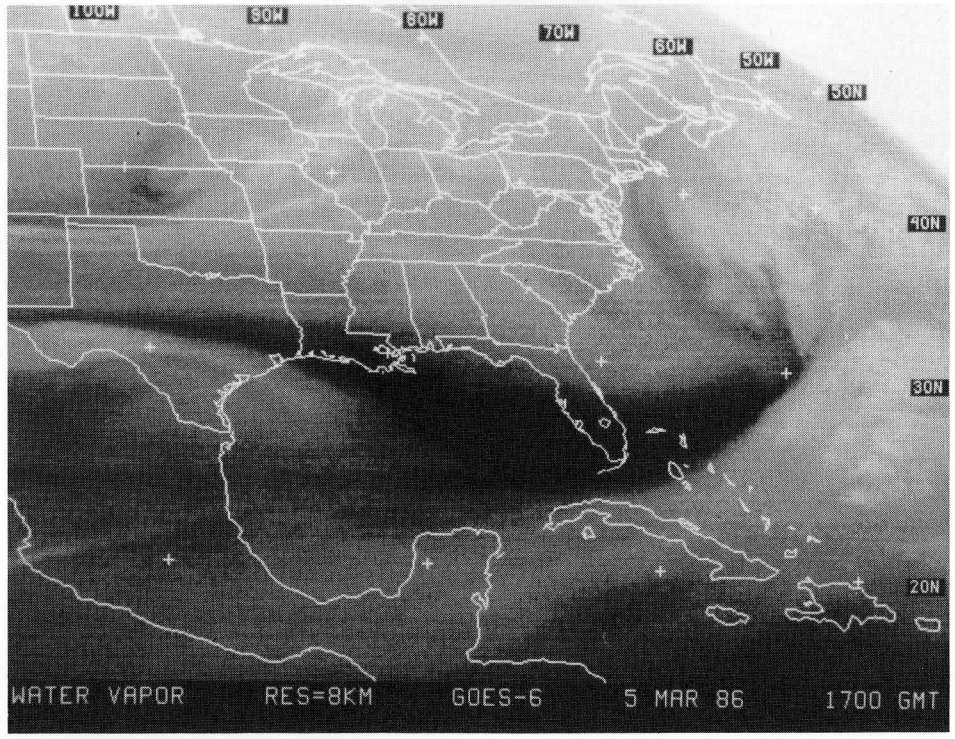
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IOP #12 - Anti-cyclone
March 6 - March 9

Satellite Synopsis

Water Vapor

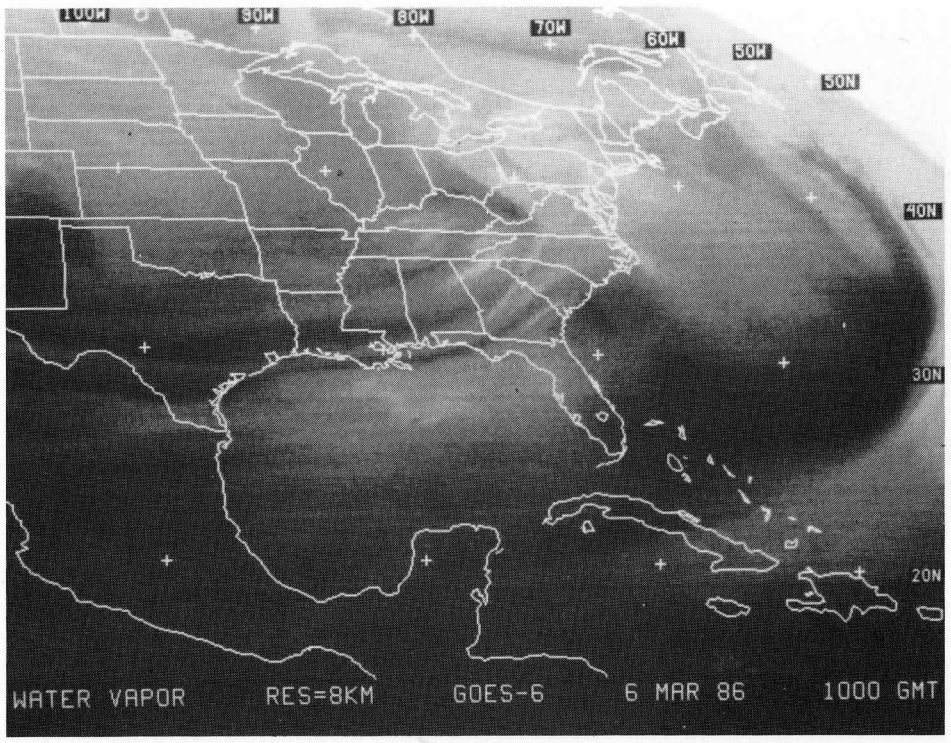
- Moist air mass at upper levels over GALE region.
- Strong short wave moves into Gulf on 8th with strong thunderstorms.

IR

- Short wave development offshore on 7th to the north of the GALE region.
- Stratocumulus deck offshore develops to the south on the 7th and 8th.
- Strong thunderstorm development in the Gulf on the 9th.

Visible

- 6th, patchy structured clouds offshore.
- 6th, frontal thunderstorm band develops with squall line development to the east of the frontal band.
- 6th, wave clouds behind front in Virginia.
- 7th, striking wave clouds spread from Virginia to South Carolina during the day with perpendicular banding in mid-level clouds.
- 8th, cloud streets over water.
- 9th, cumulus field grows during day in Georgia with a sharp cut-off to a cumulus field near the Gulf Stream.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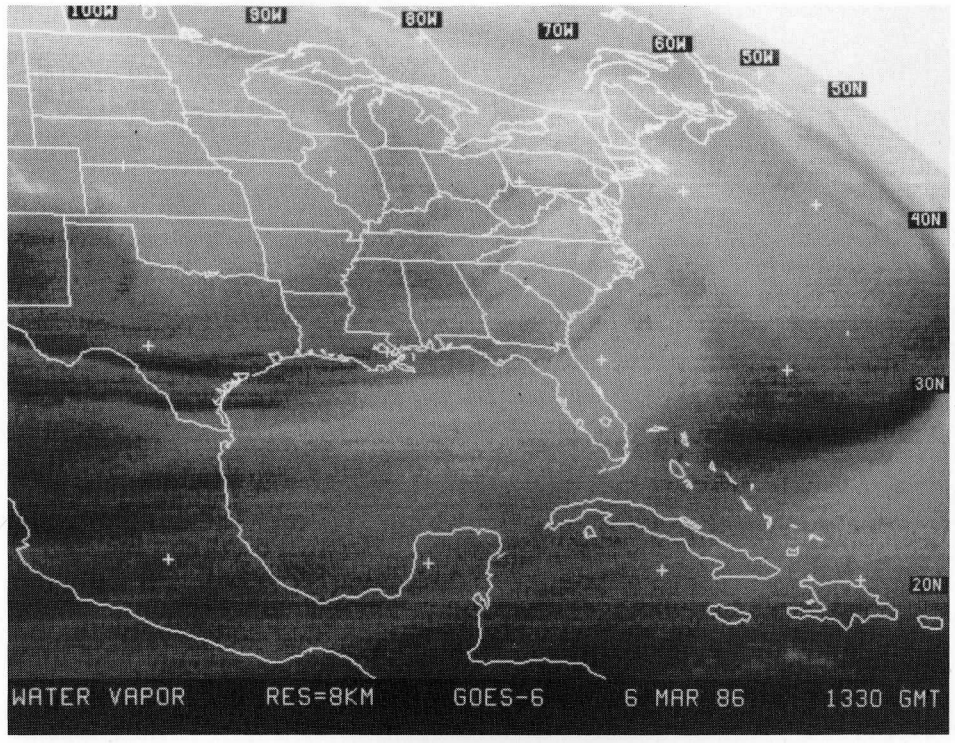
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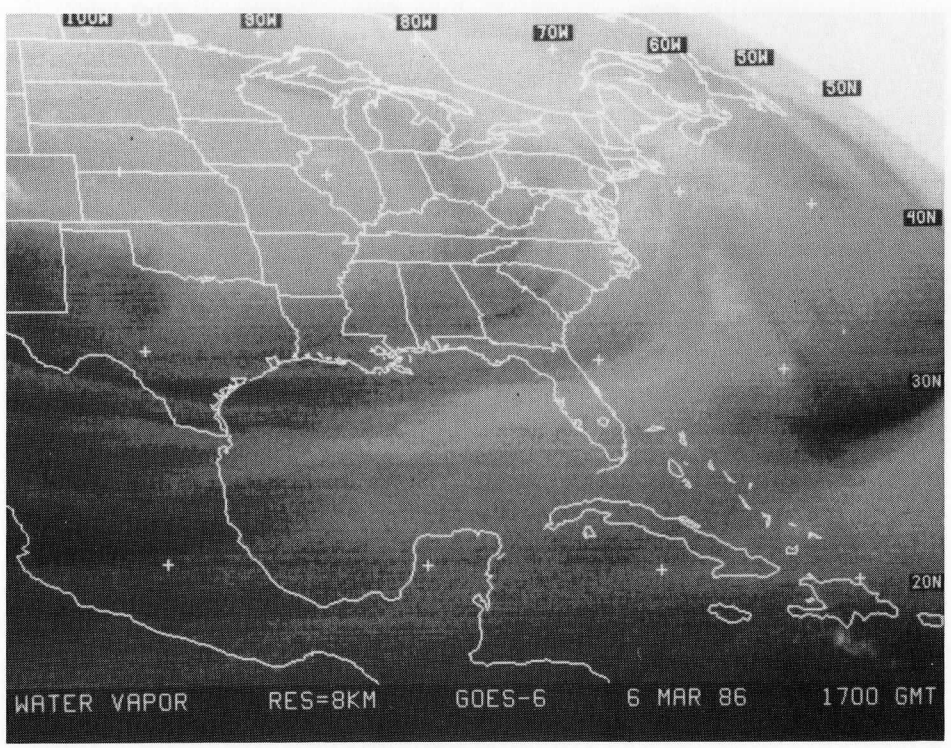
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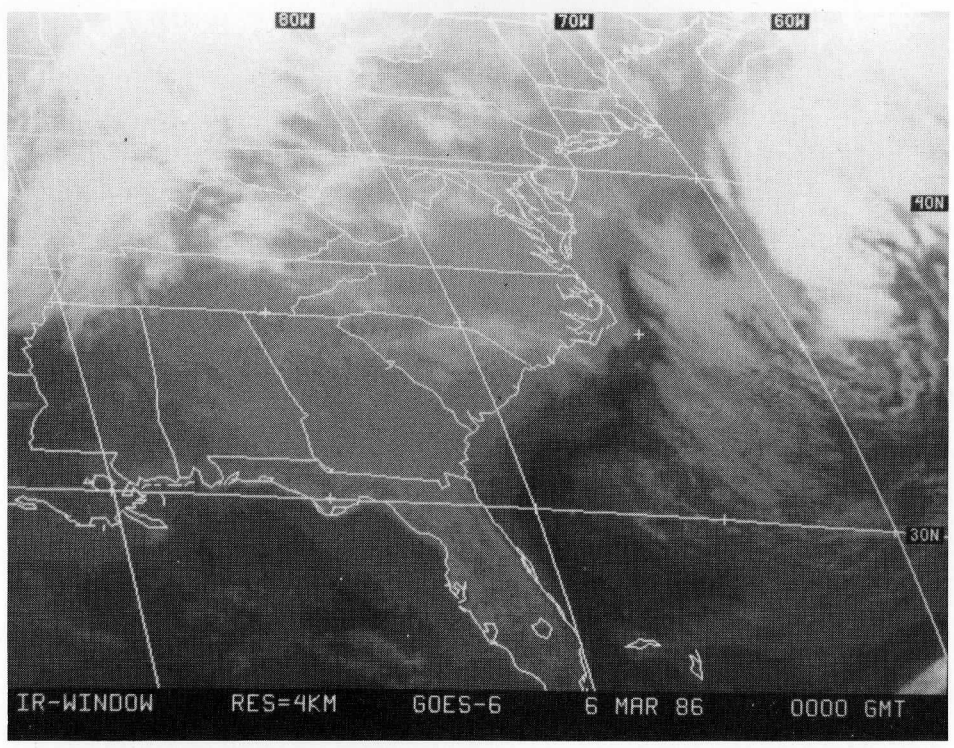
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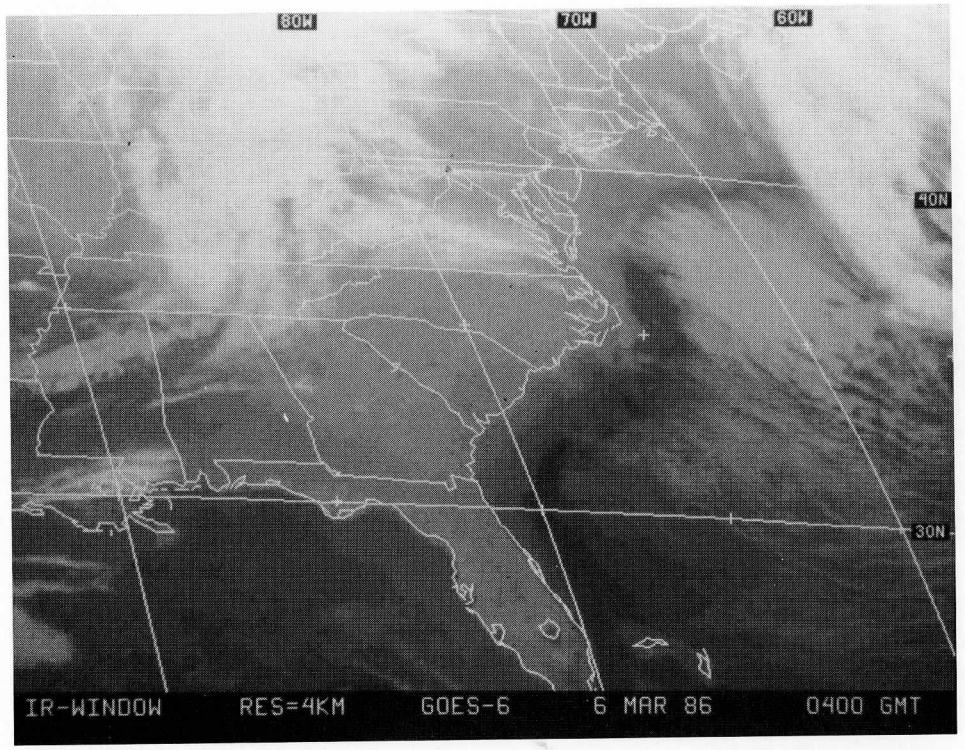
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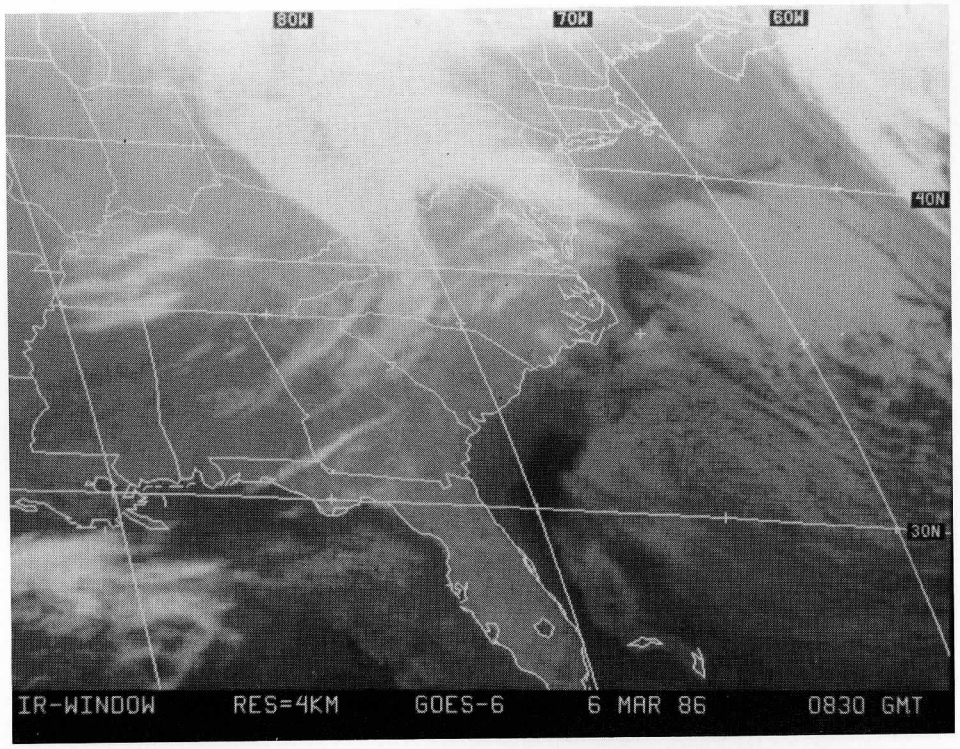
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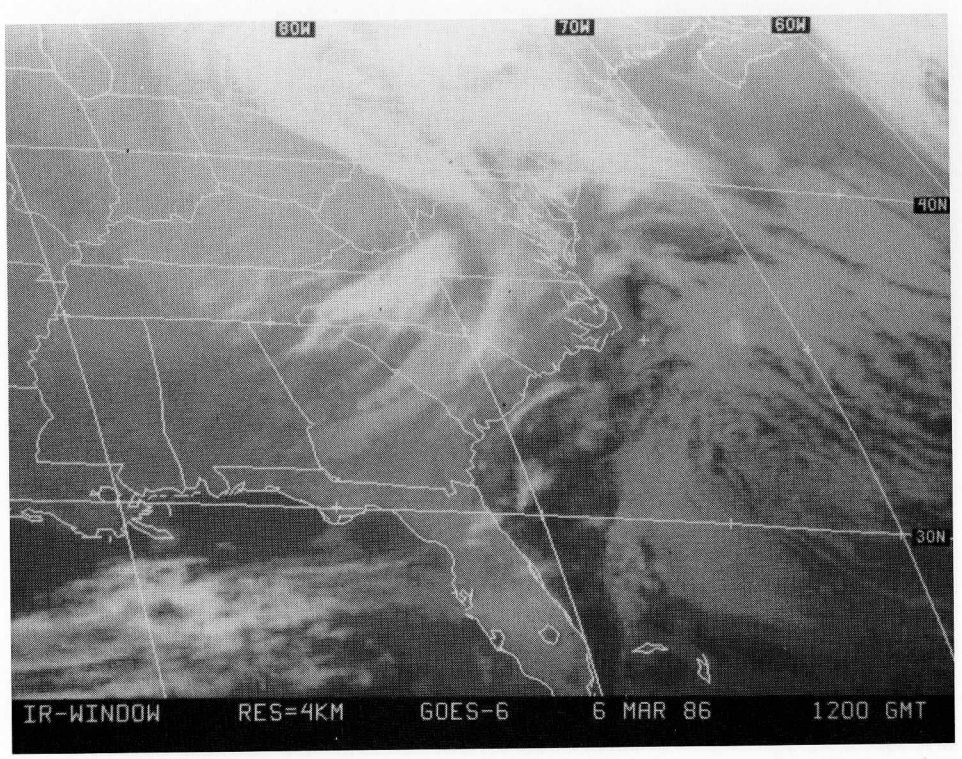
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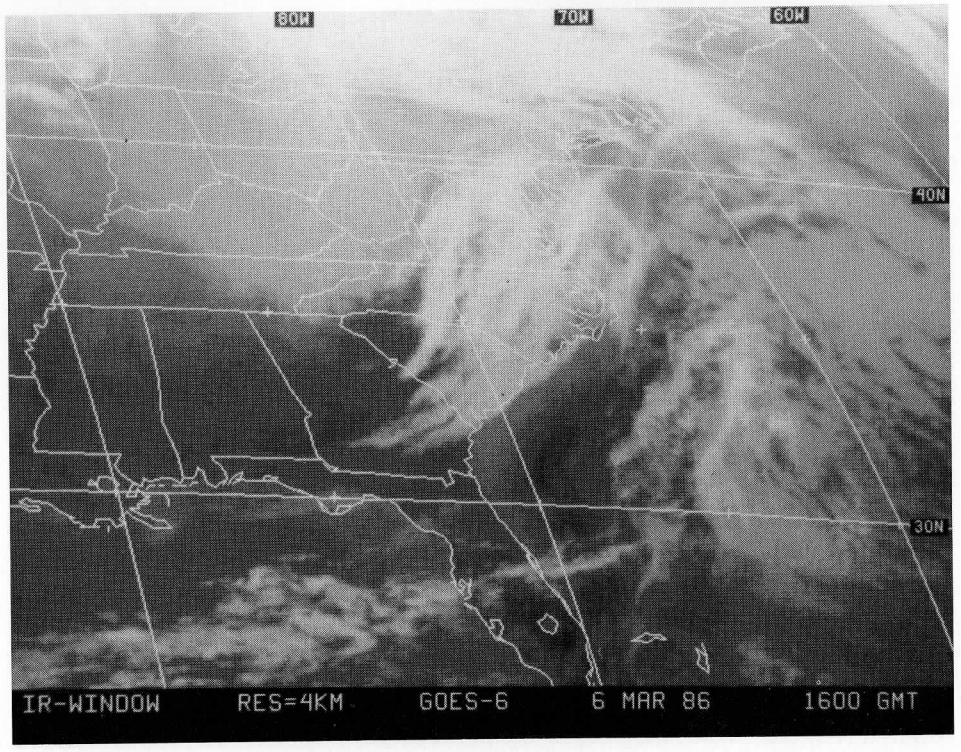
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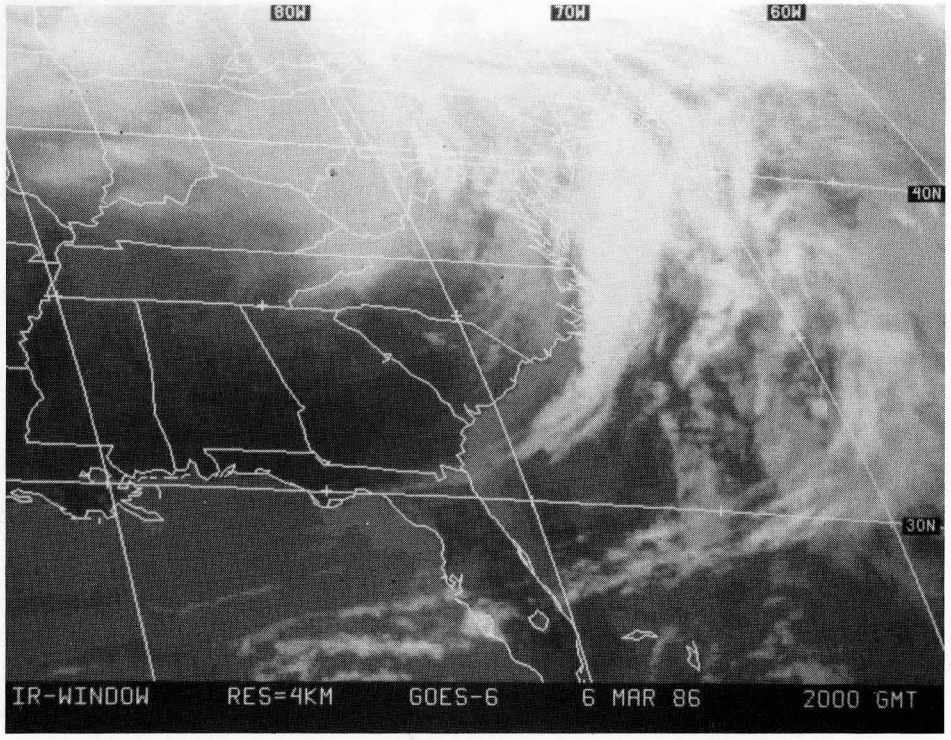
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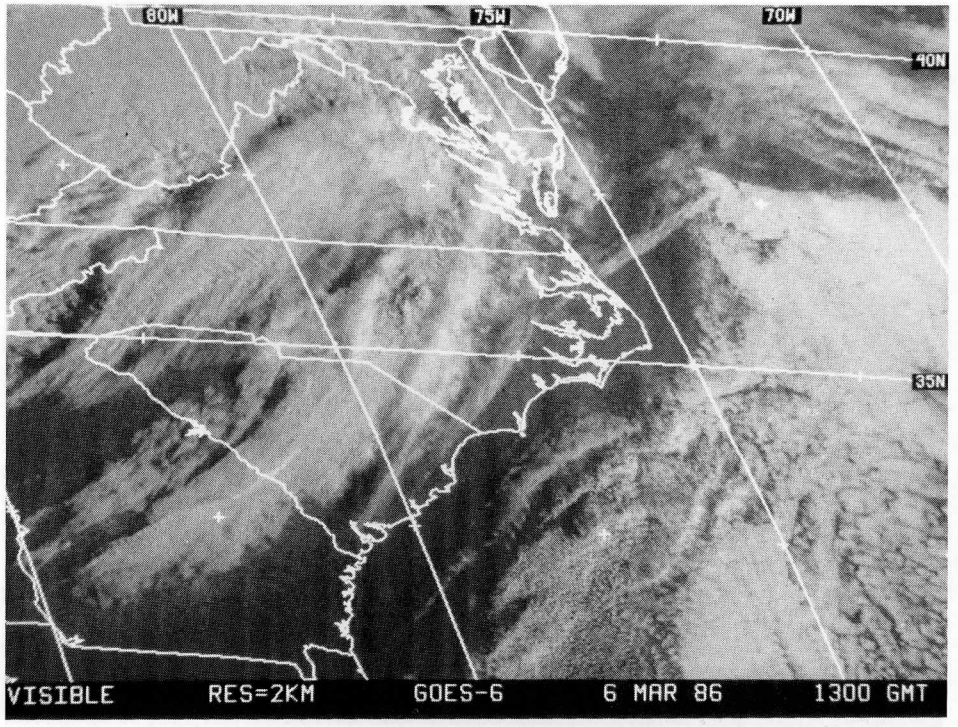
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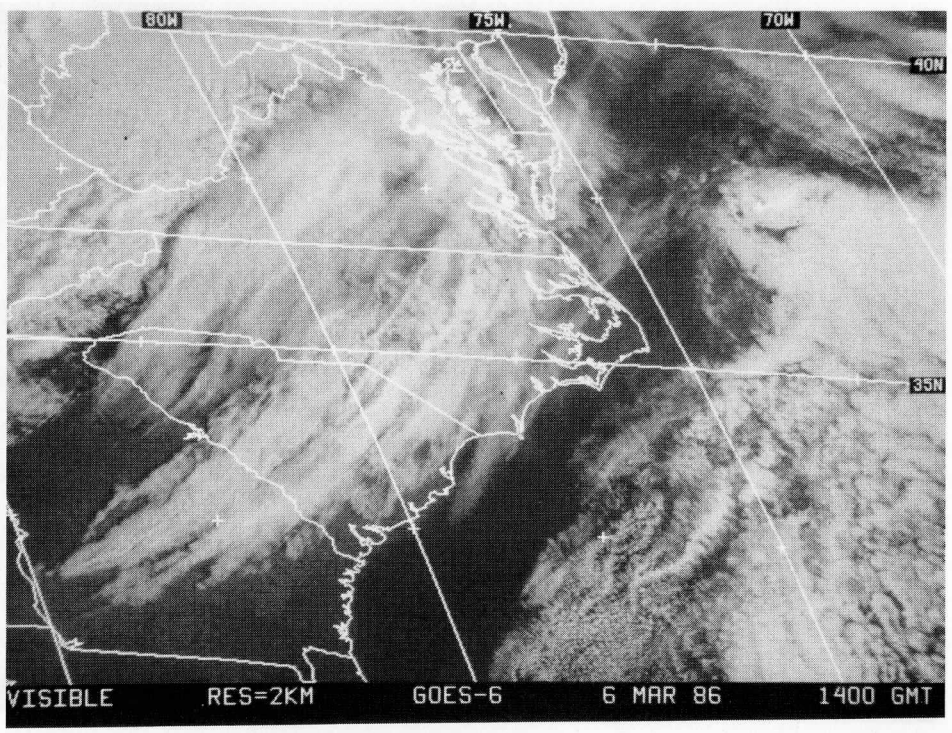
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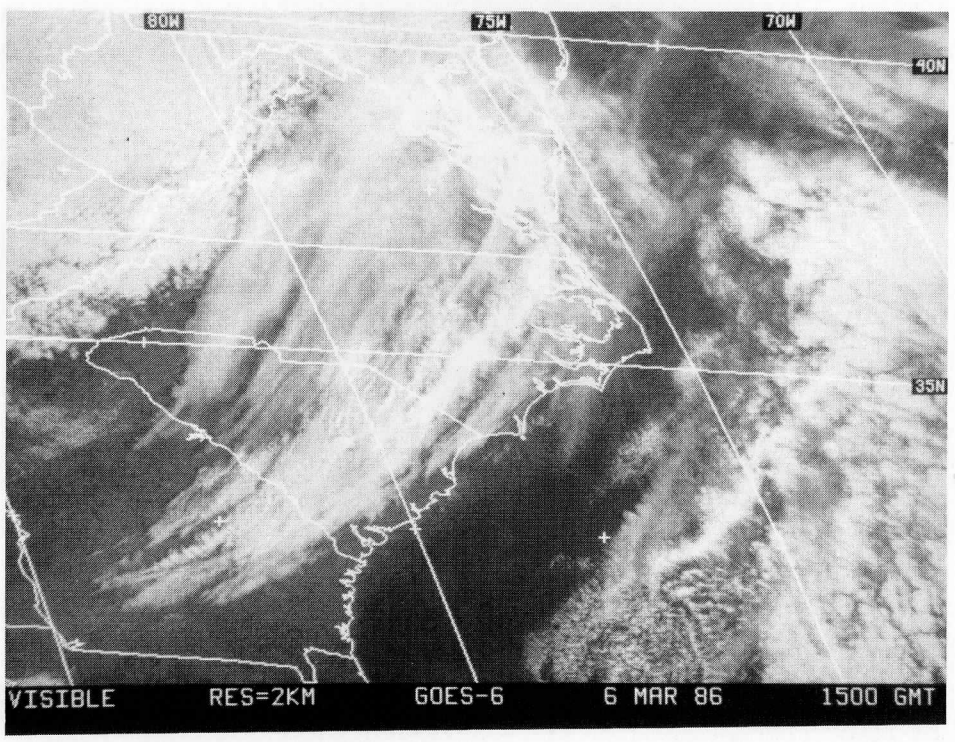
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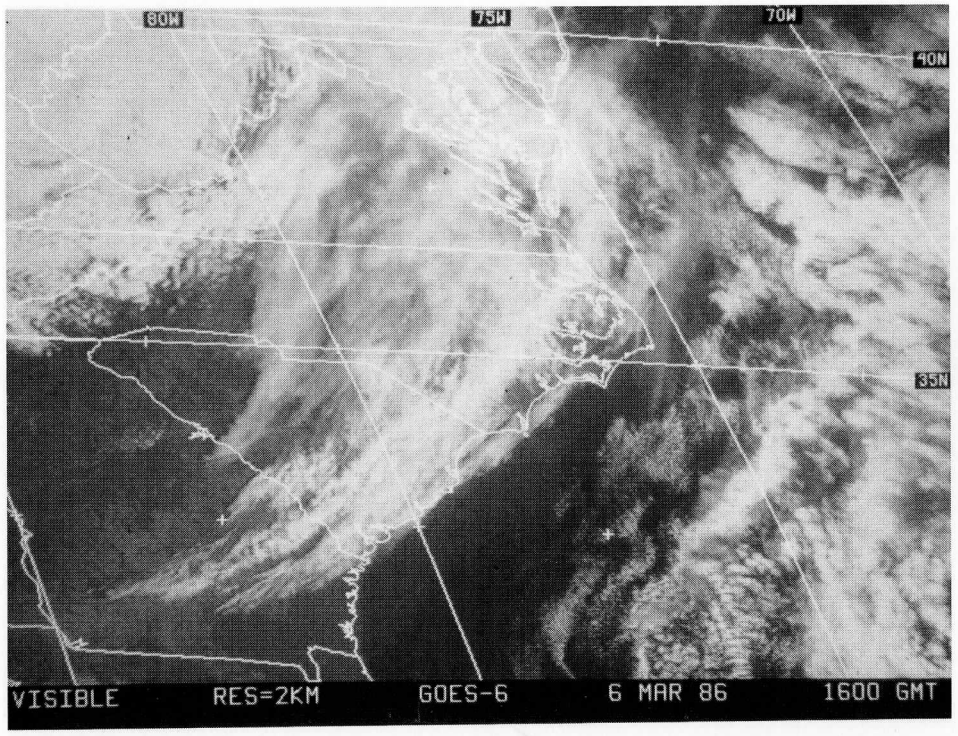
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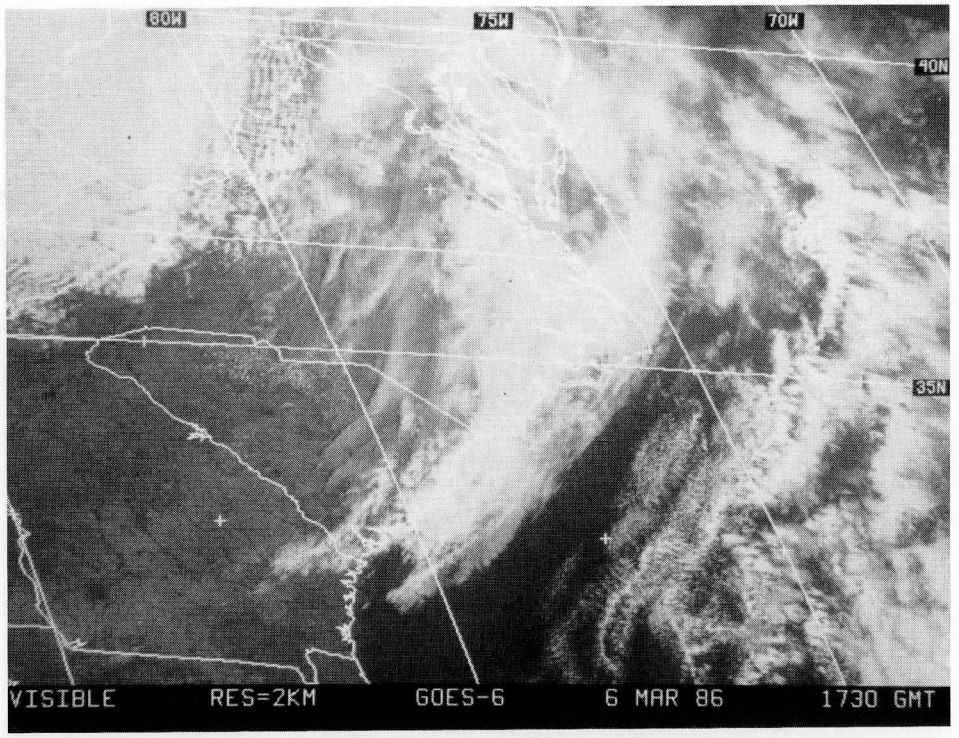
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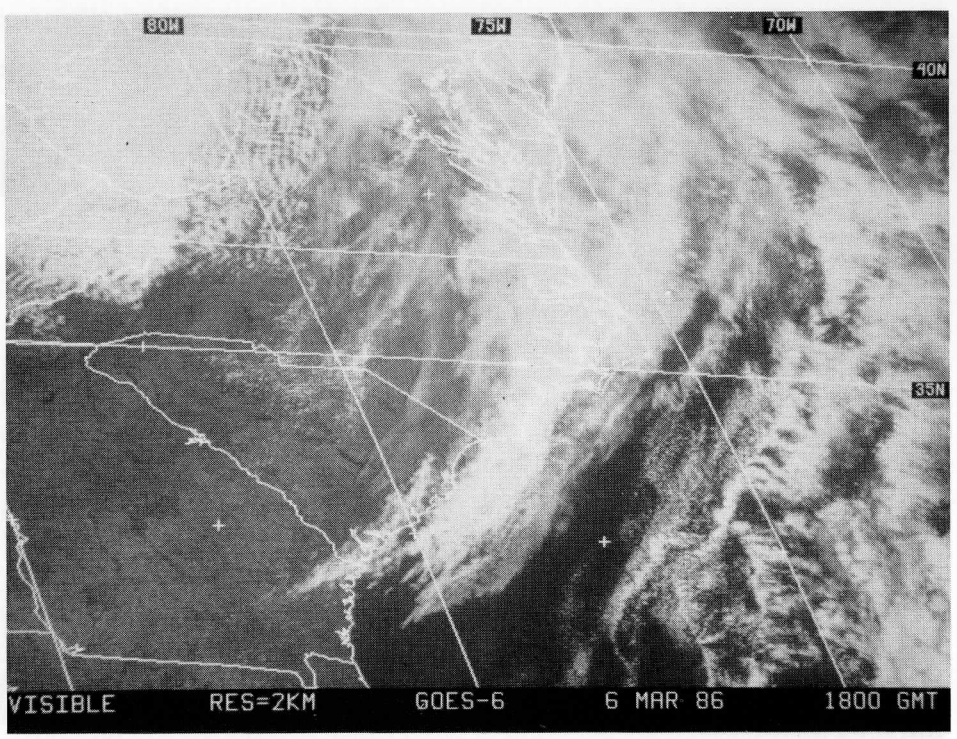
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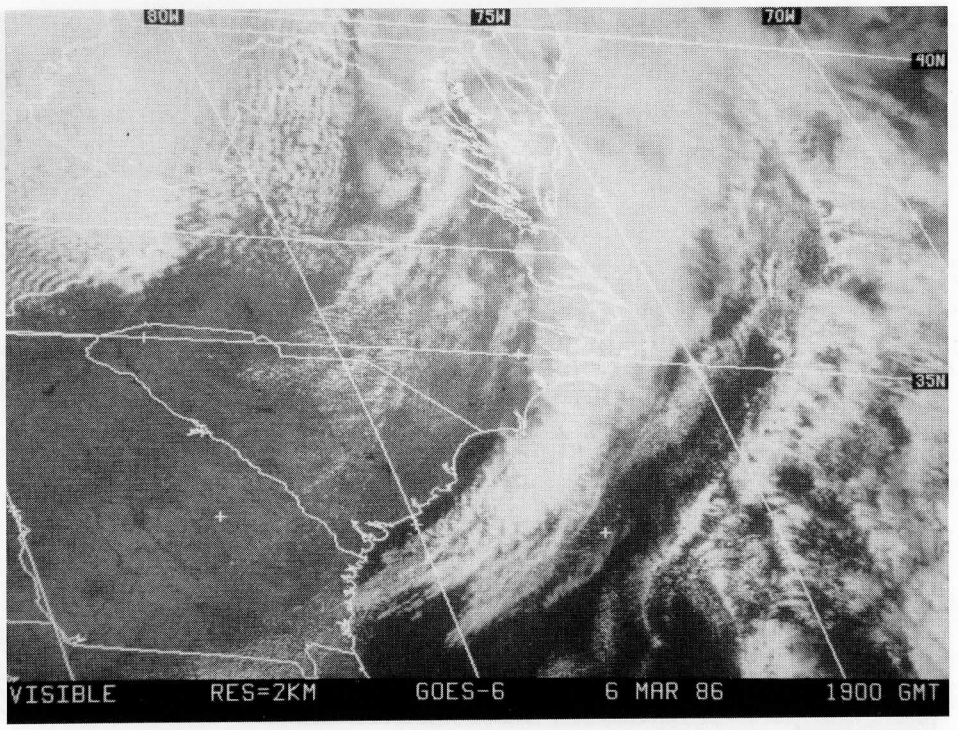
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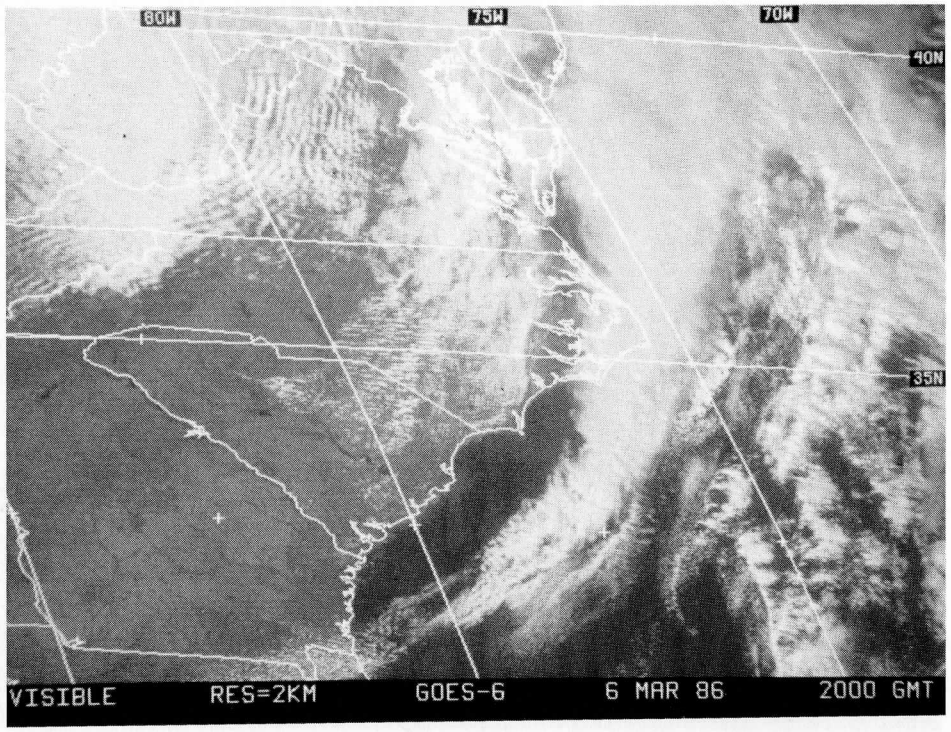
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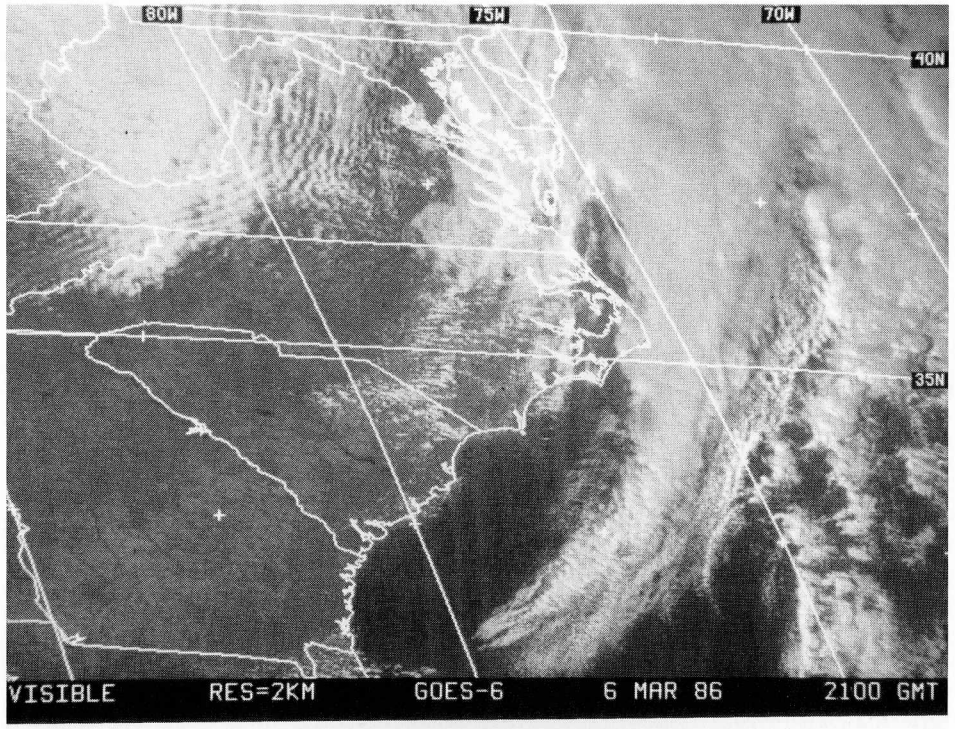
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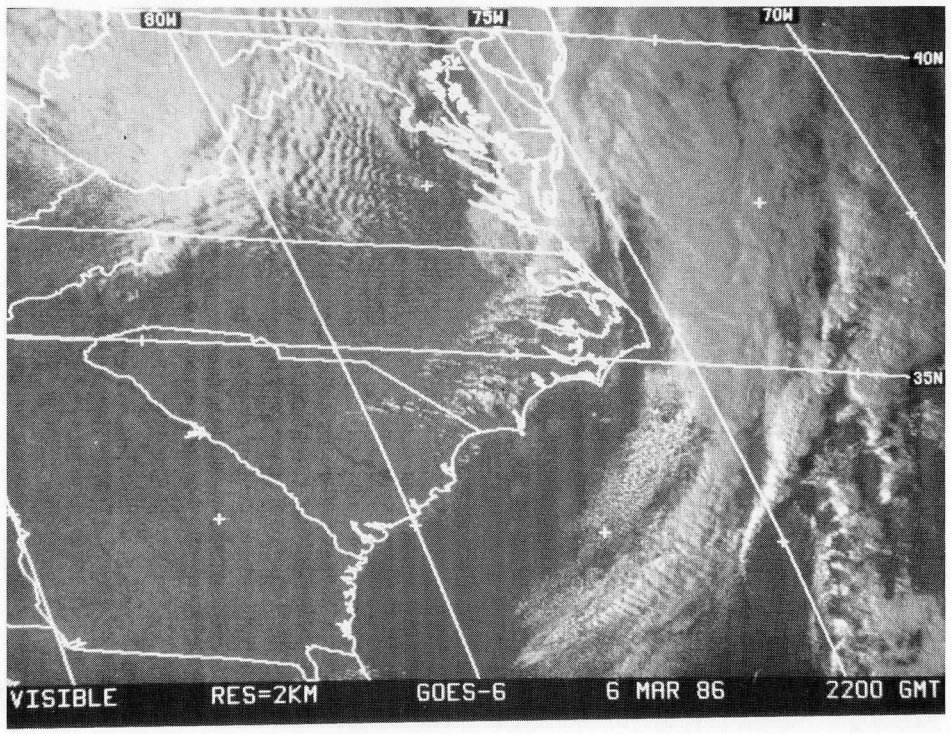
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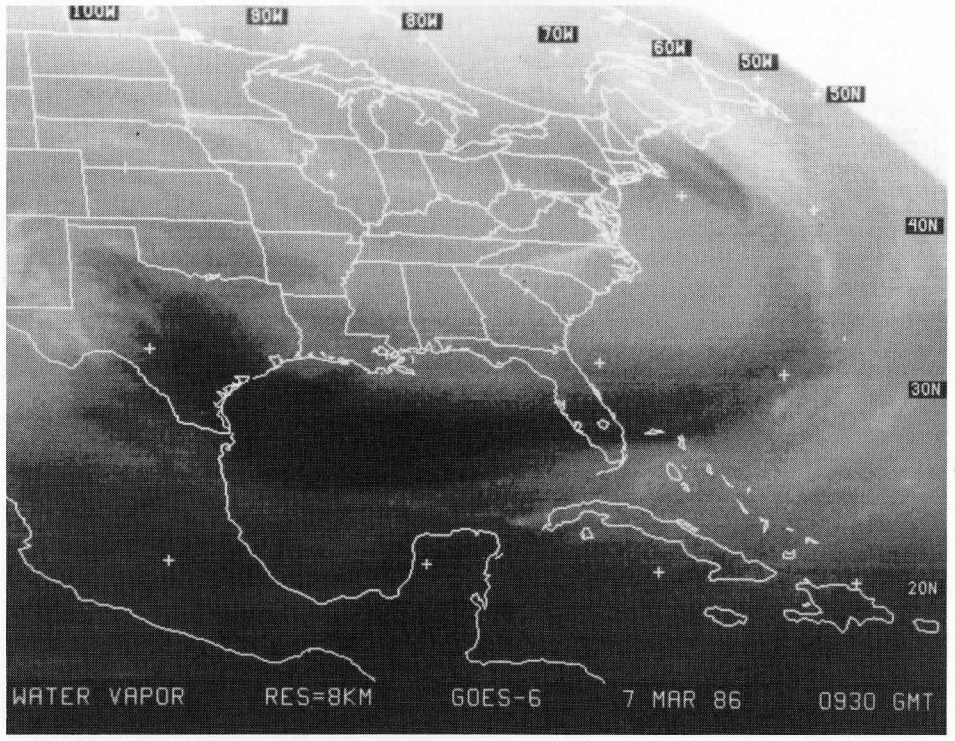
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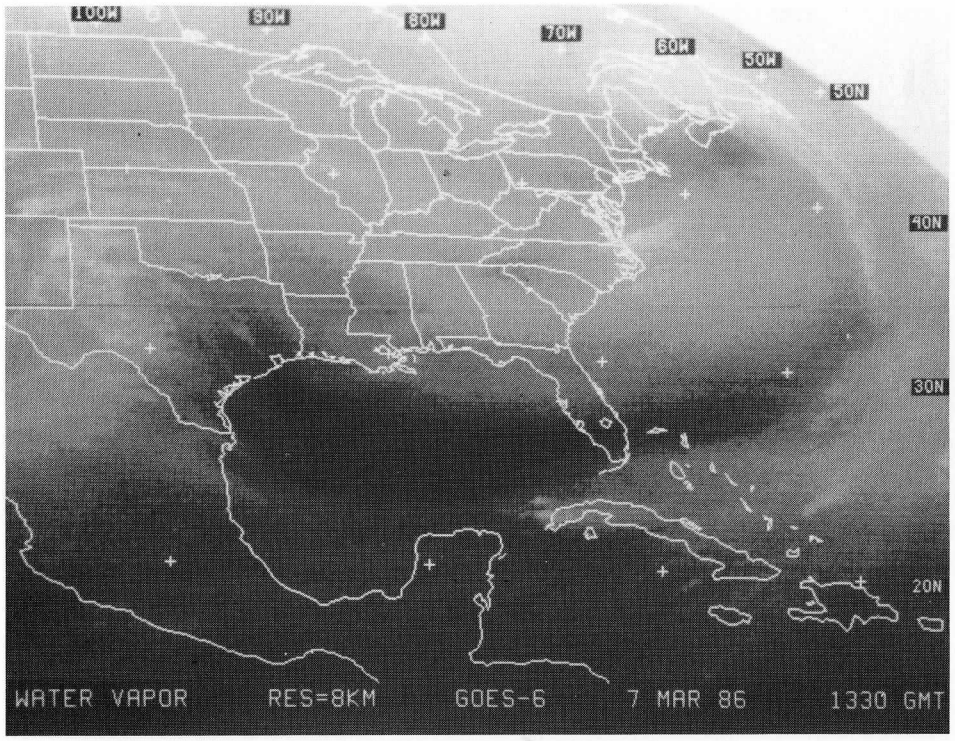
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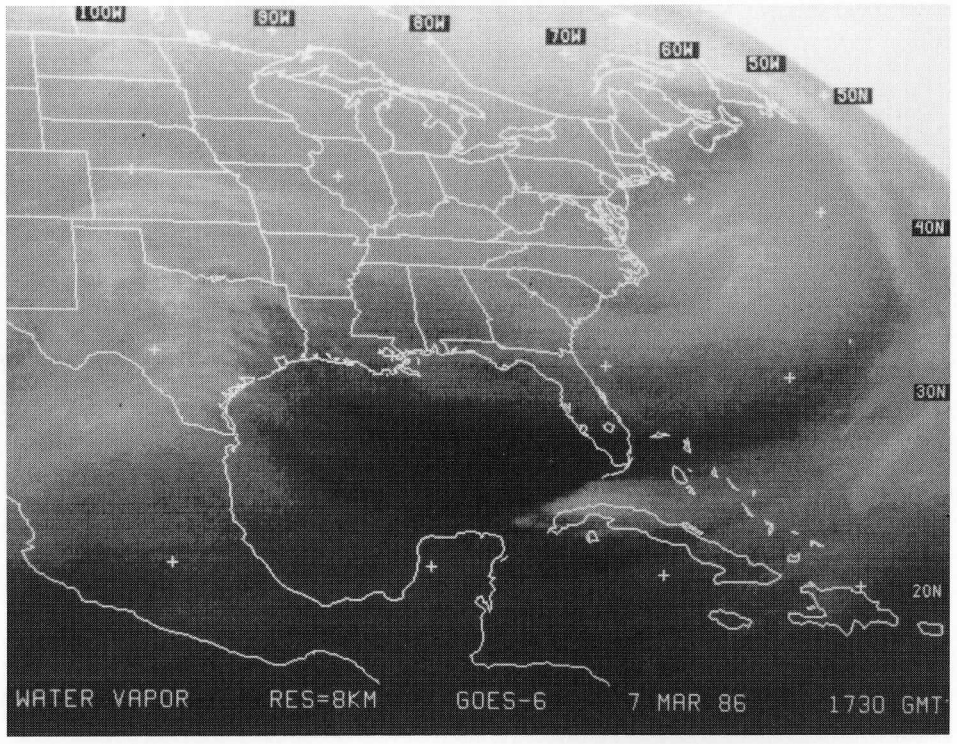
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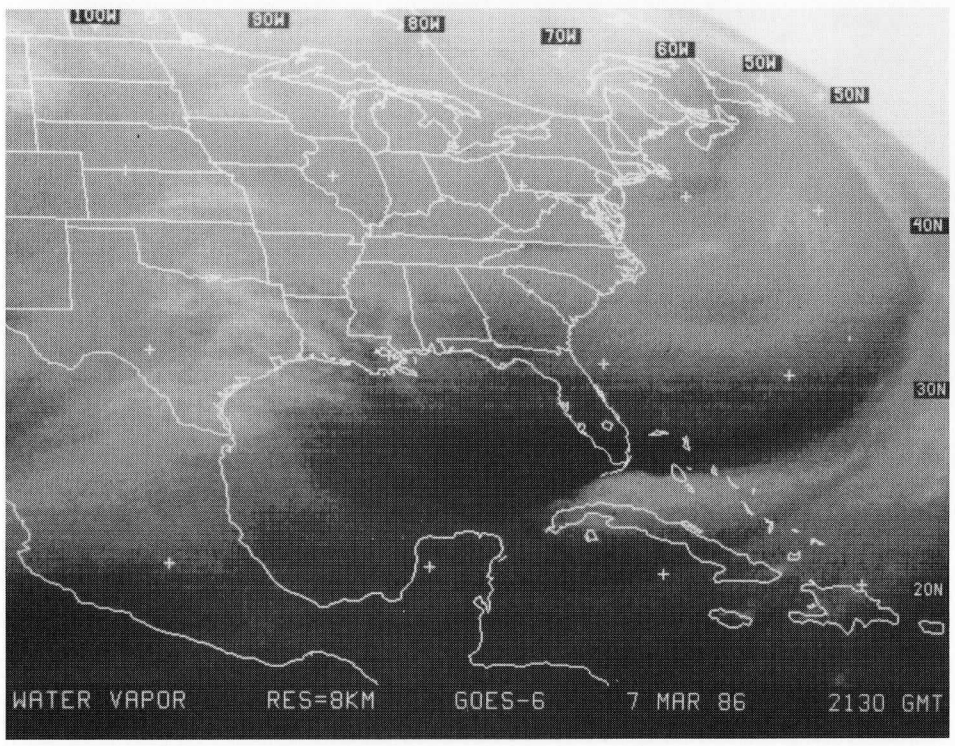
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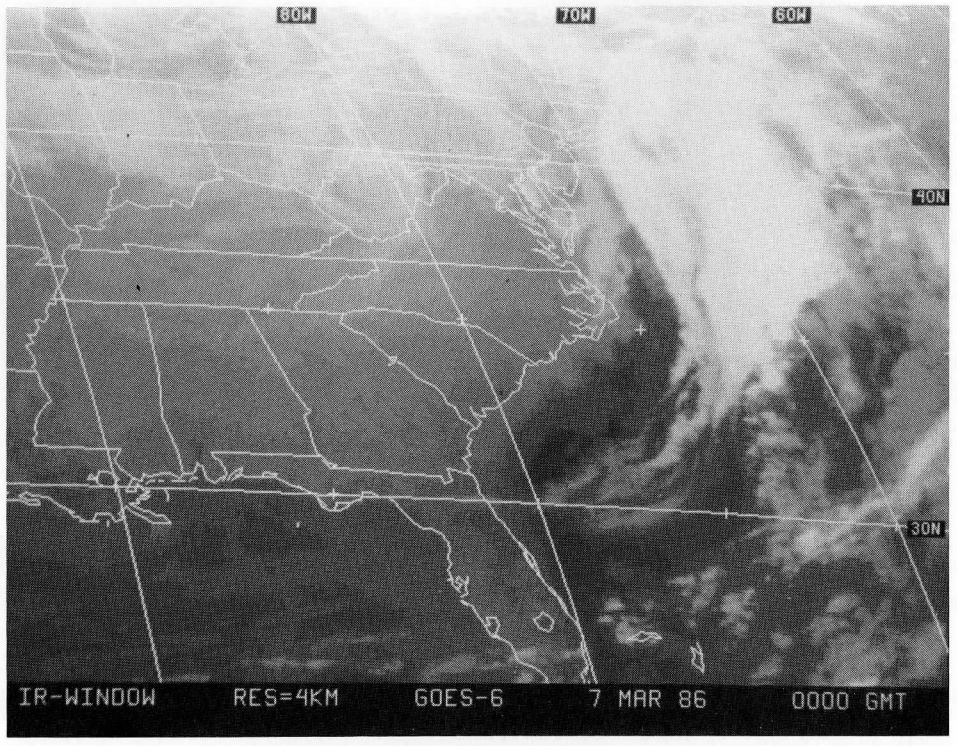
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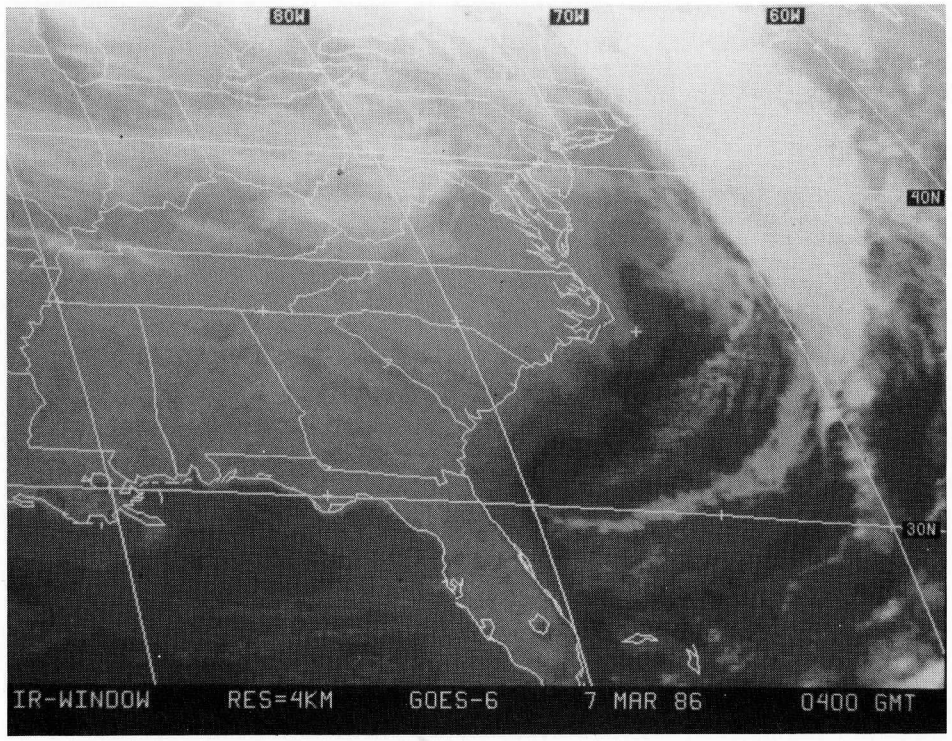
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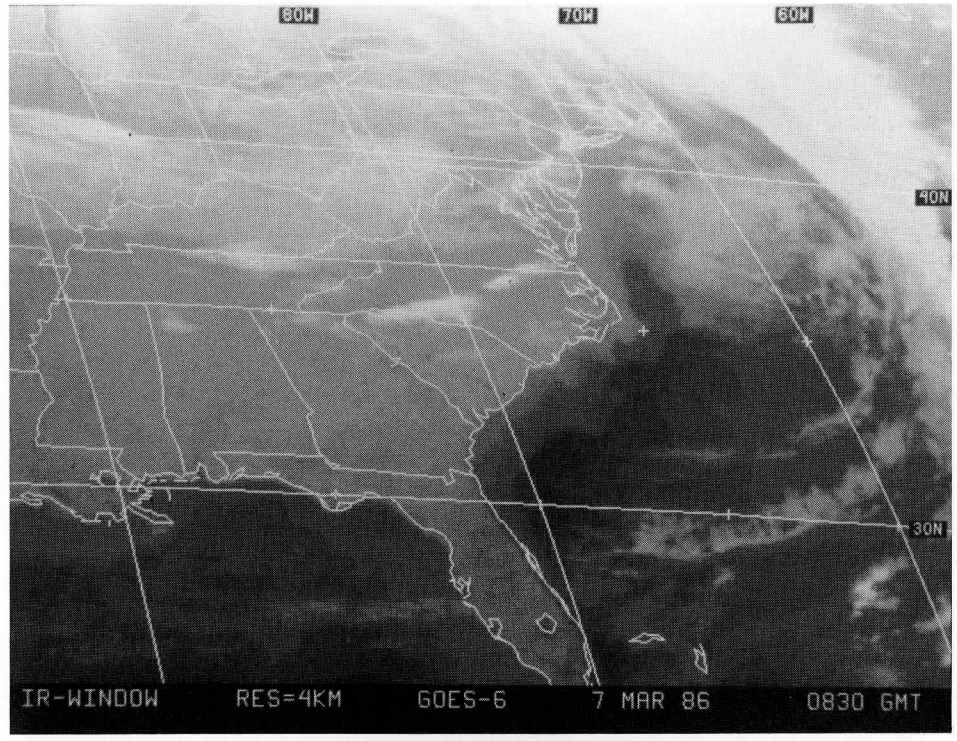
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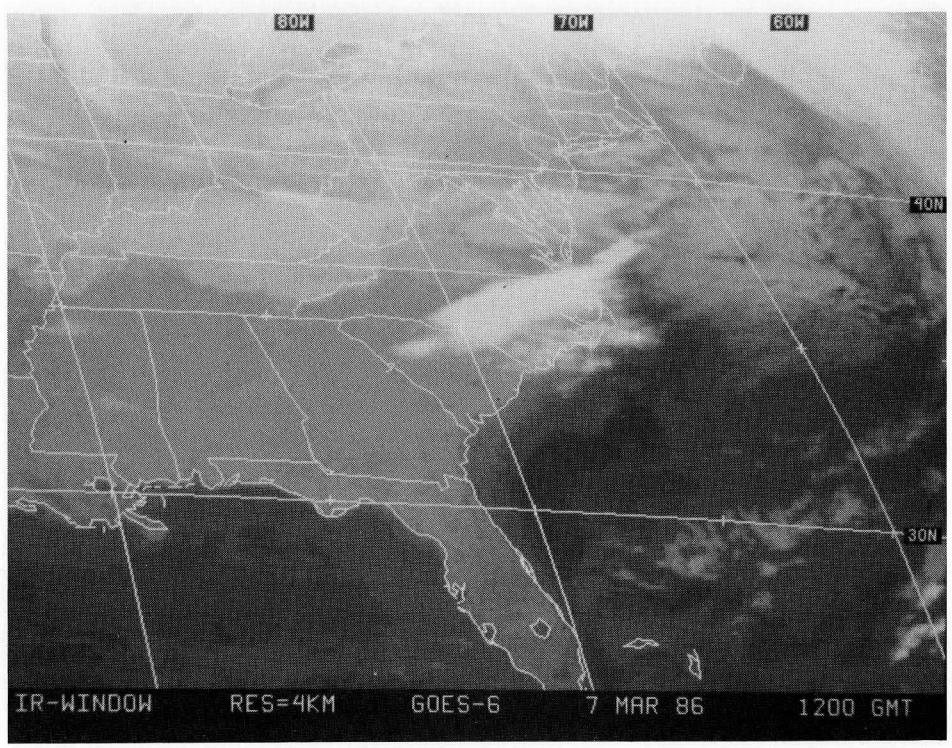
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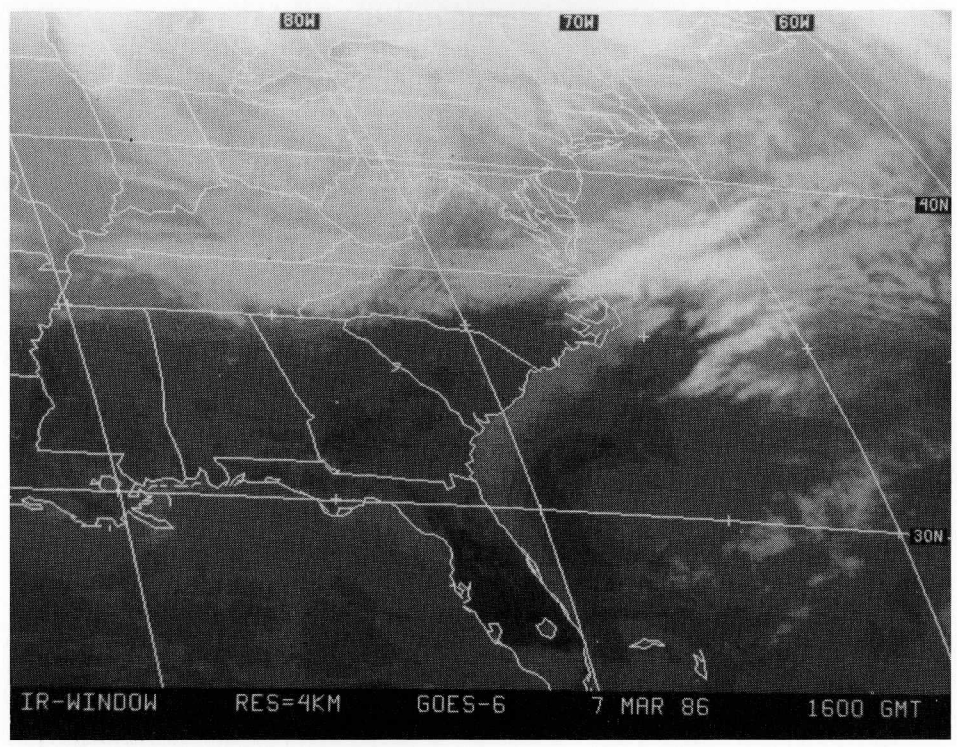
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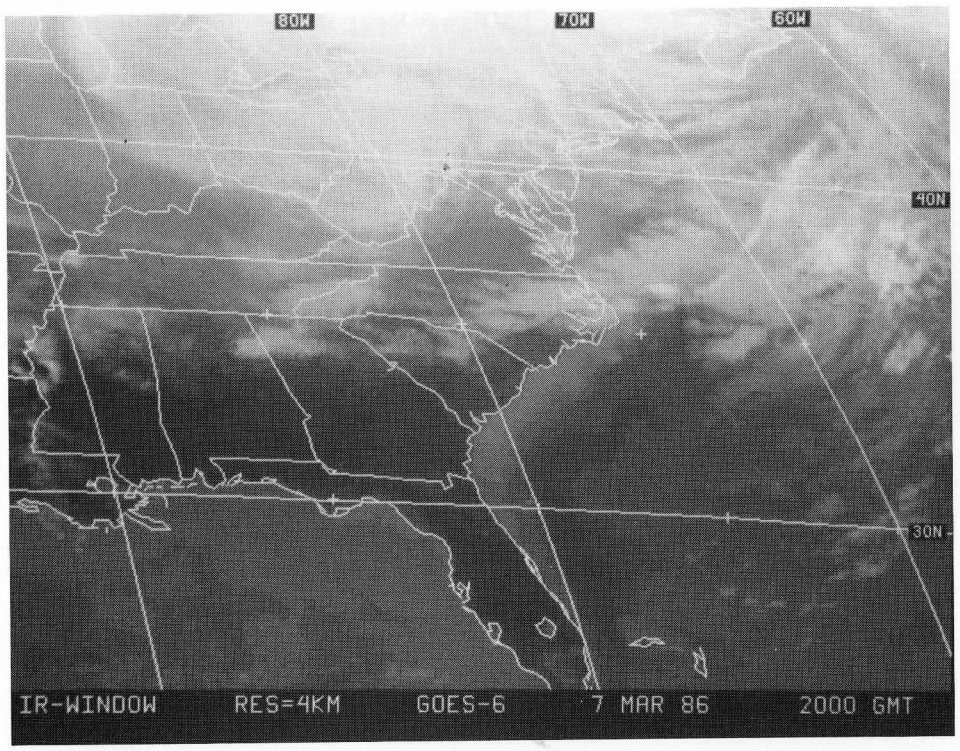
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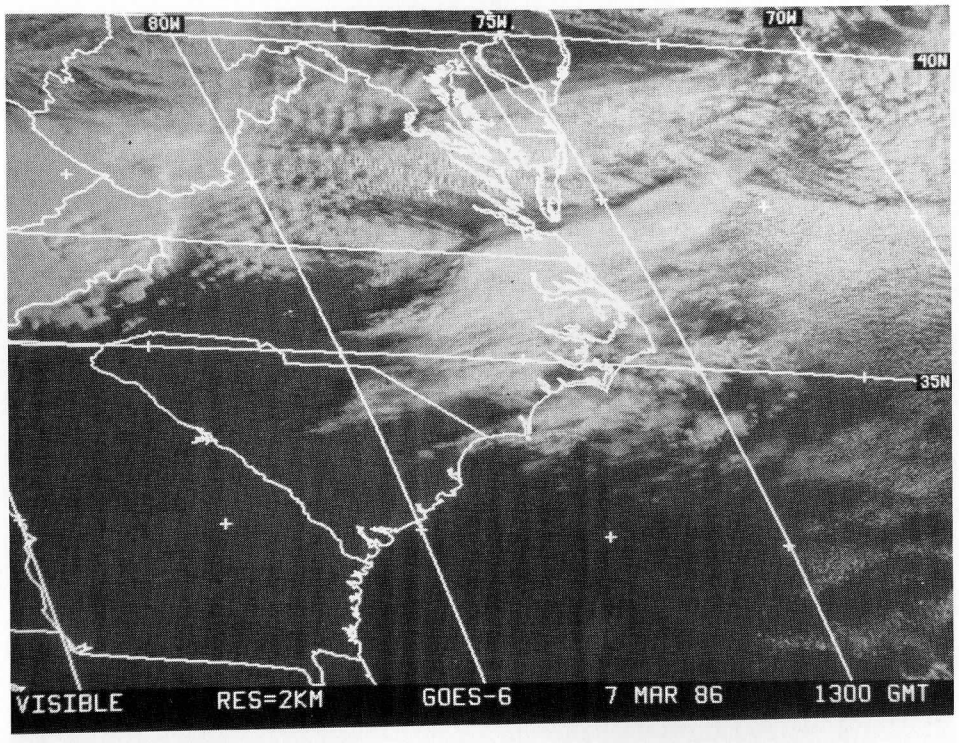
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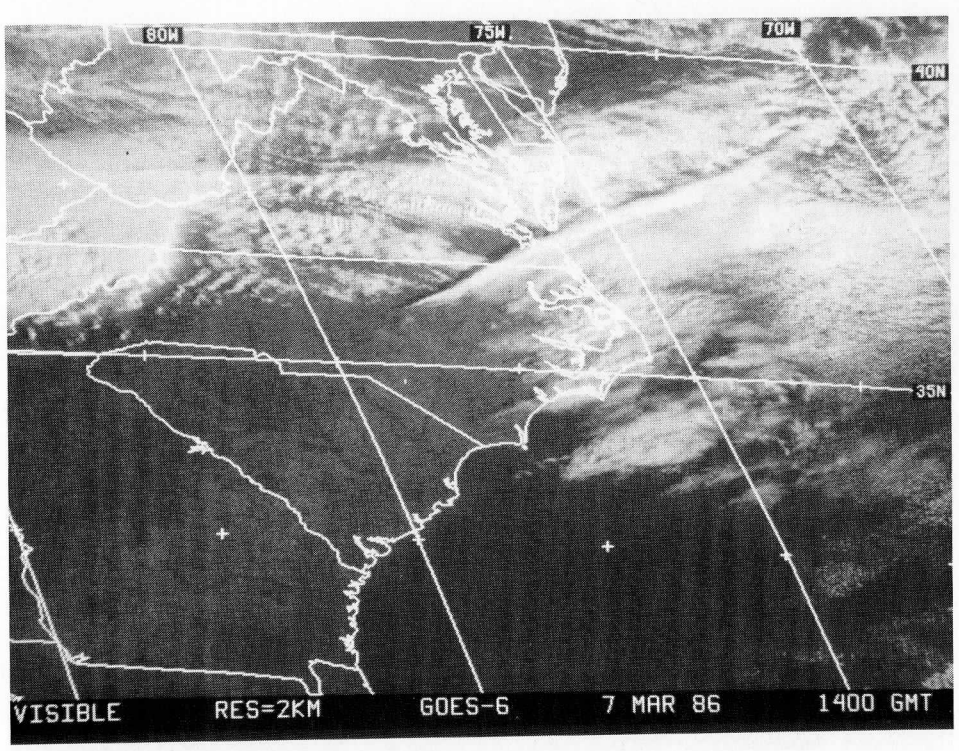
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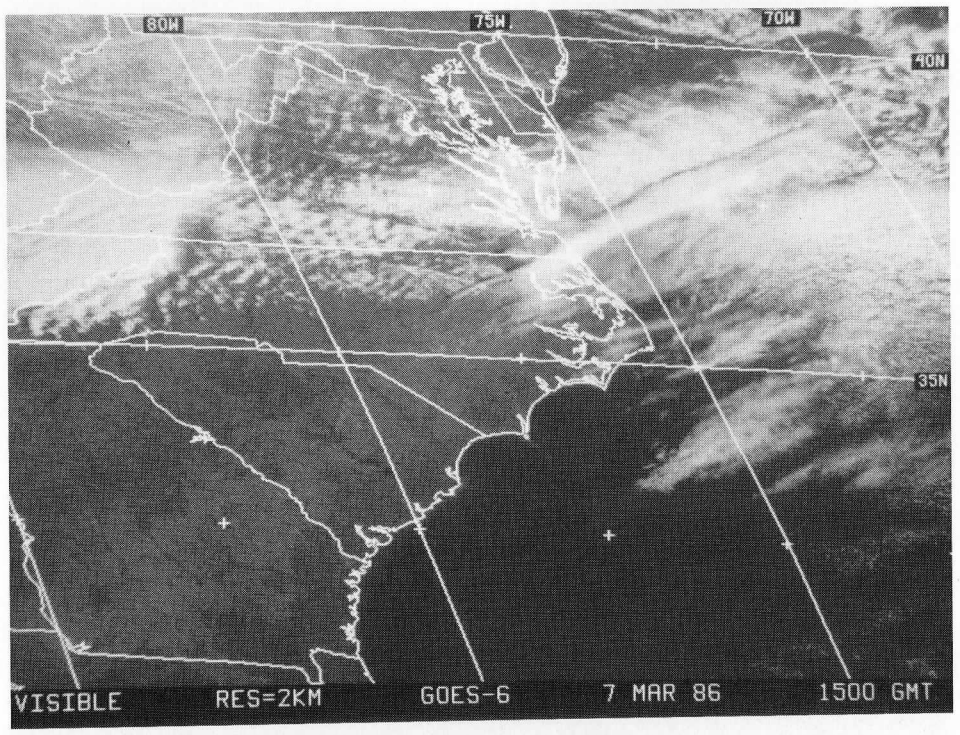
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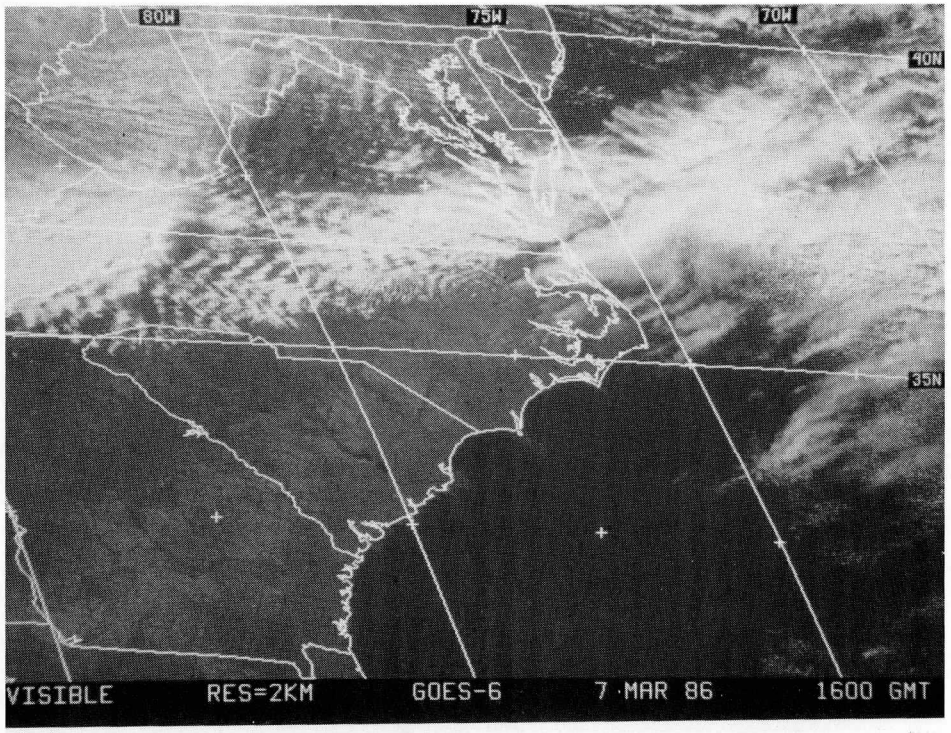
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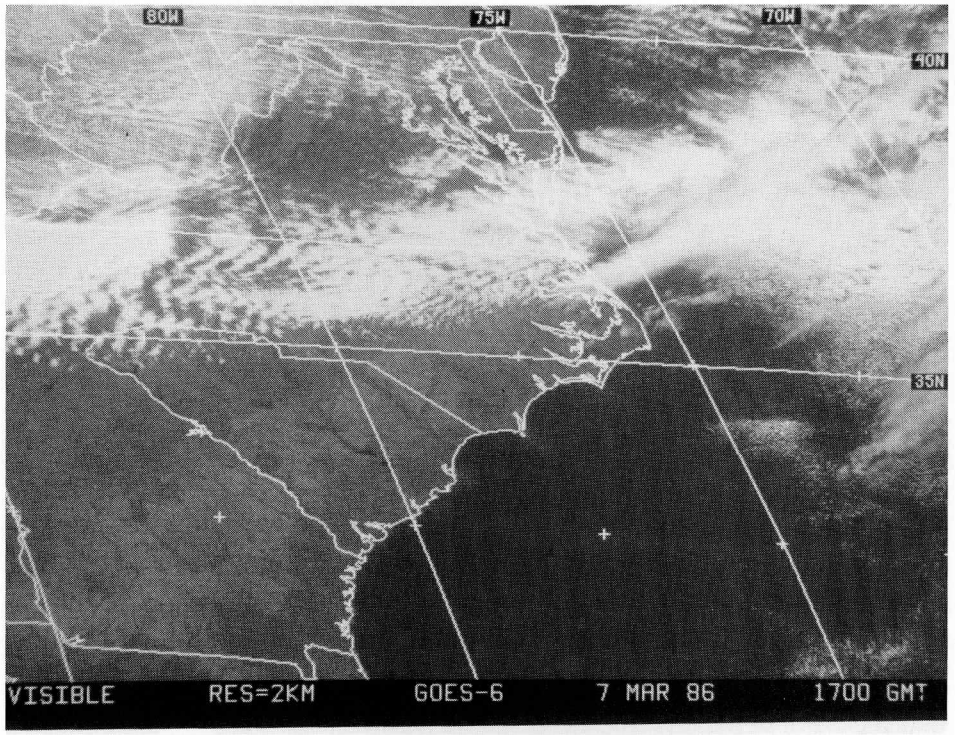
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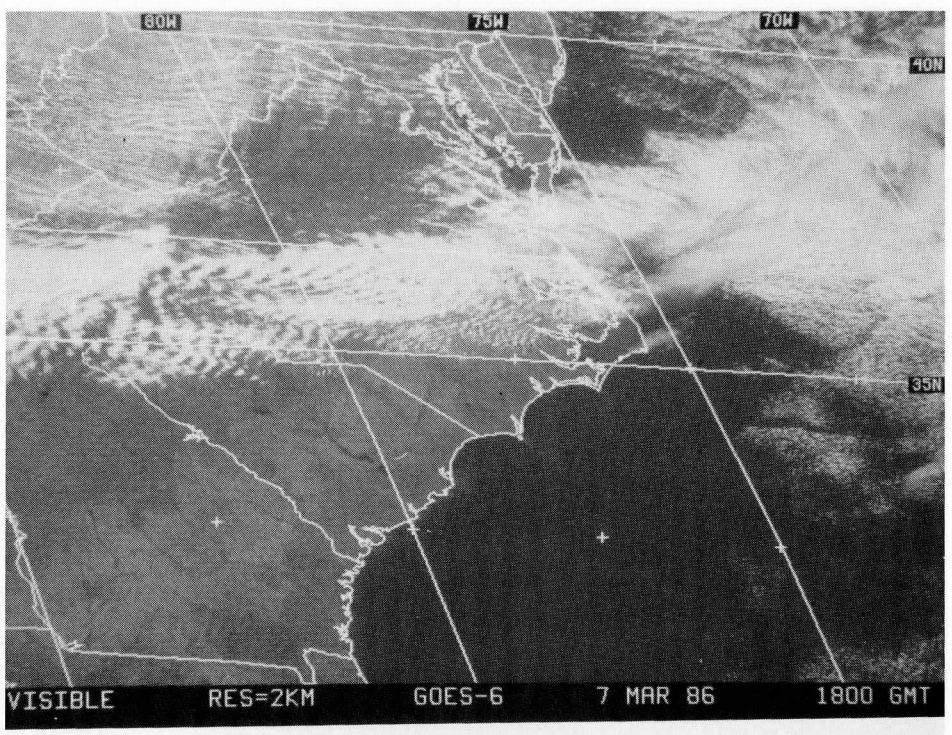
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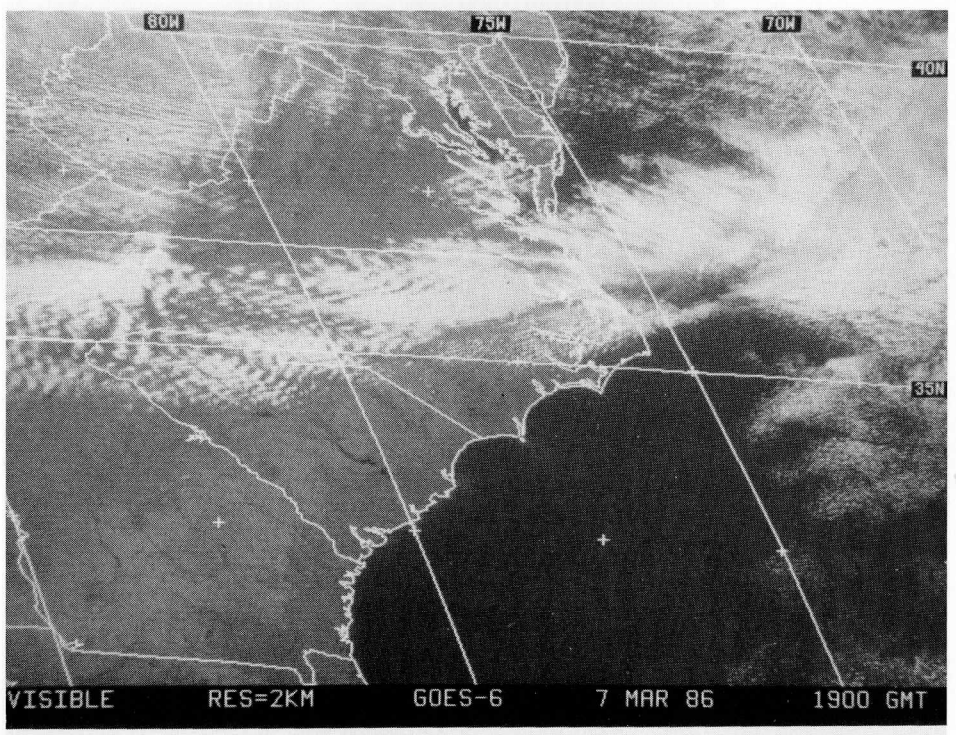
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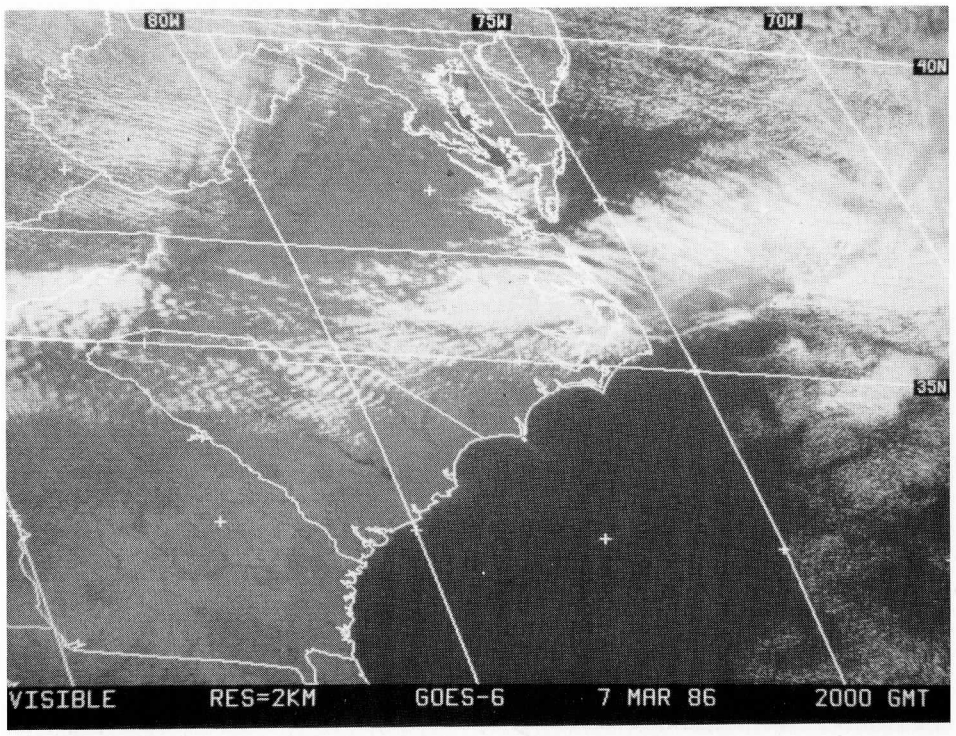
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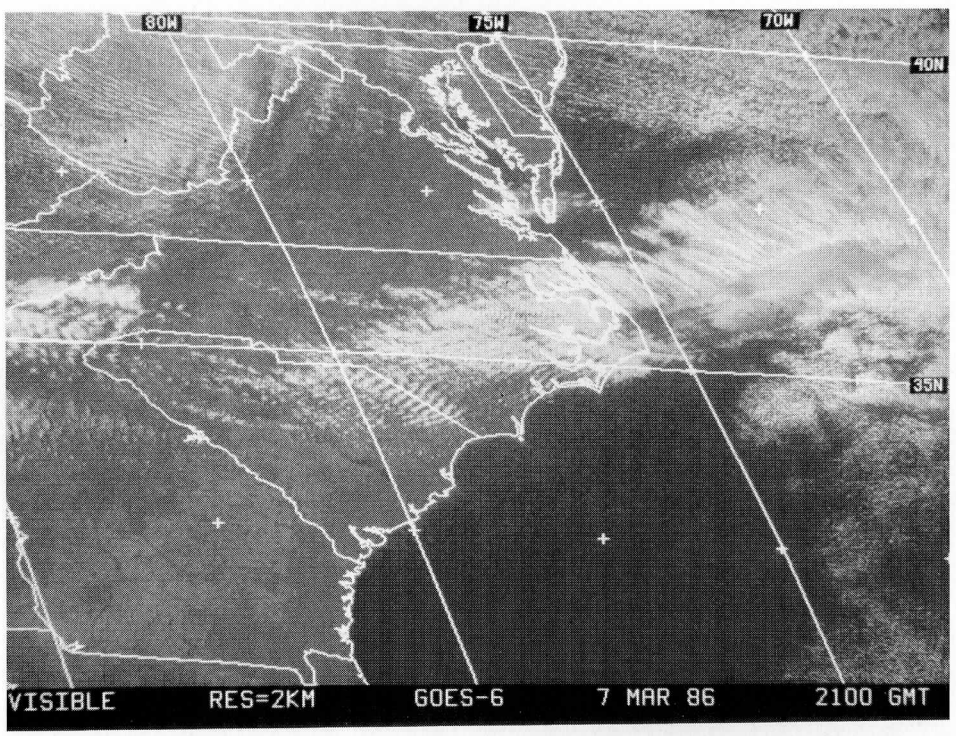
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20N
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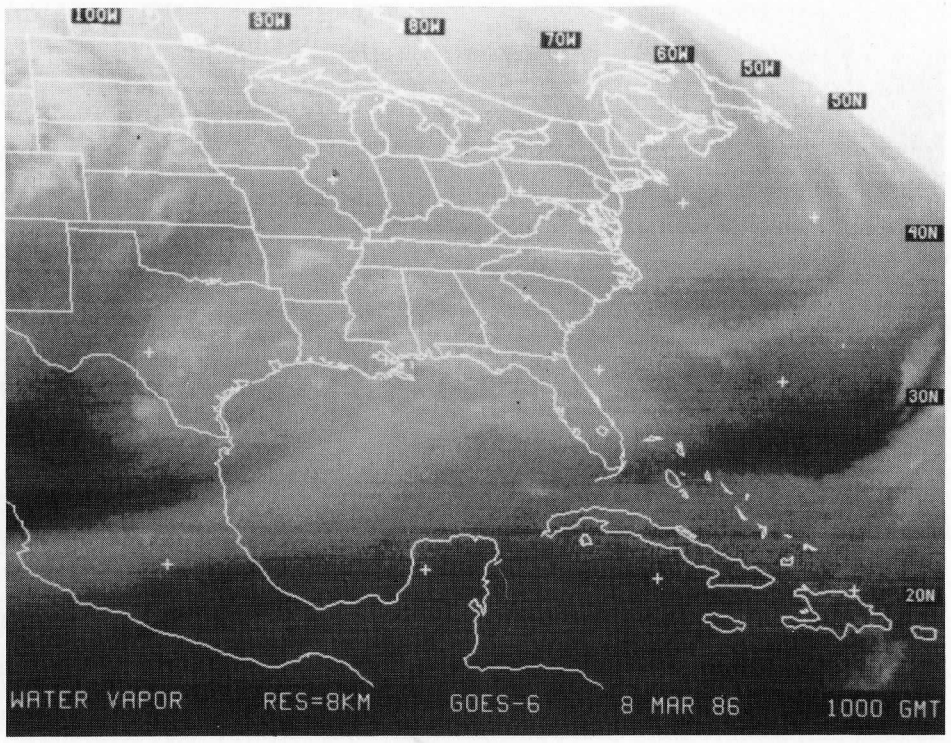
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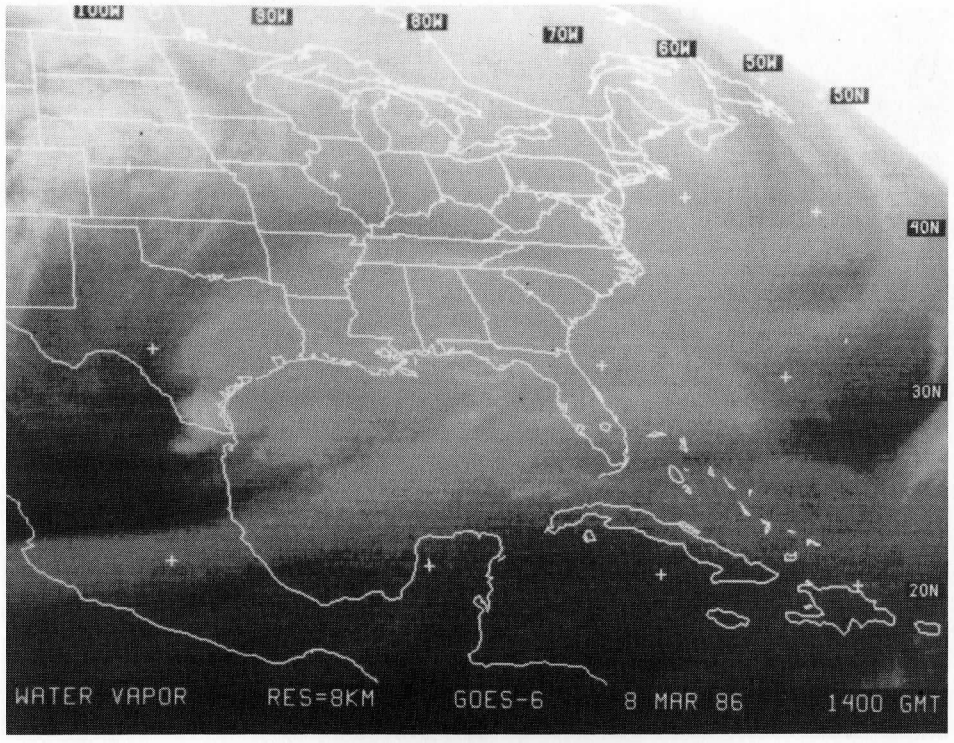
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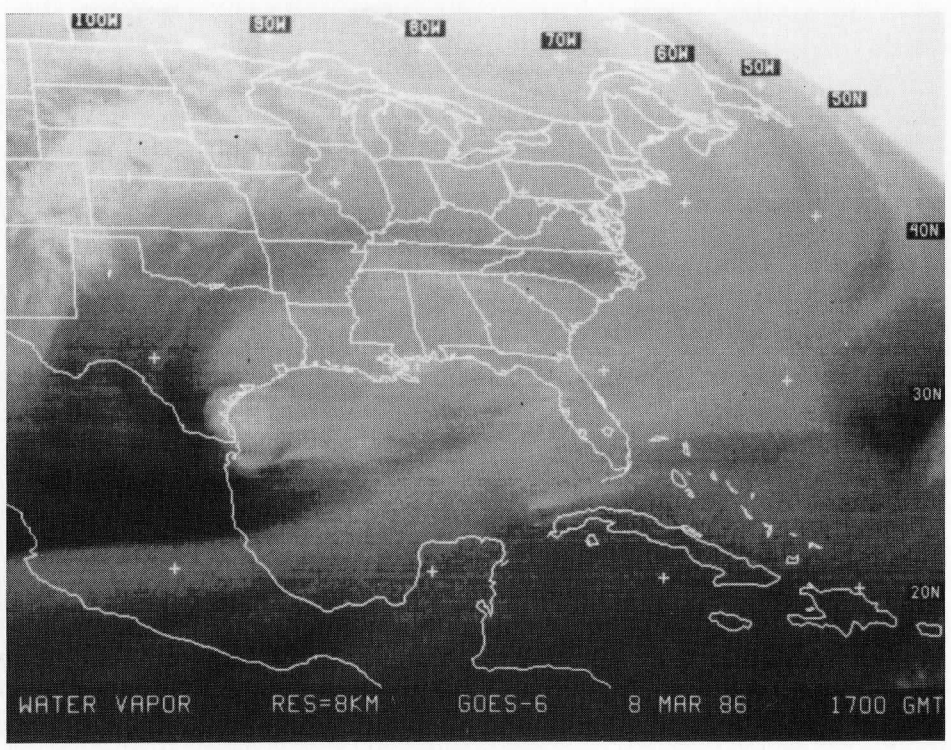
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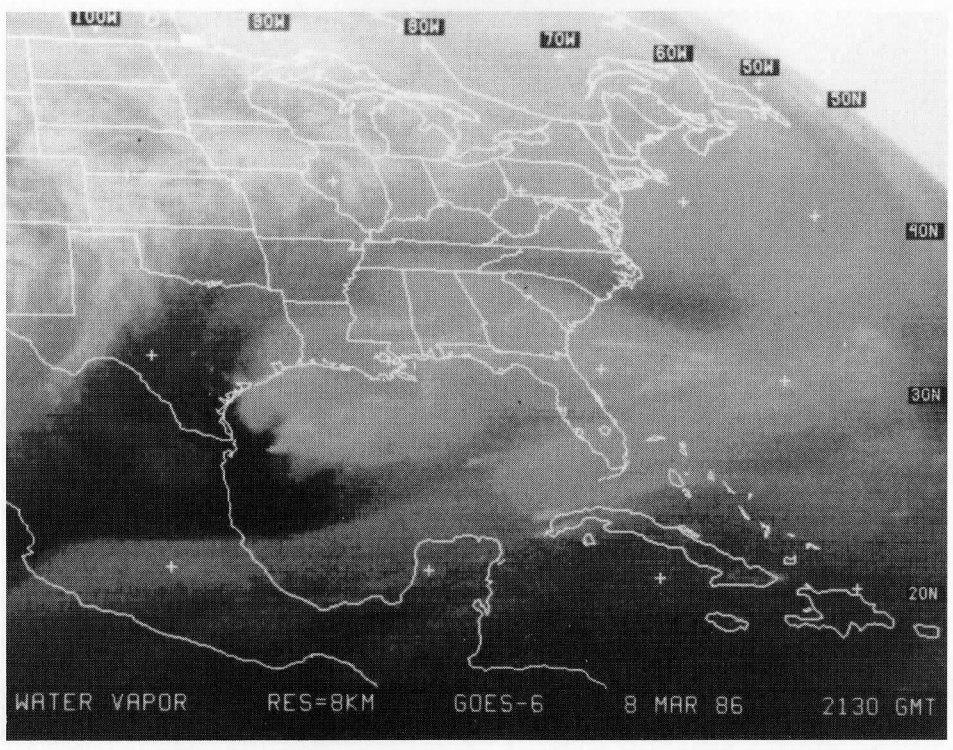
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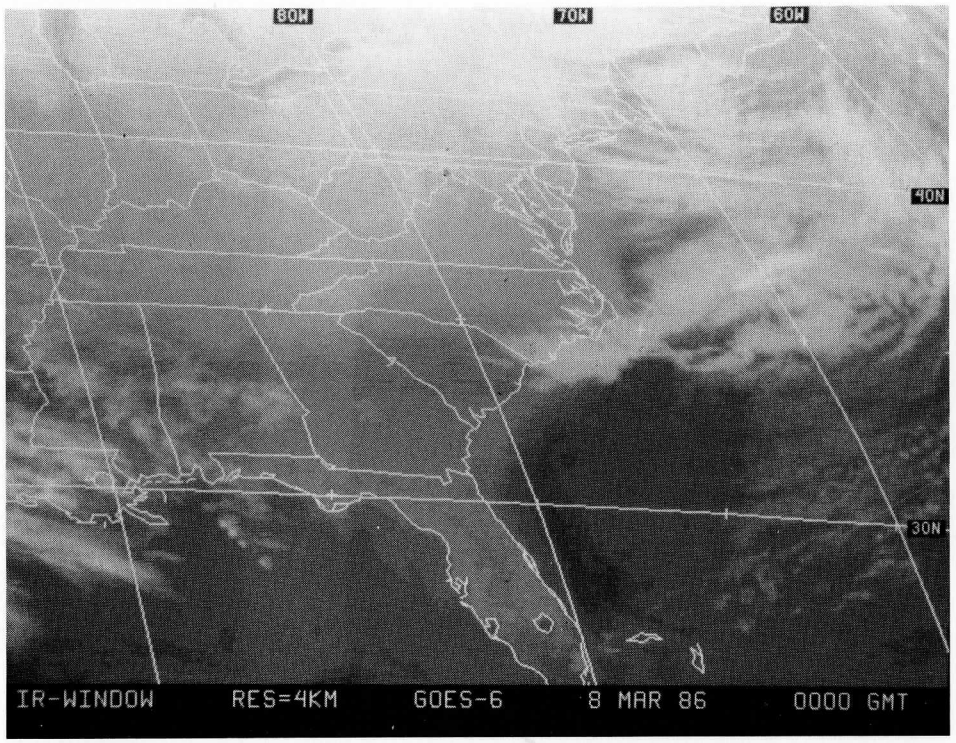
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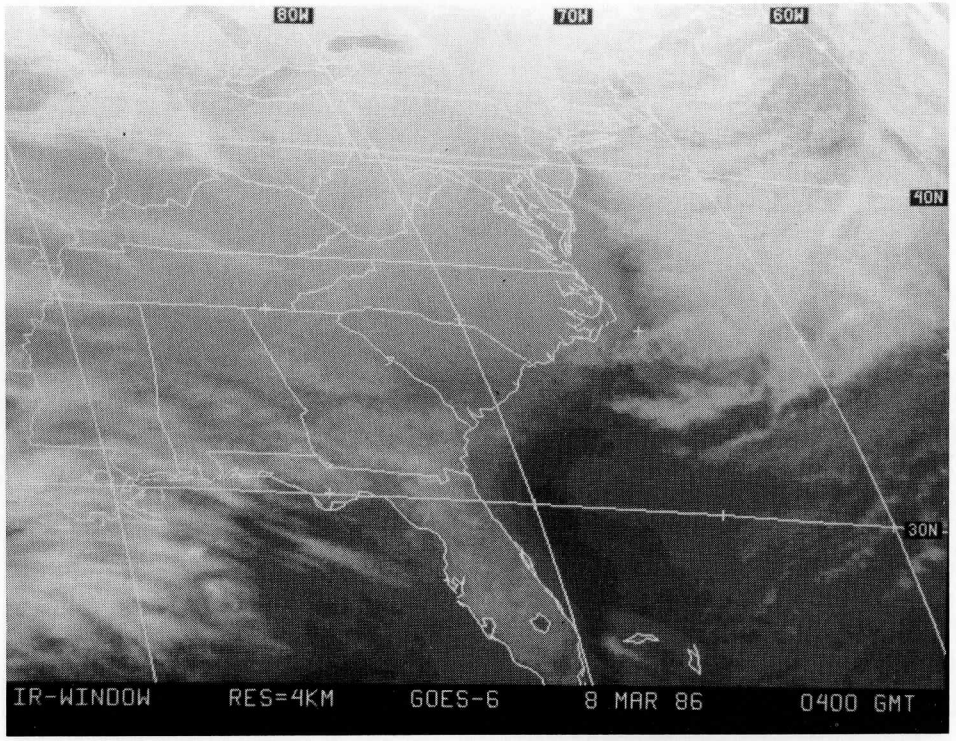
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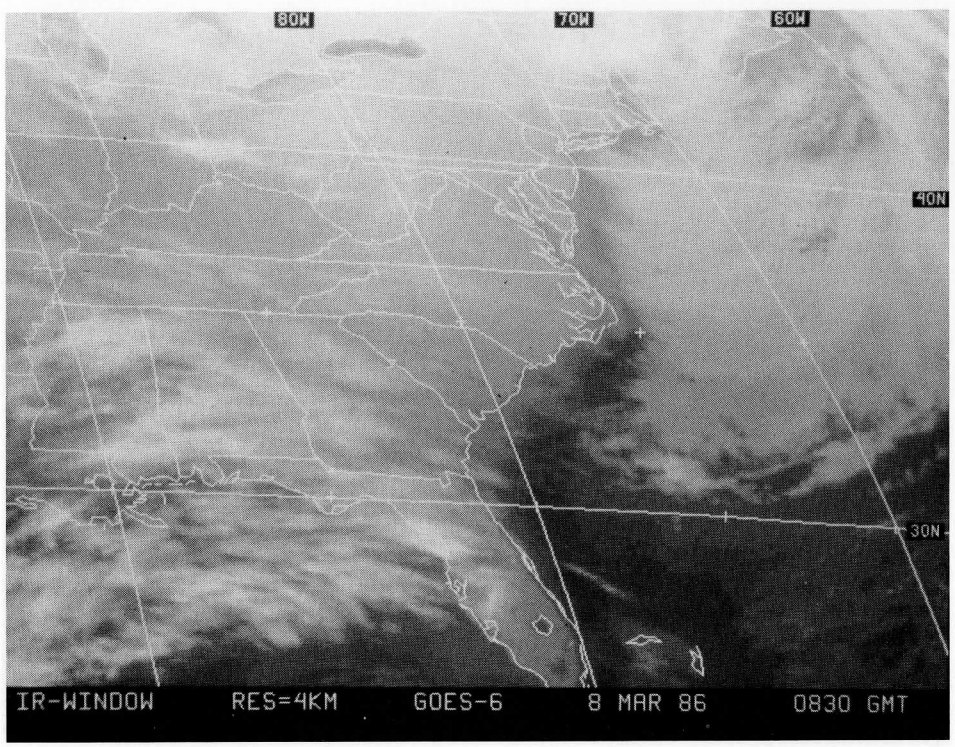
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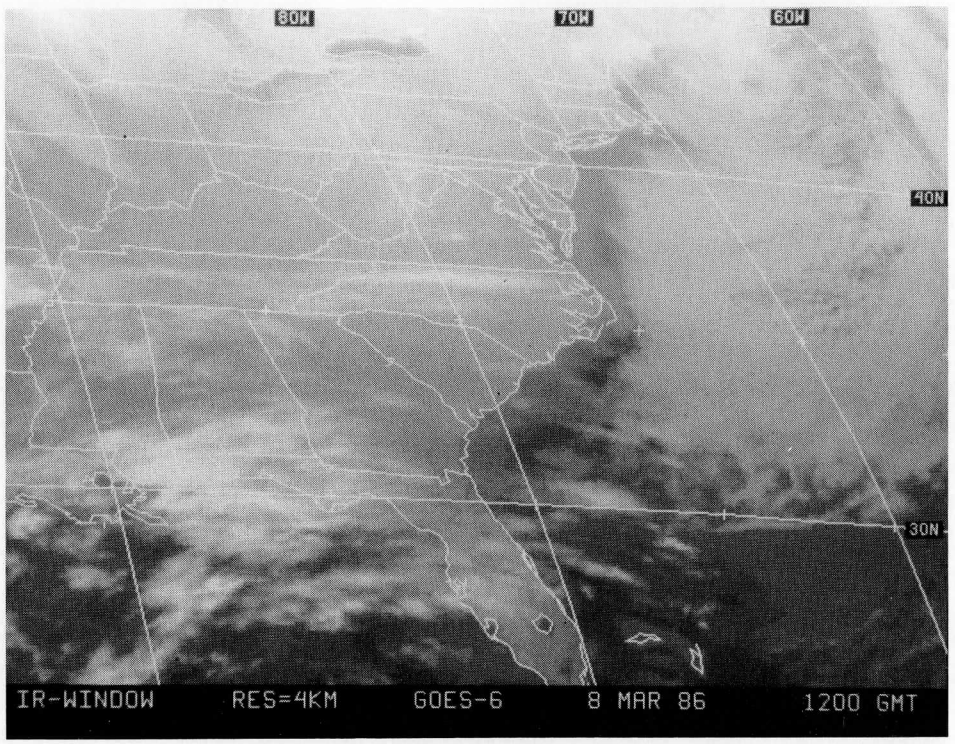
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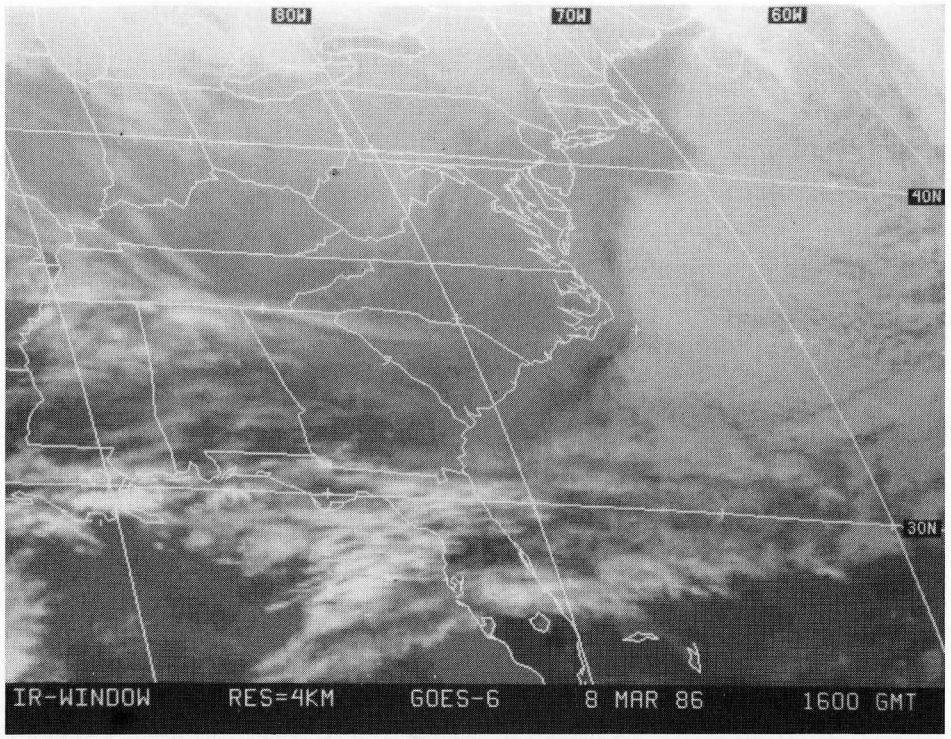
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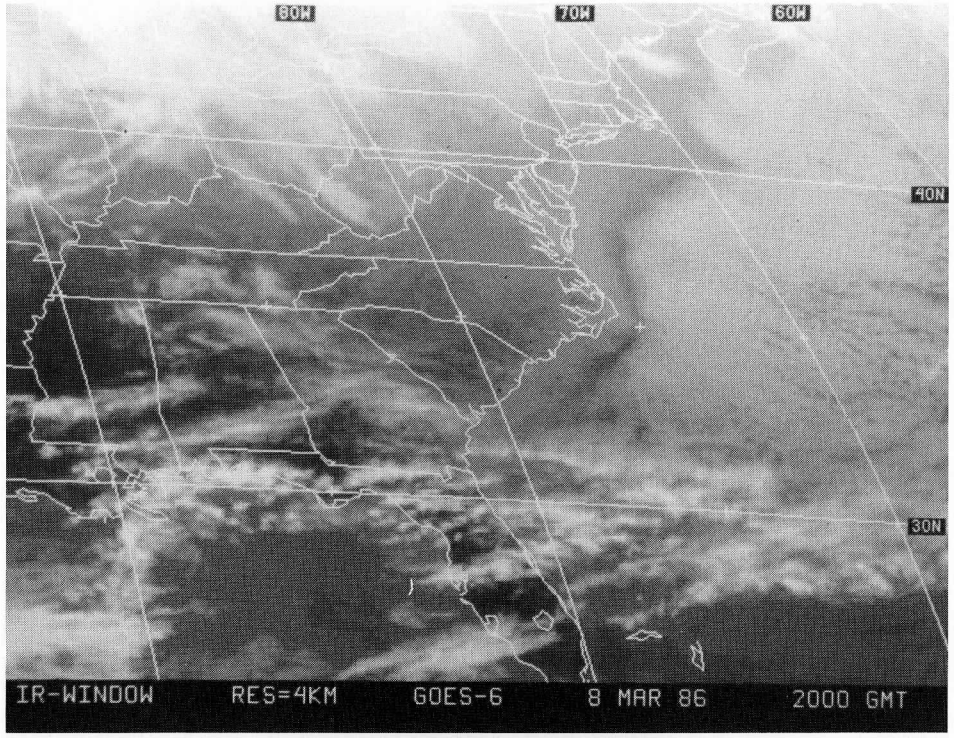
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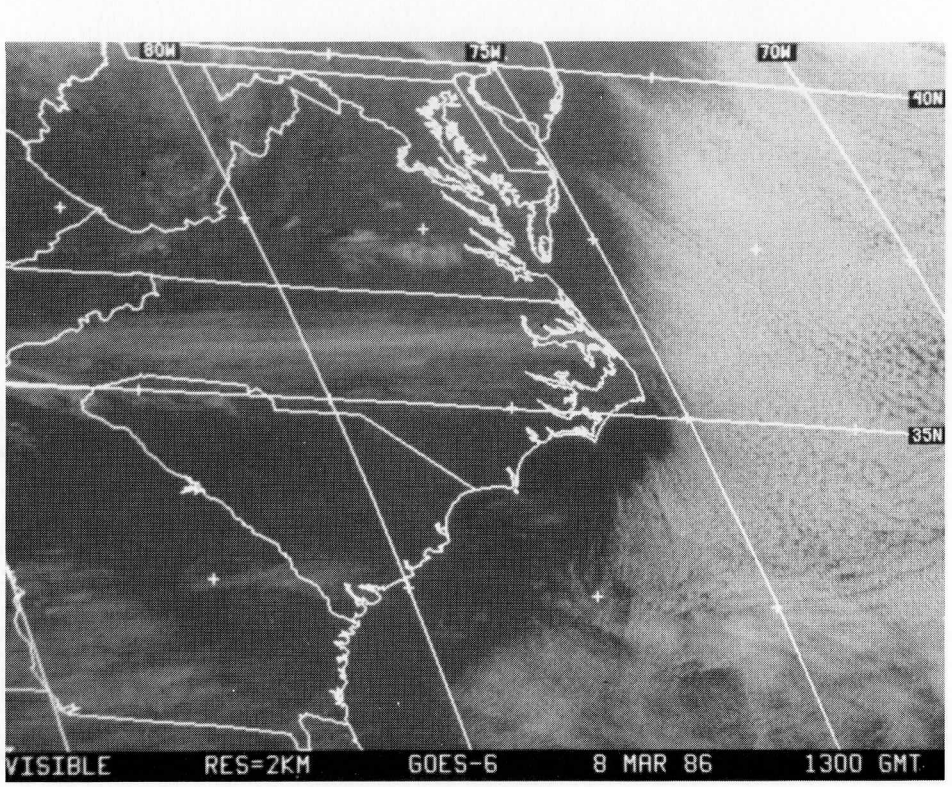
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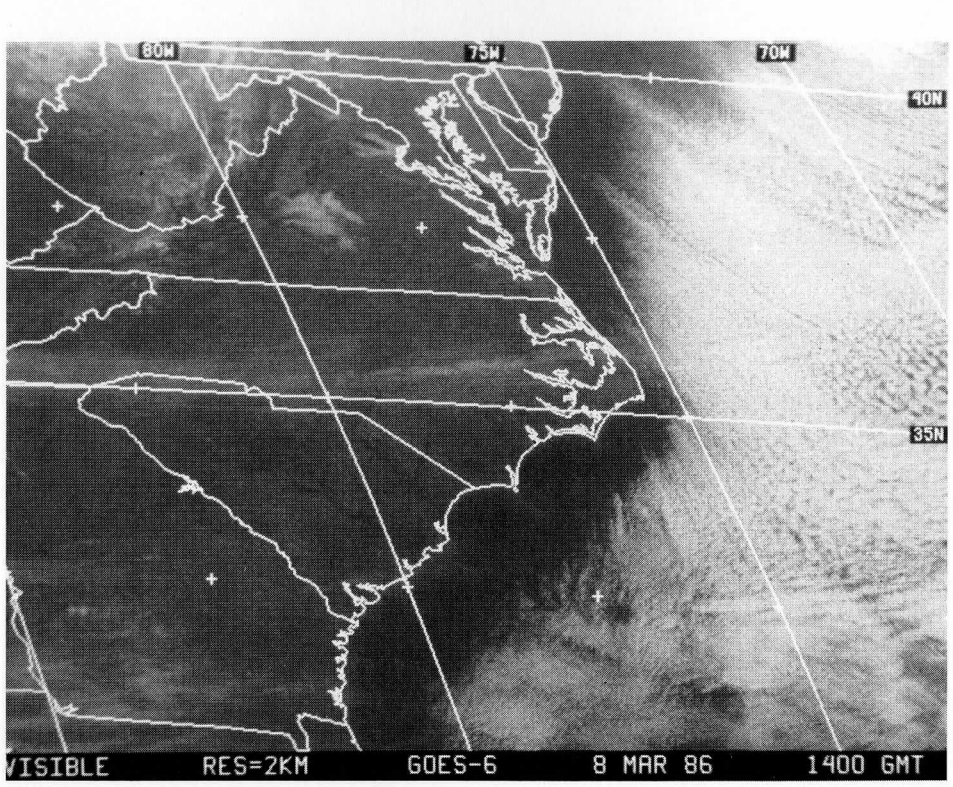
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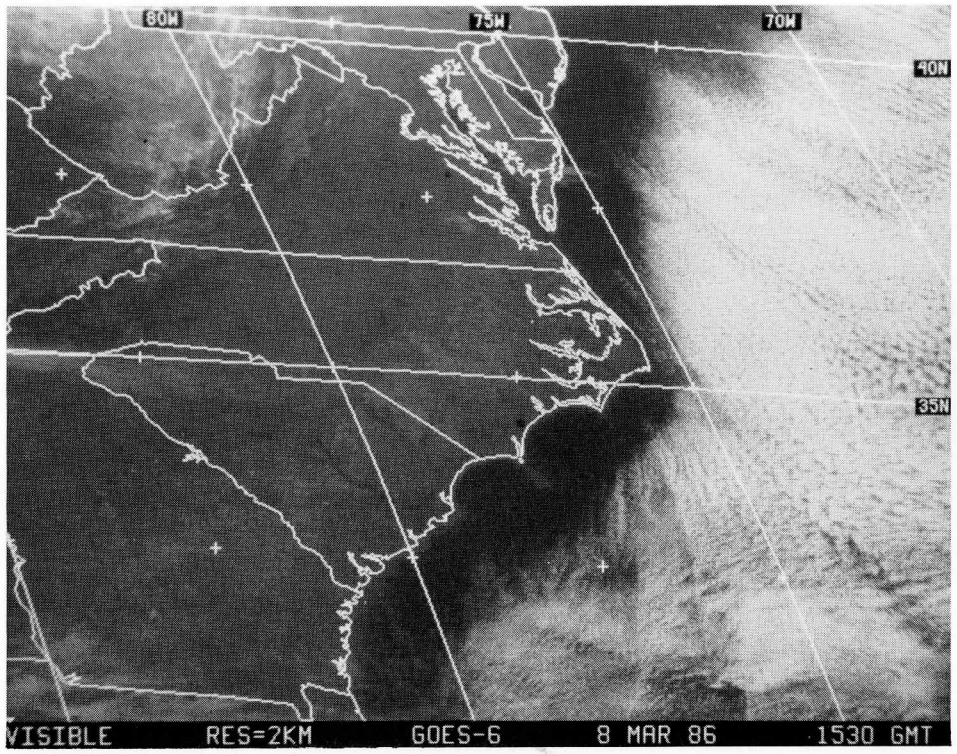
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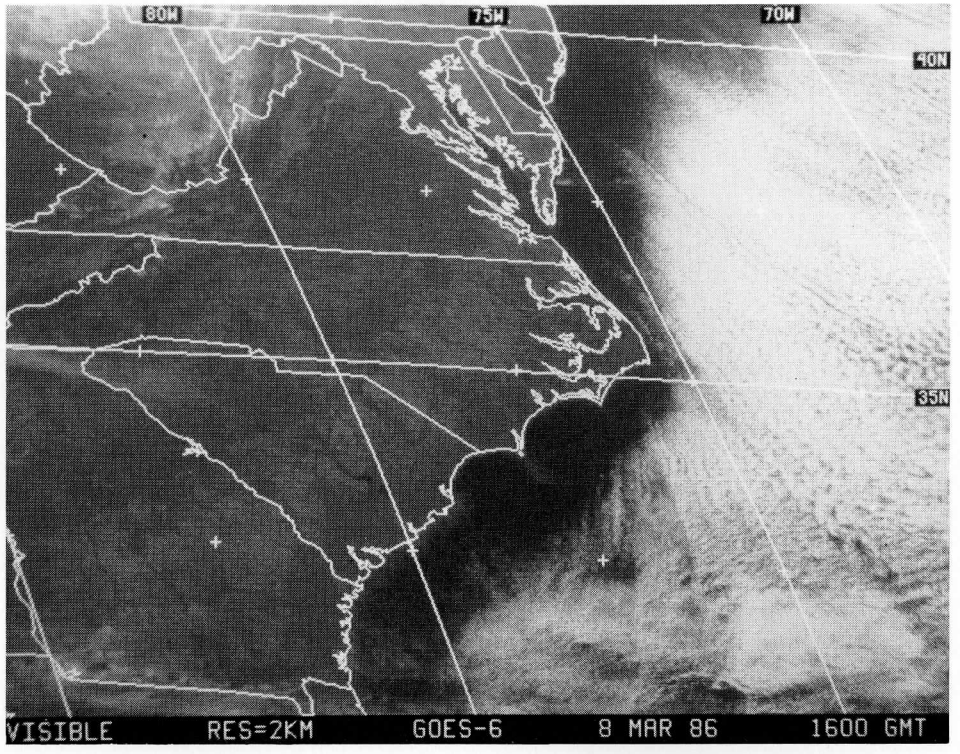
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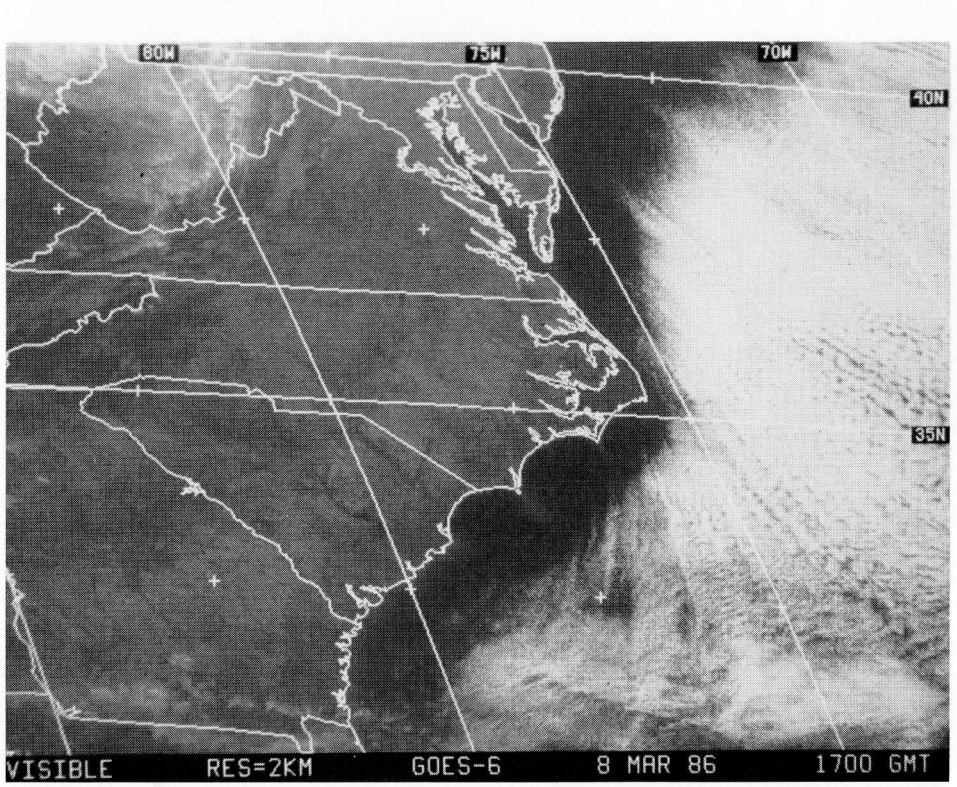
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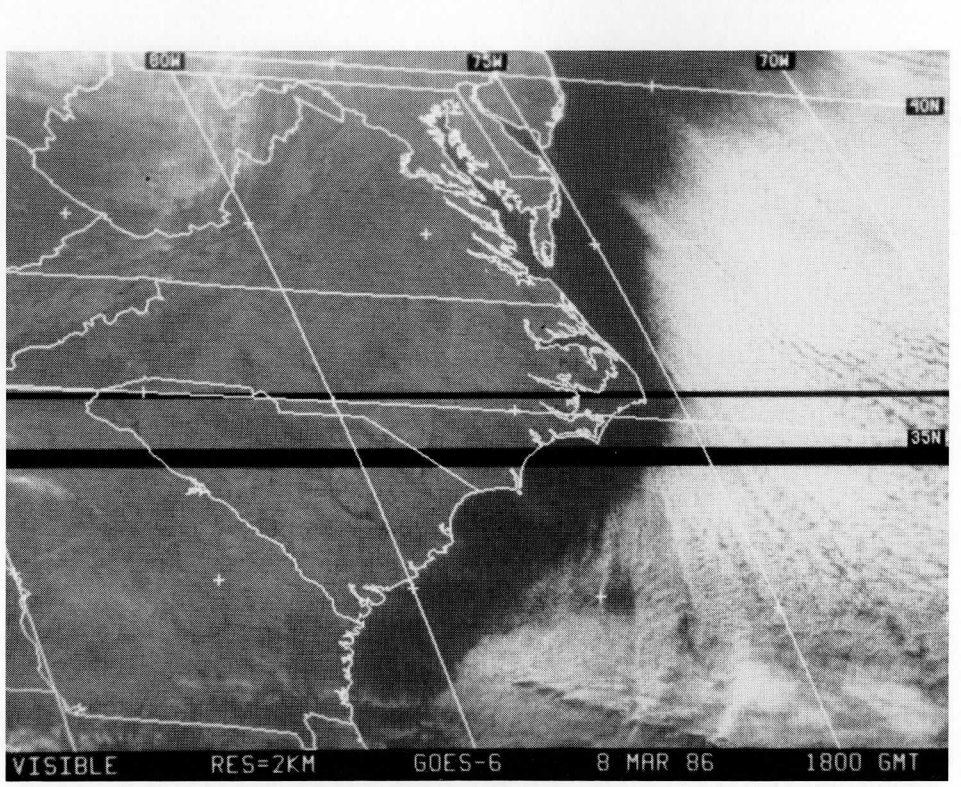
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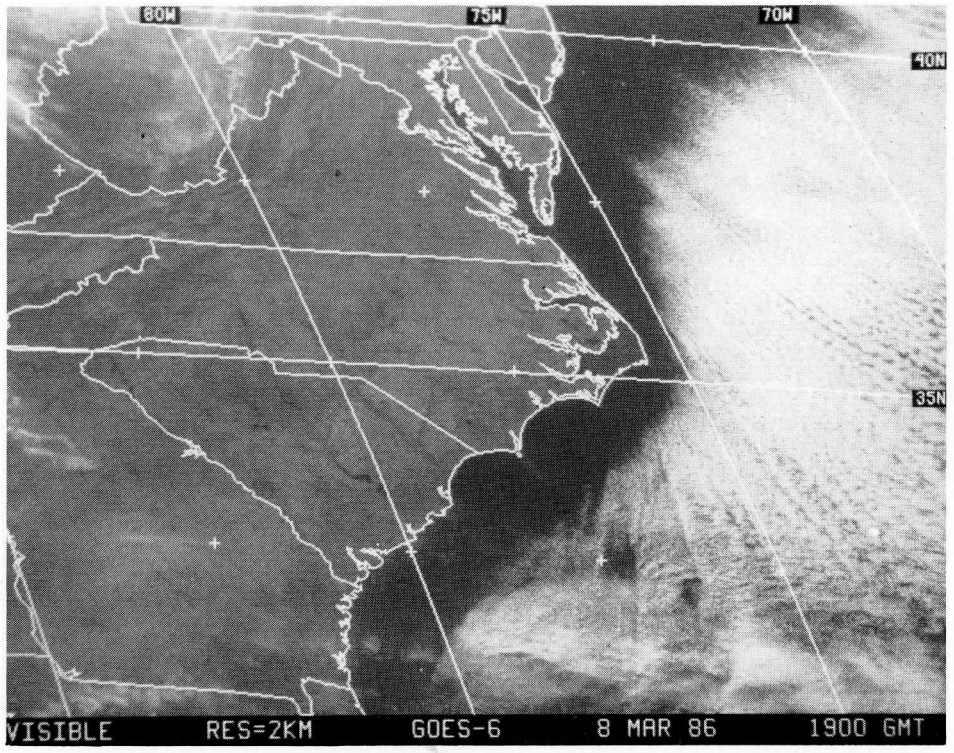
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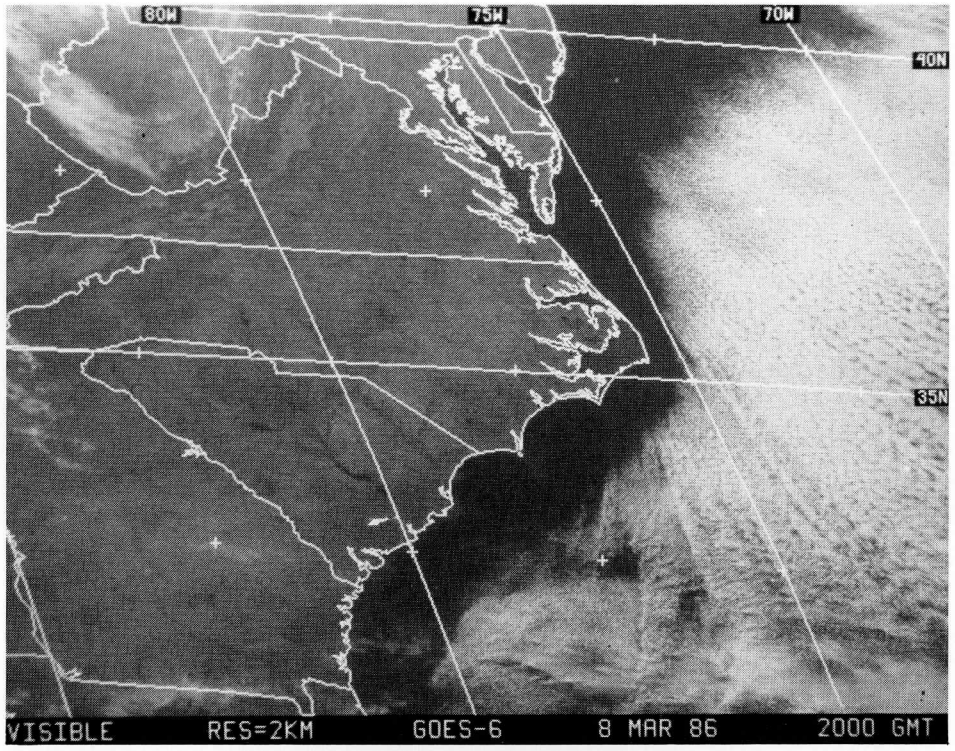
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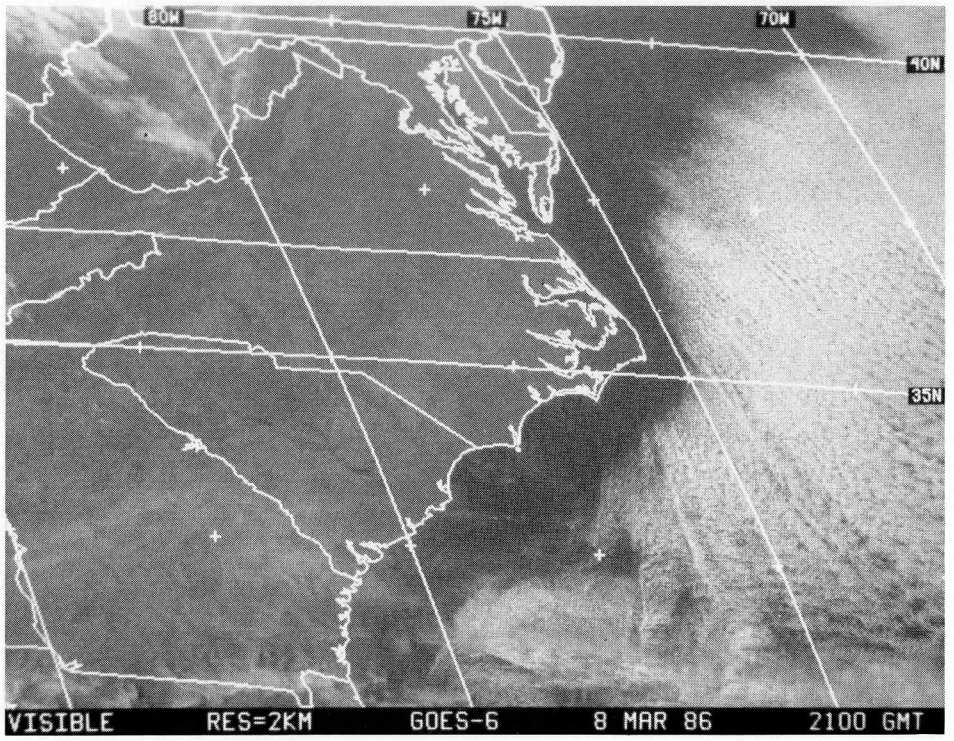
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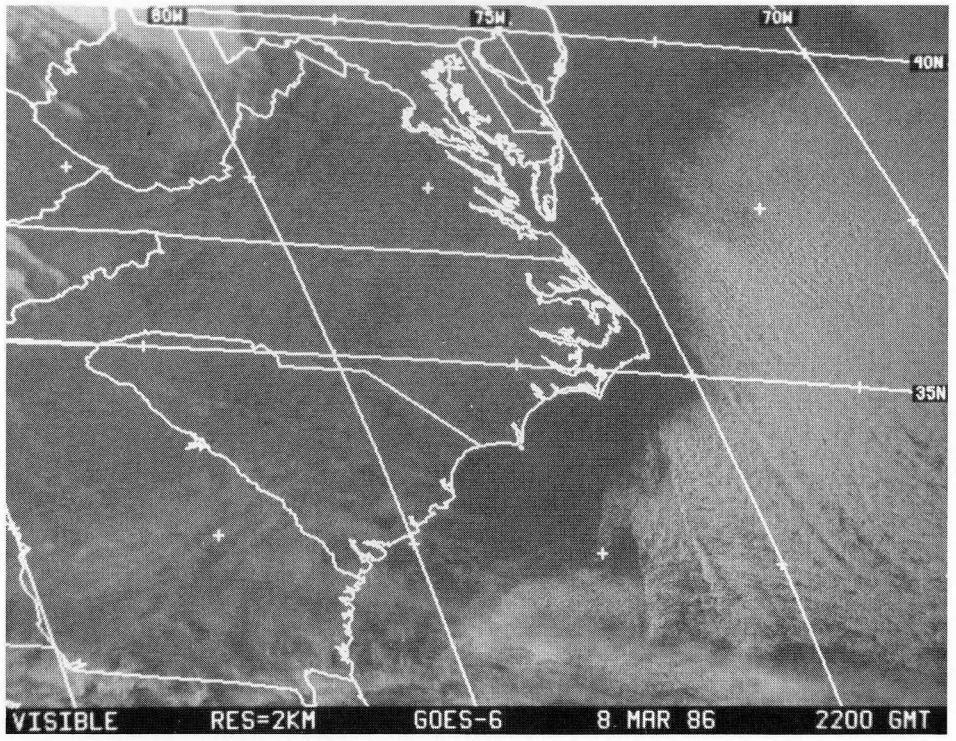
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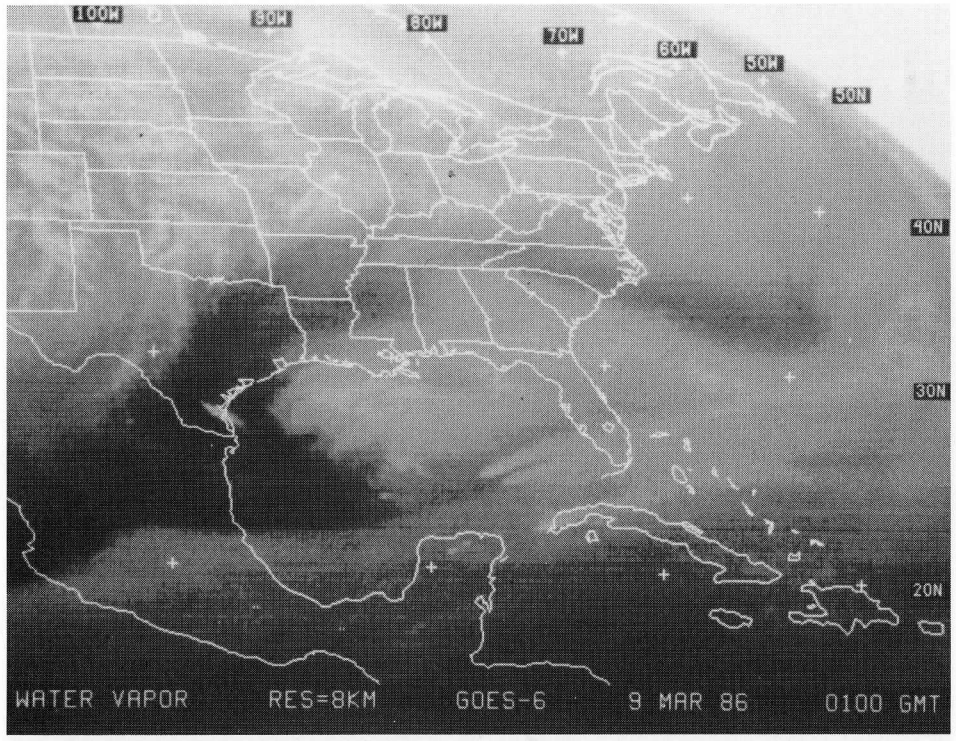
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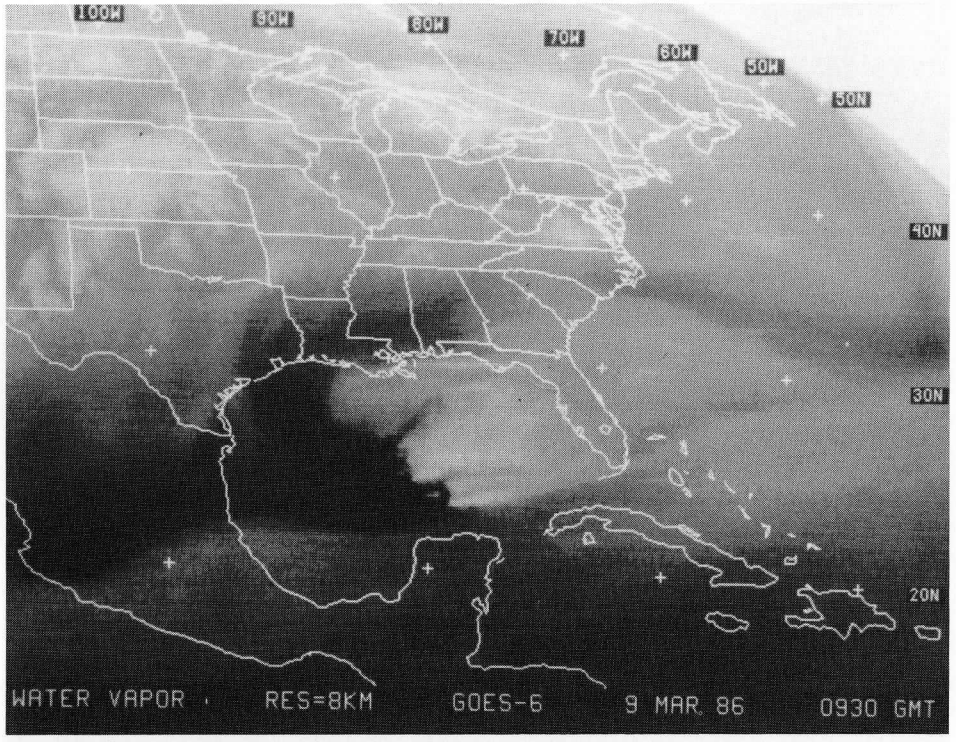
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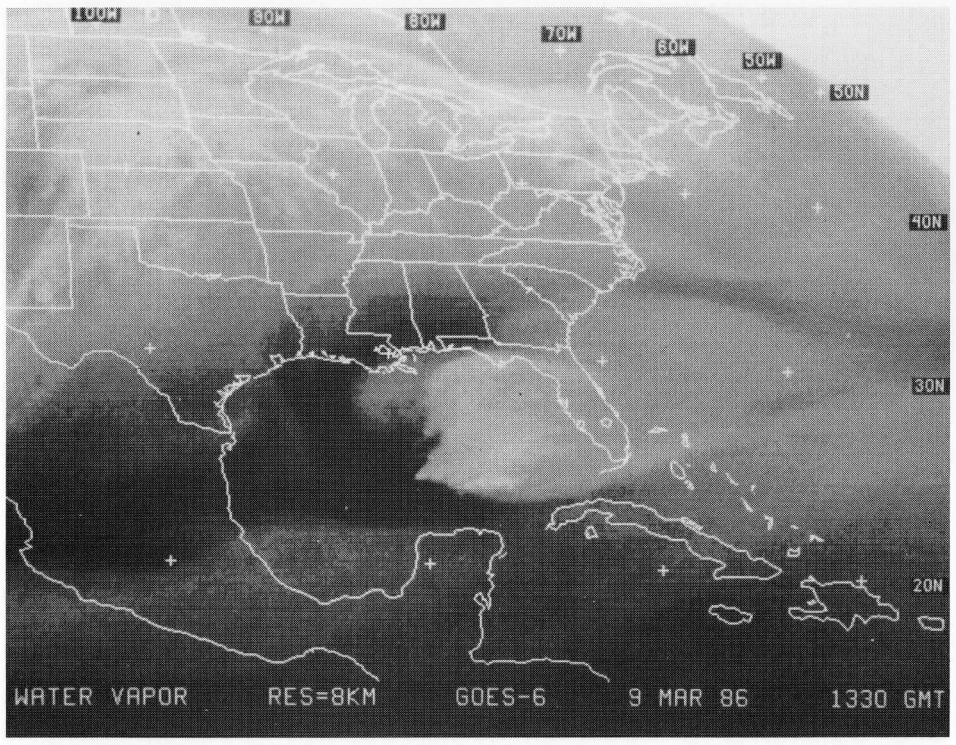
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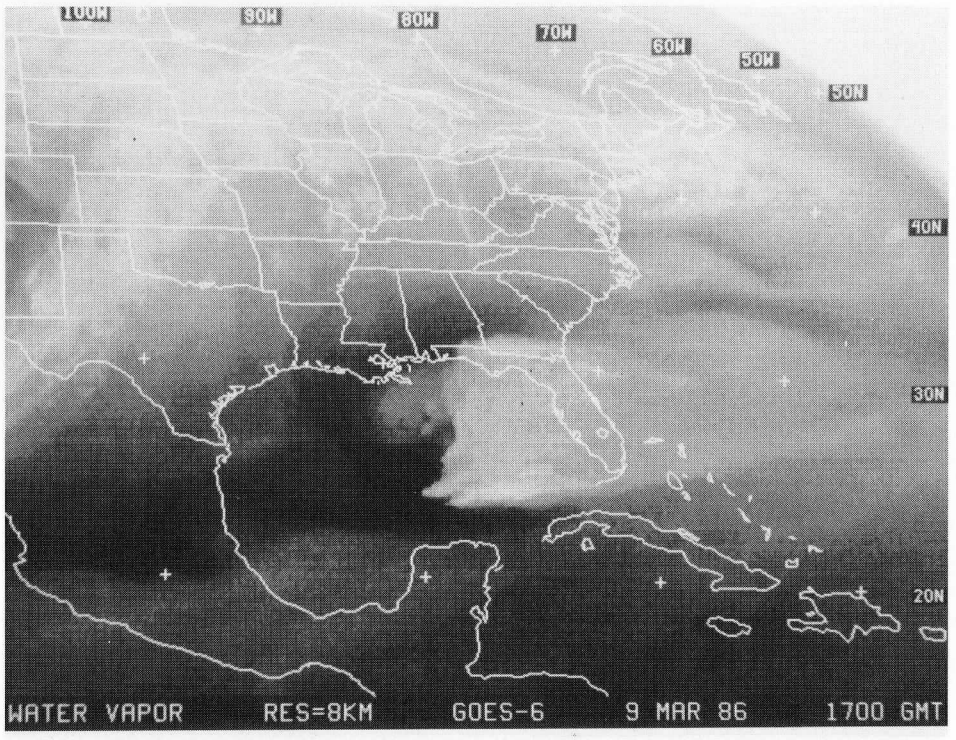
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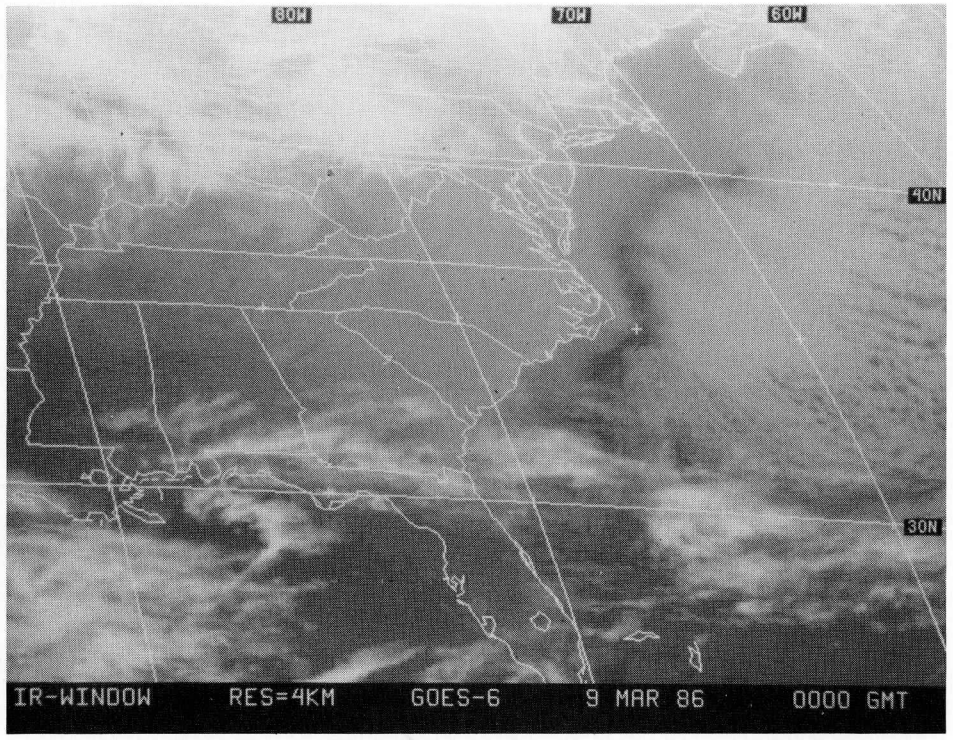
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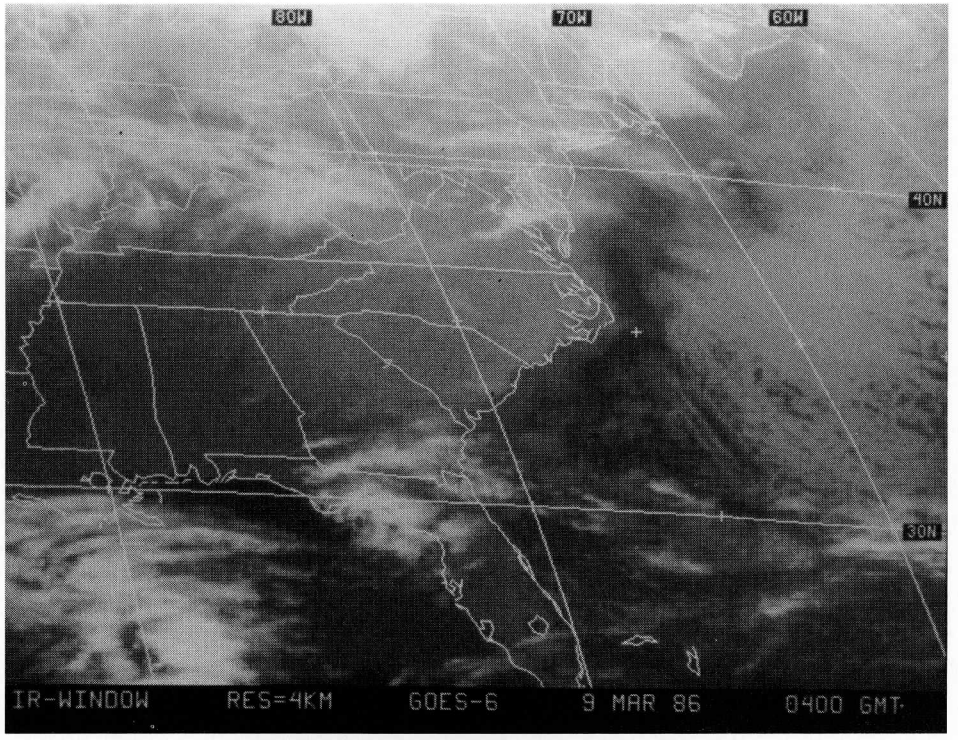
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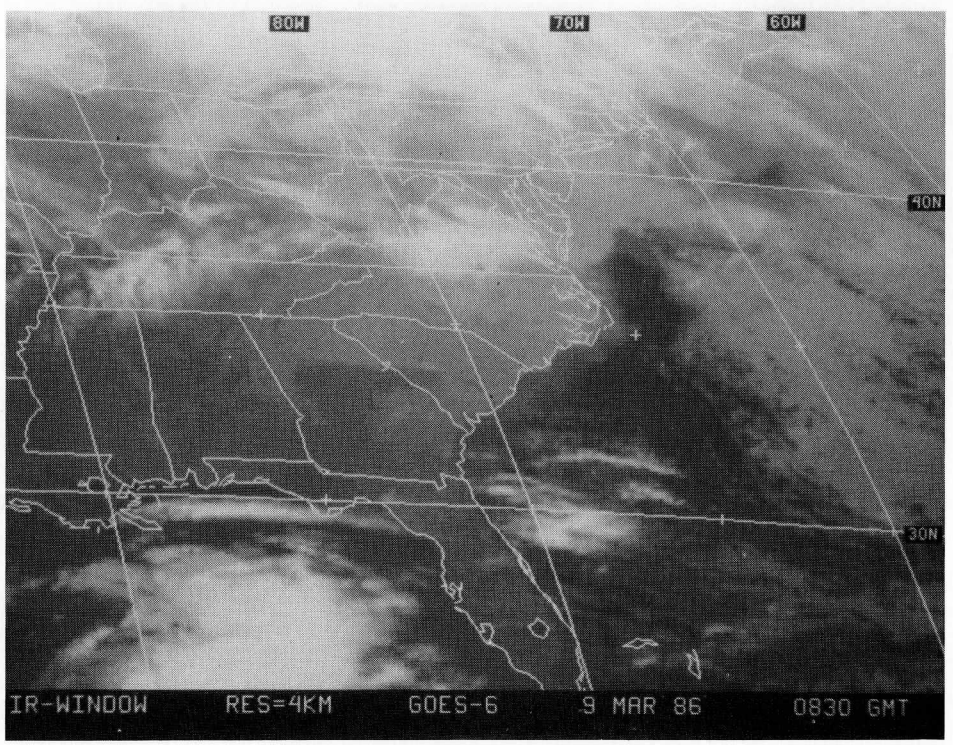
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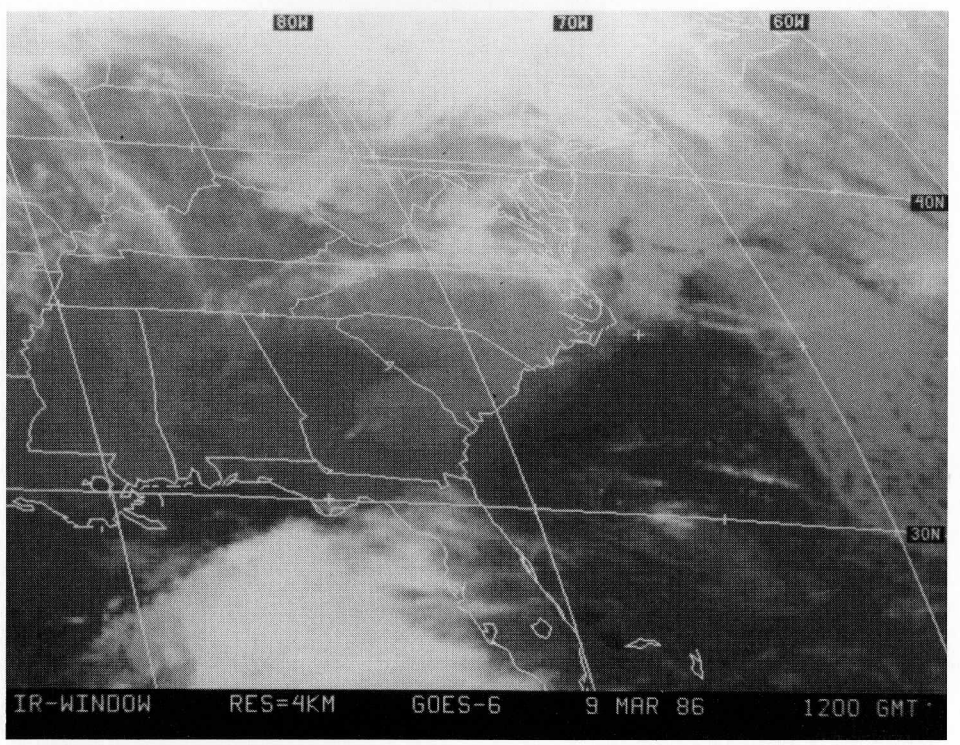
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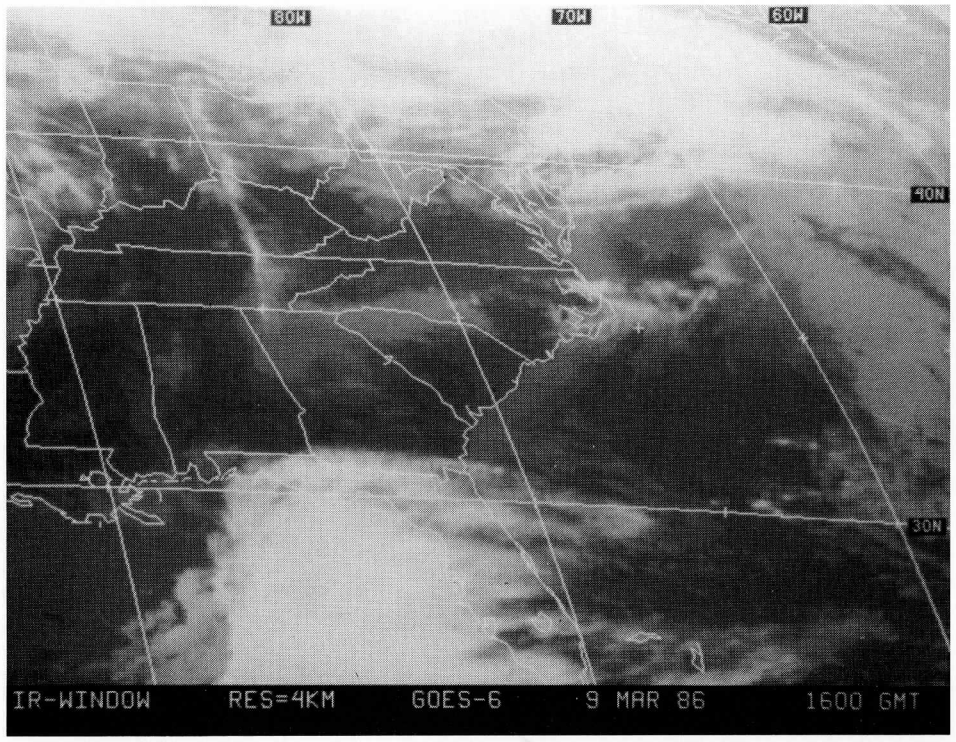
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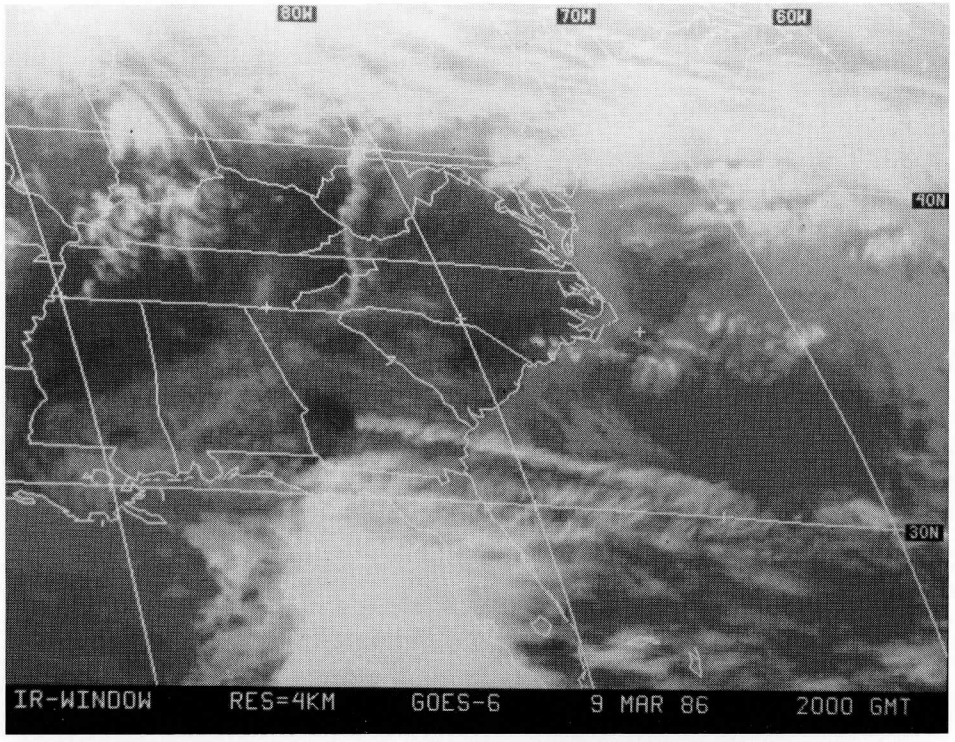
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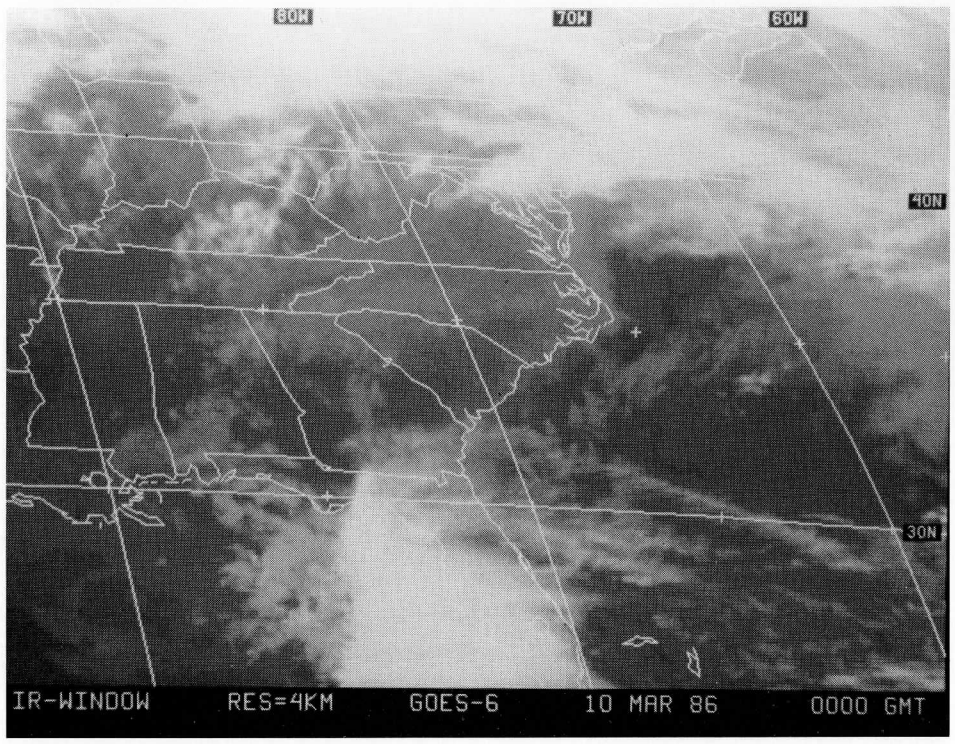
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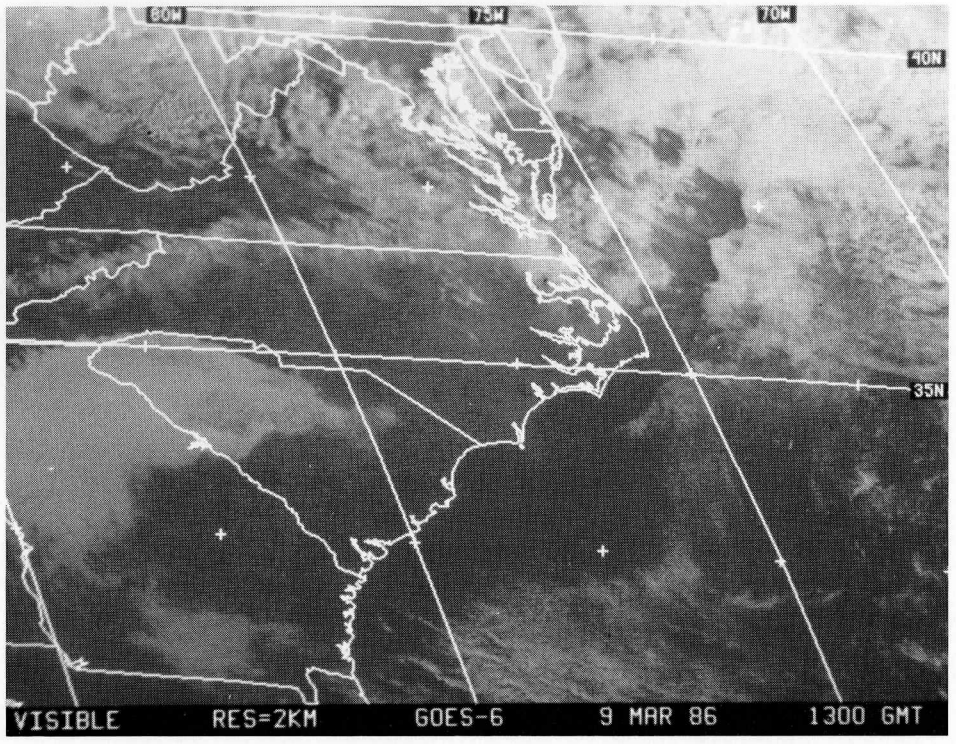
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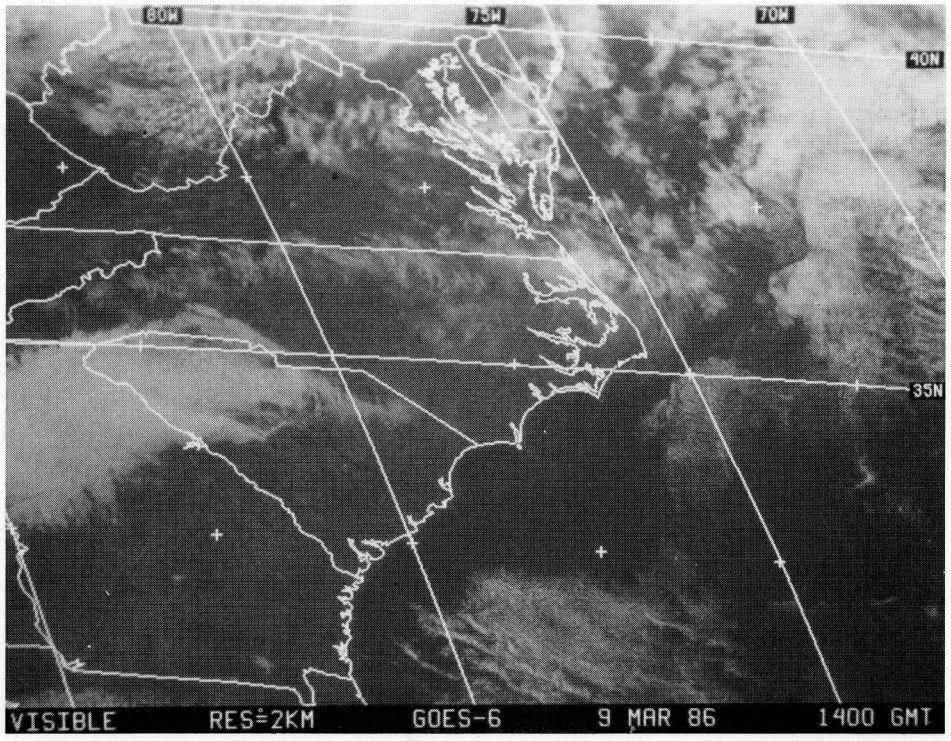
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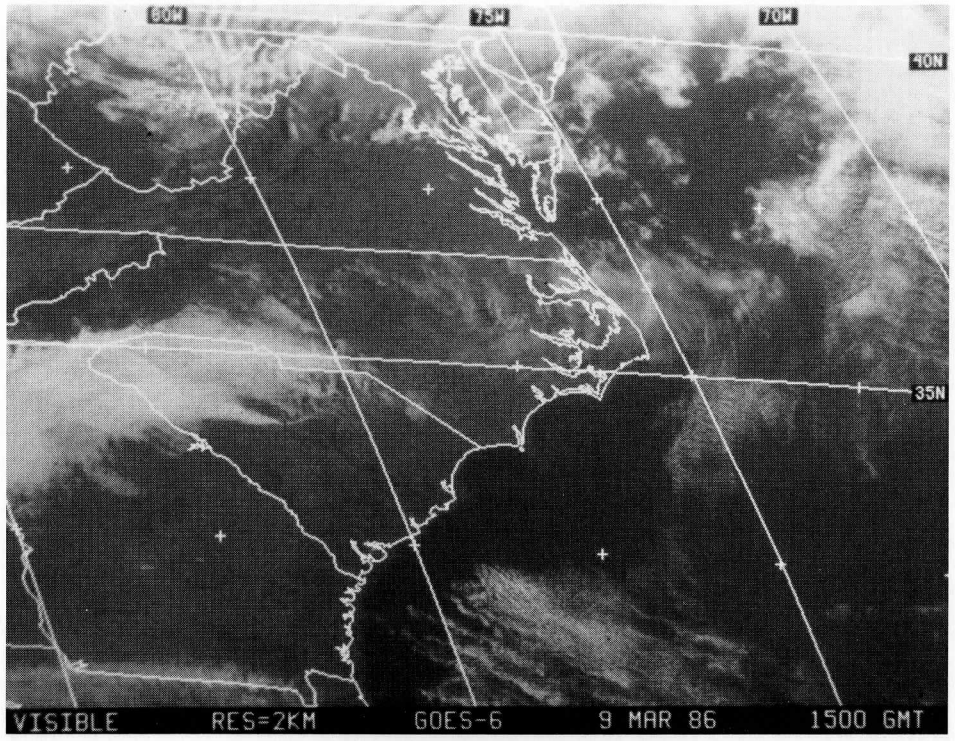
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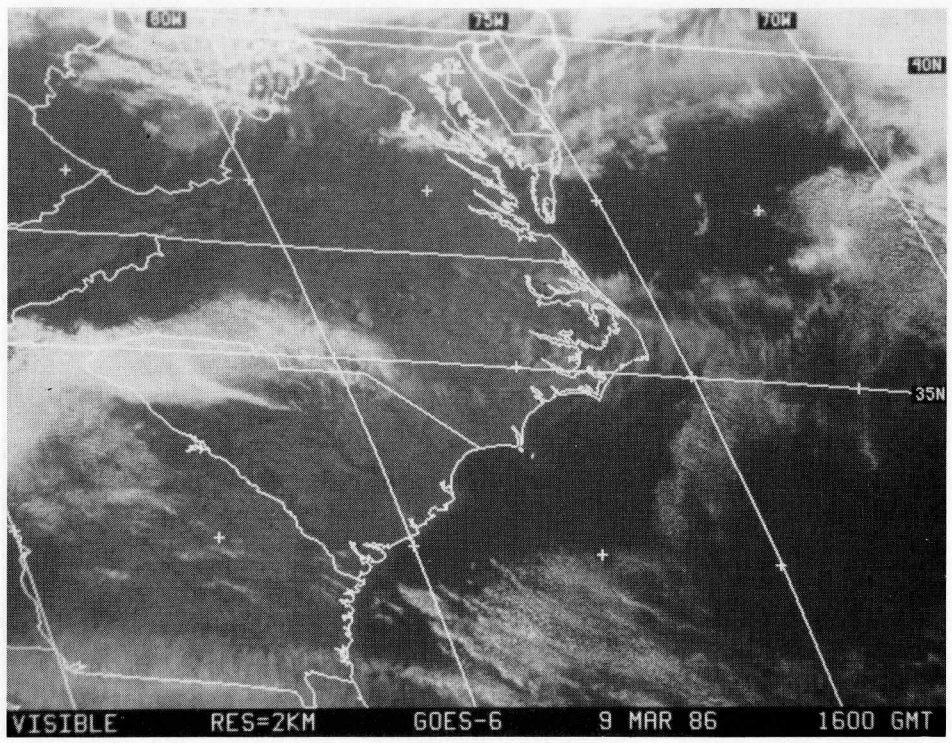
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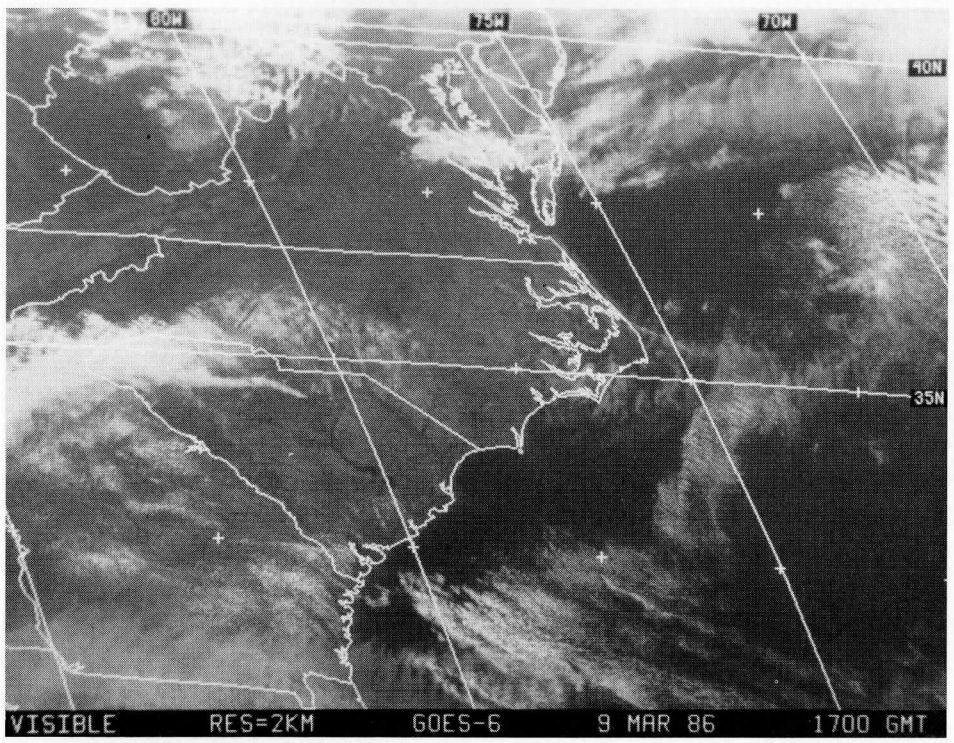
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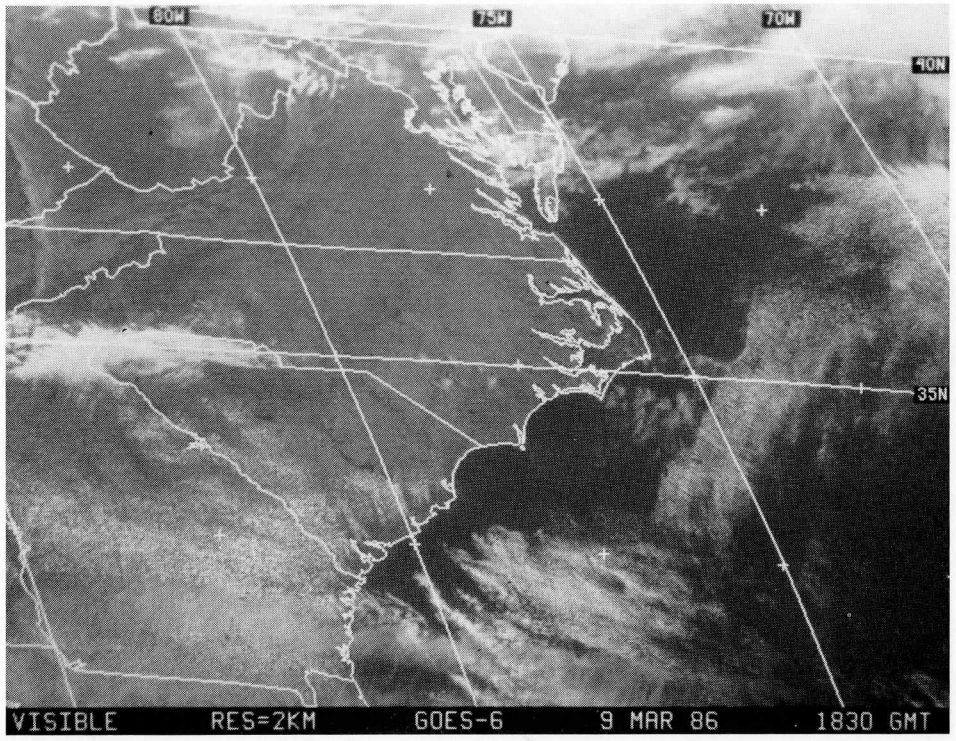
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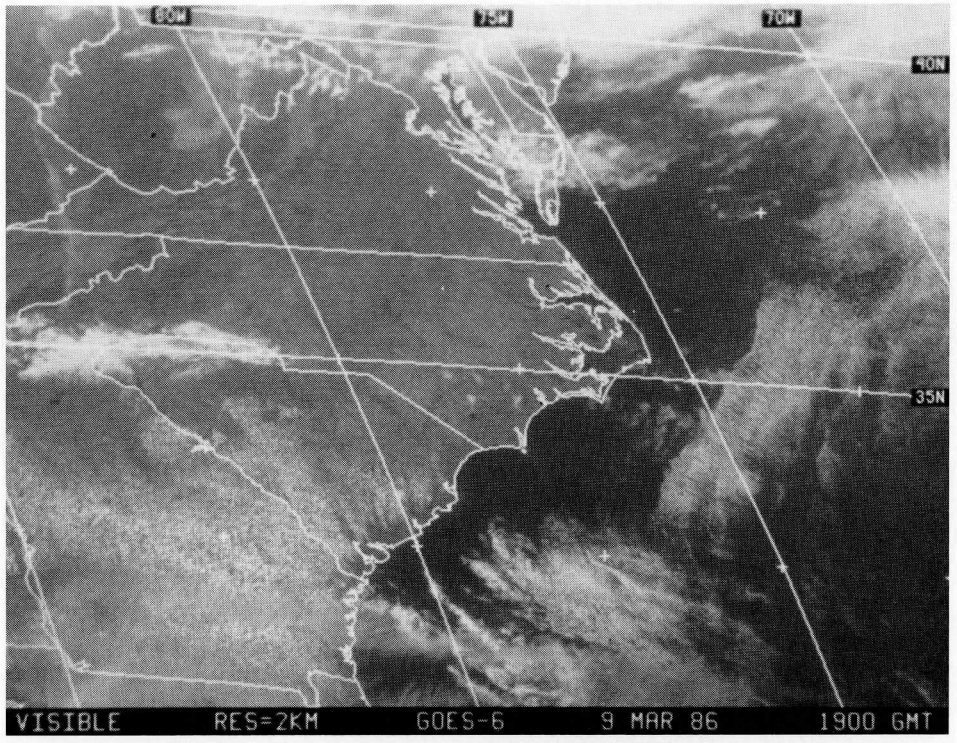
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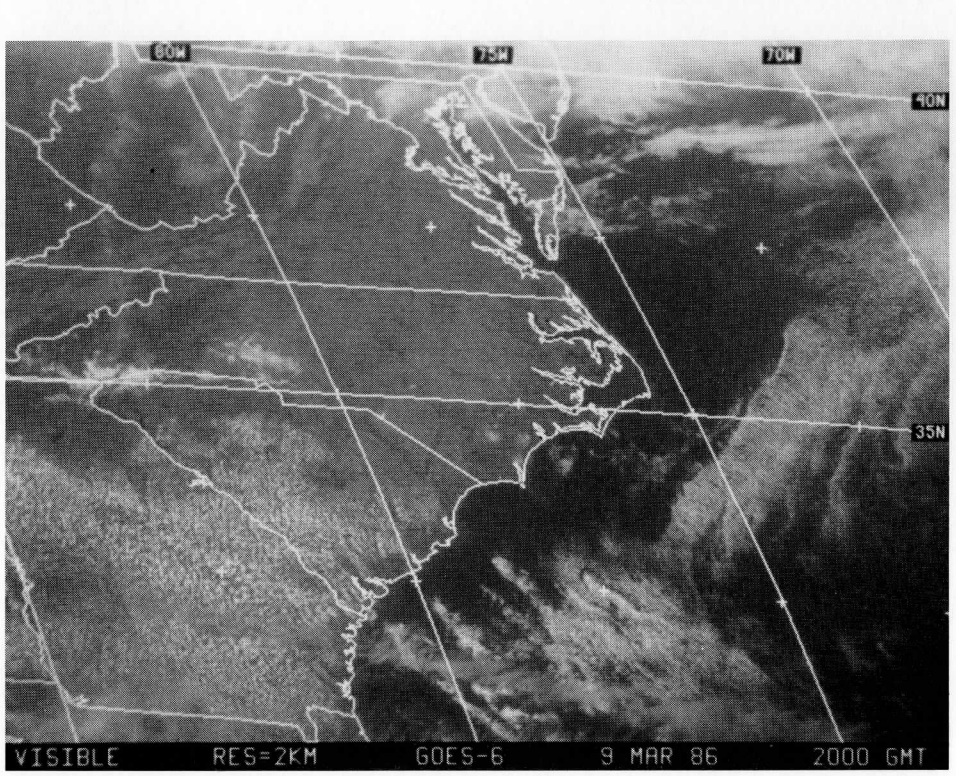
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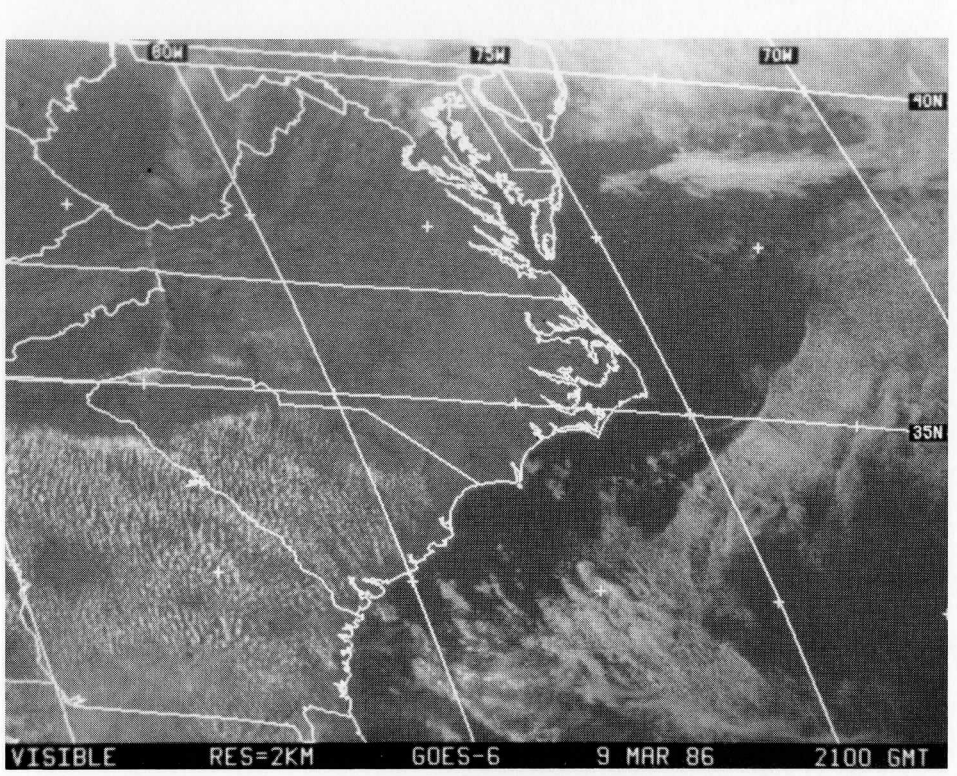
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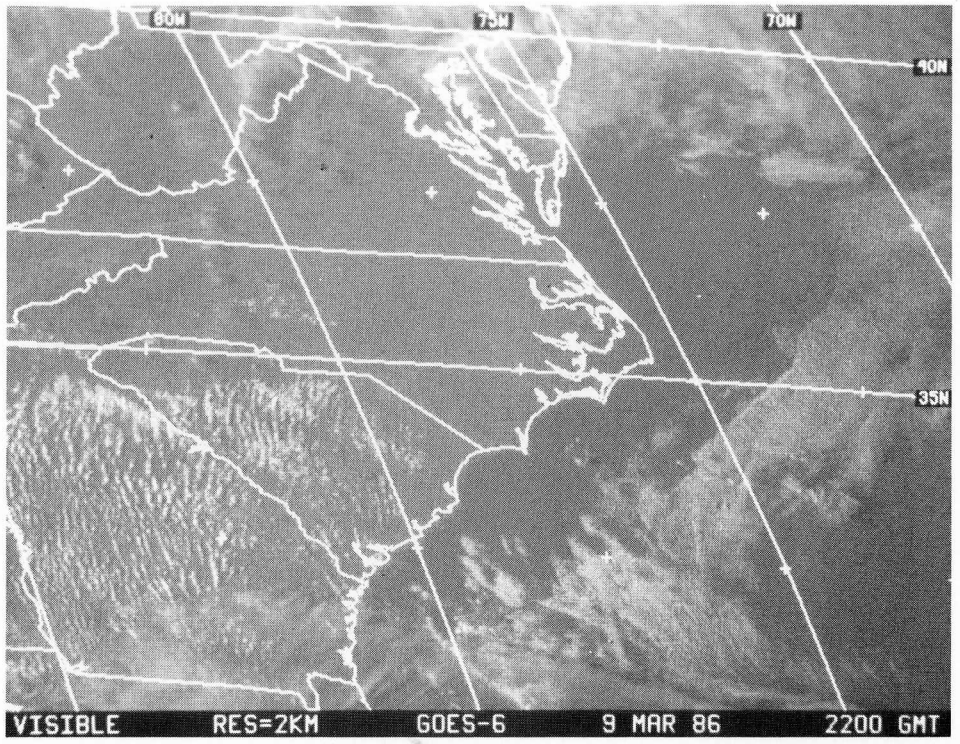


END OF IOP

IOP #13 - Coastal Front / Convectively Active Cyclogenesis
March 11 - March 15

Satellite Synopsis

Water Vapor

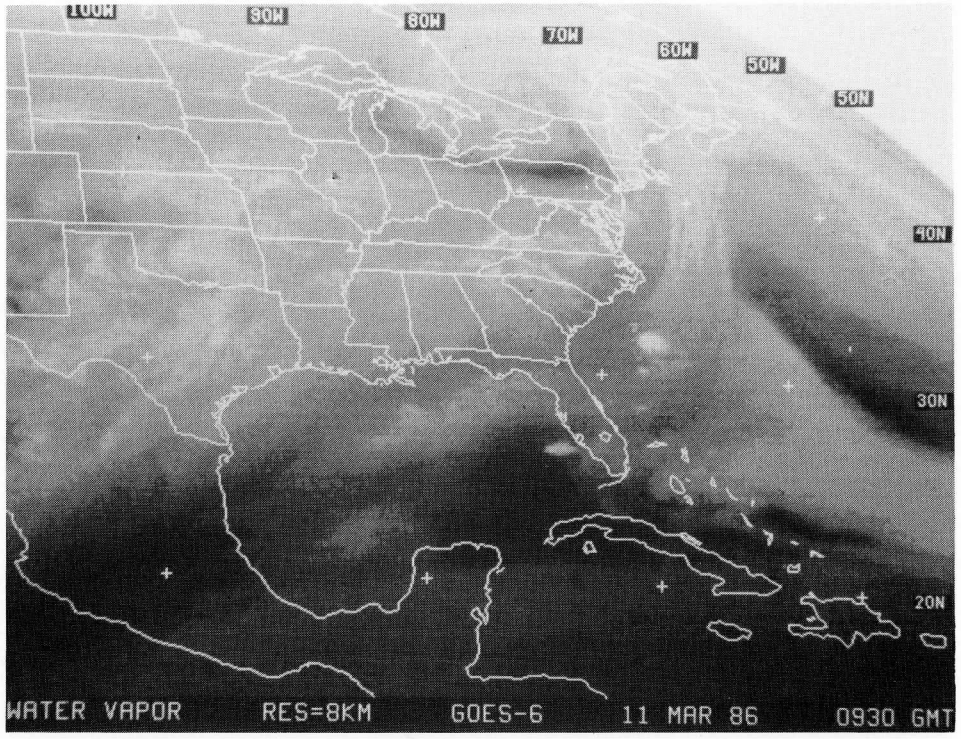
- Limited water vapor data due to RISOP mode.
- 11th, thunderstorms over the Gulf Stream.
- 11th, strong moisture structure to east of GALE region.
- 11th, wave/circulation in Texas panhandle.
- 11th, wave/circulation northwest of Maine.
- 15th, thunderstorms in the Gulf of Mexico.

IR

- 11th, thunderstorms over Gulf Stream off North Carolina dissipate.
- 12th, strong thunderstorms quickly develop at 20 GMT and dissipate by 00 GMT on the 13th.
- 13th, very strong squall line moves in from the Mississippi Valley and develops south into the Gulf.
- 14th, two separate thunderstorm lines.
- 14th, wave wraps up over the Ohio valley.

Visible

- 11th, many cloud features are evident:
  stratus features (lines);
  very distinct boundary off Delaware mid-day;
  wave clouds in West Virginia, Maryland, and Pennsylvania early in the day.
- Gulf Stream thunderstorms with impressive convergence lines and rope clouds.
- 12th, weak Gulf Stream convergence lines with some thunderstorms off the South Carolina coast late.
- 12th, sea breeze evident on Georgia, South Carolina coast and rapid convective development late.
- 14th, frontal thunderstorm line.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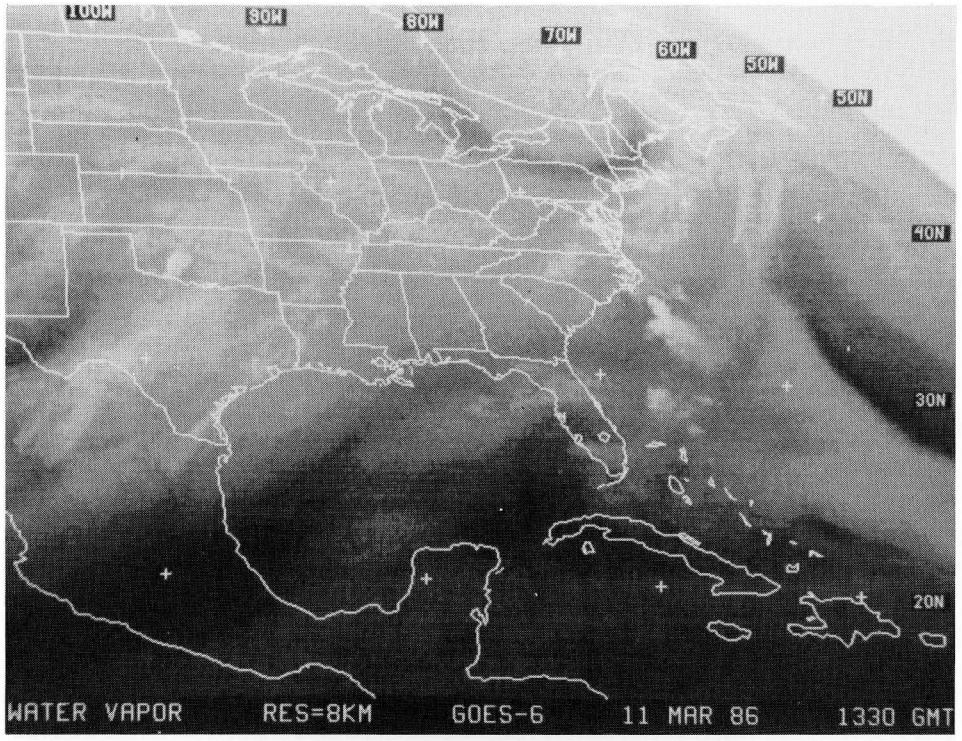
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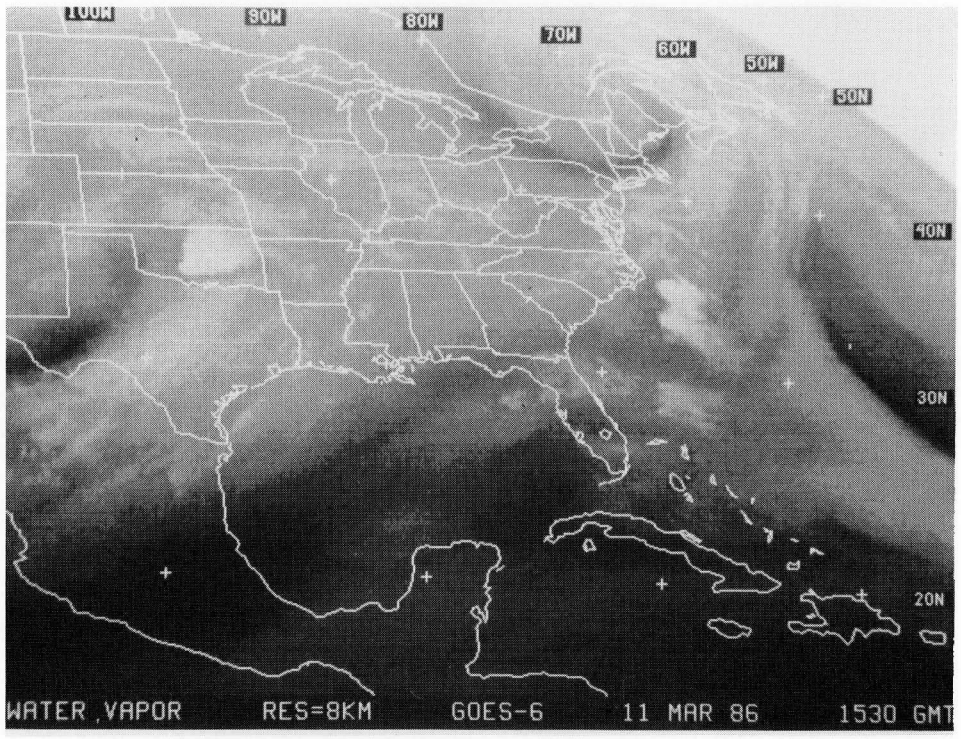
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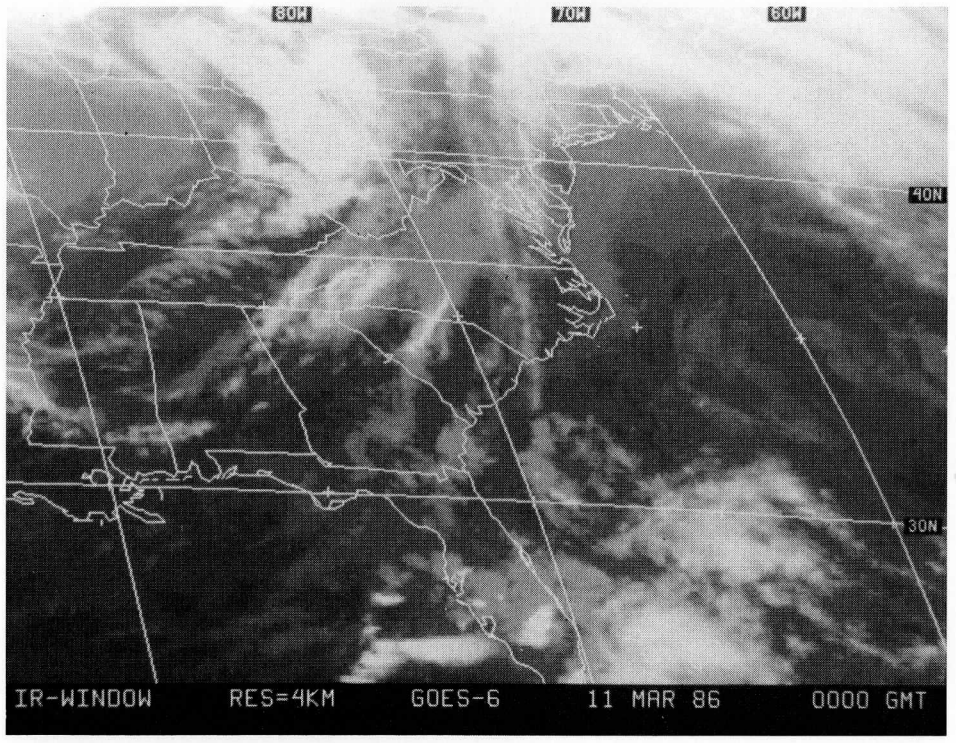
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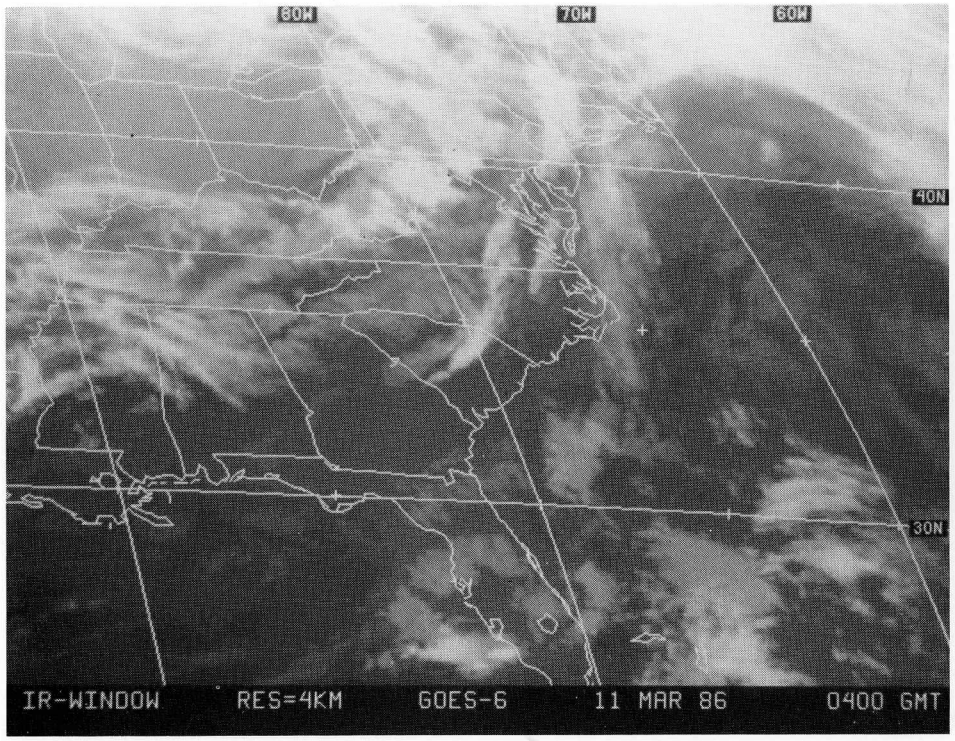
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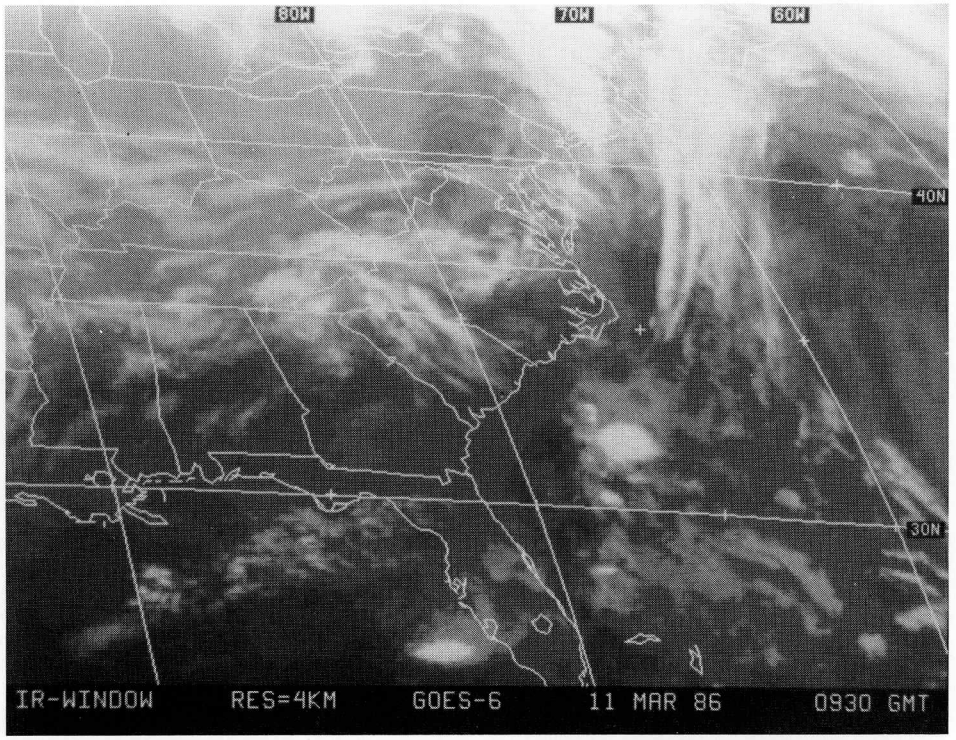
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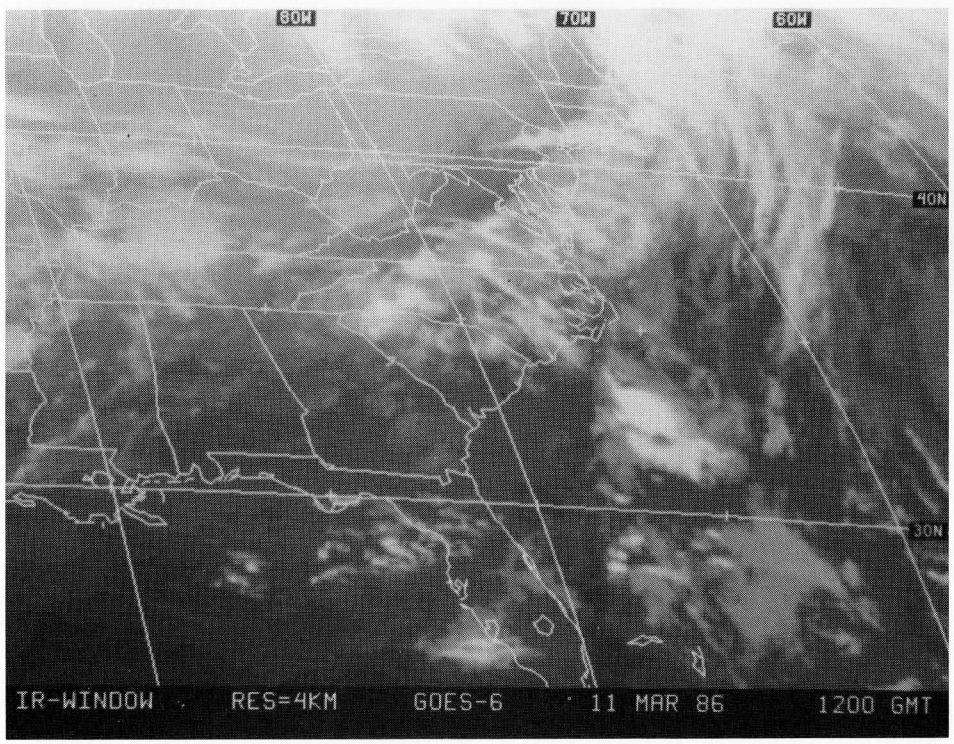
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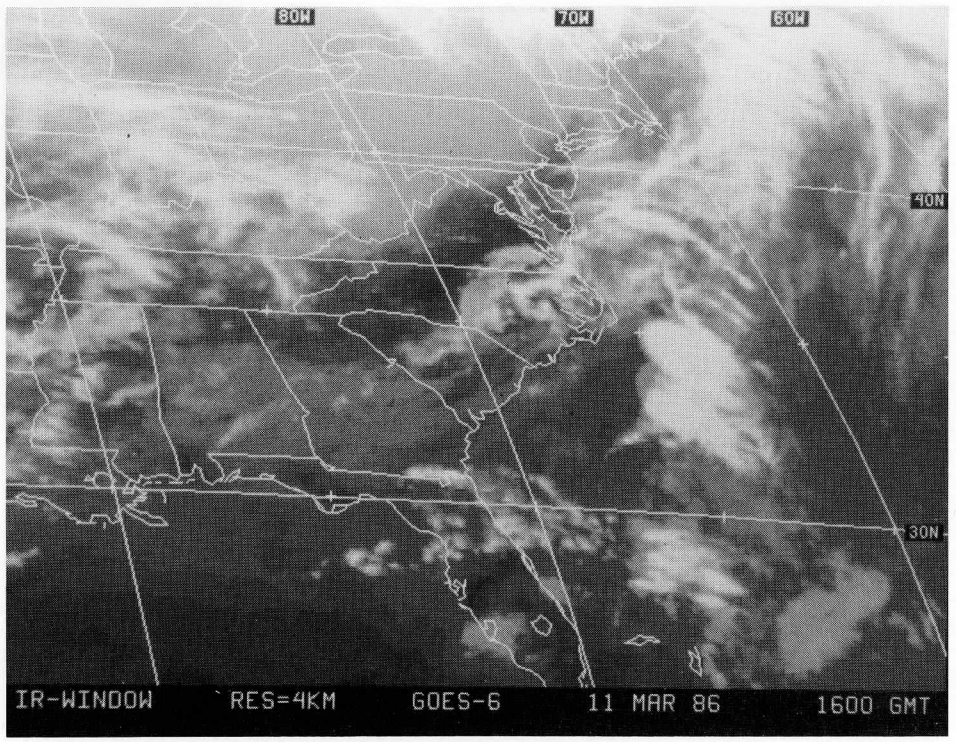
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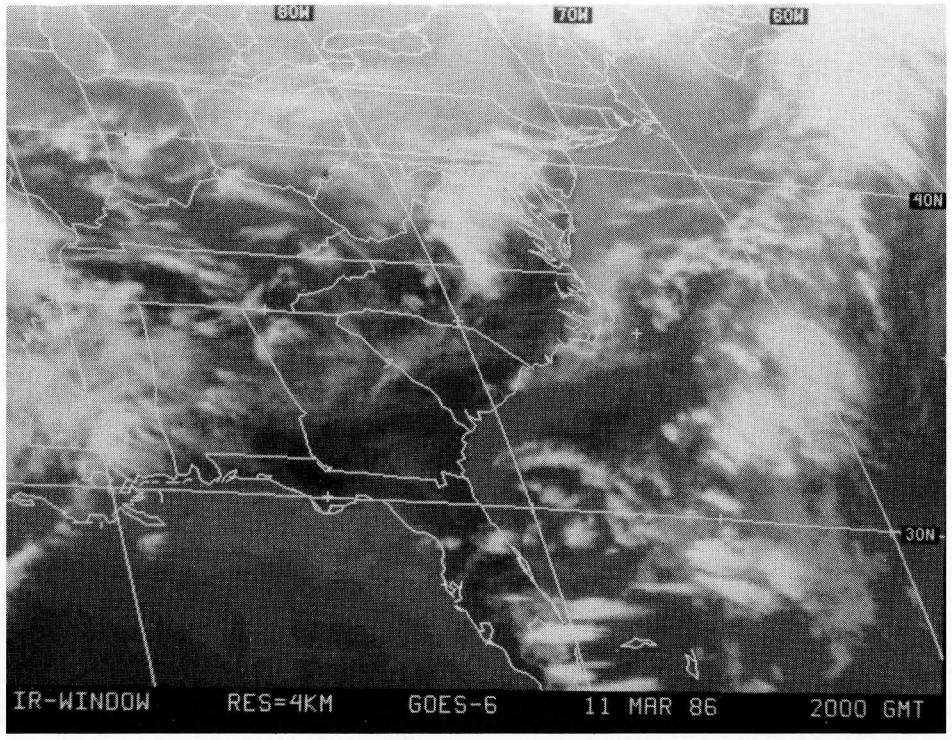
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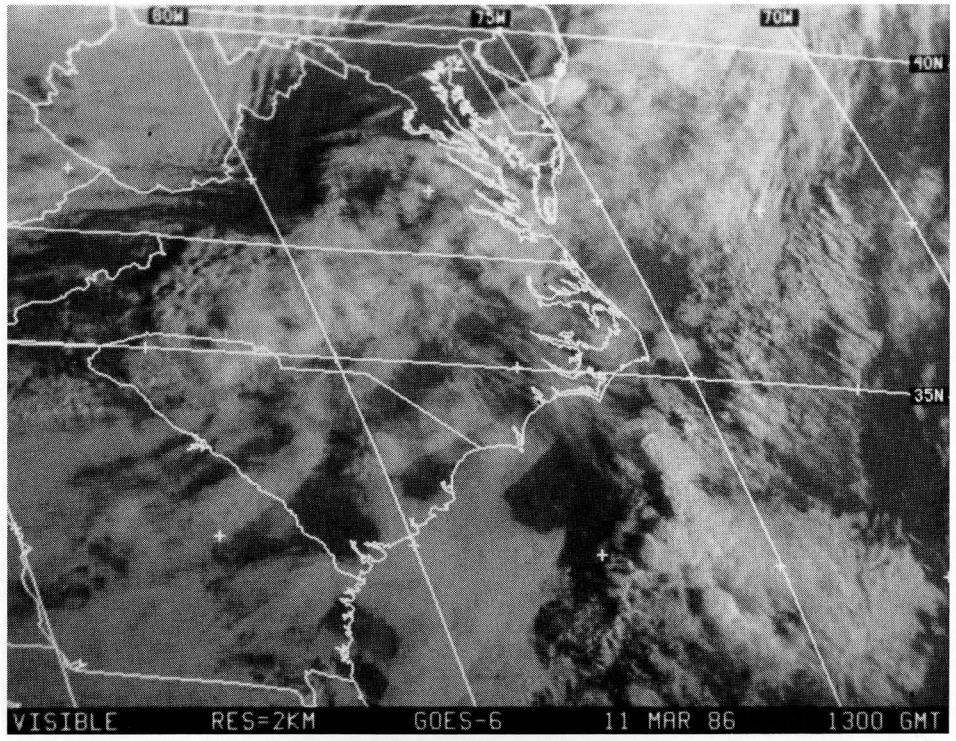
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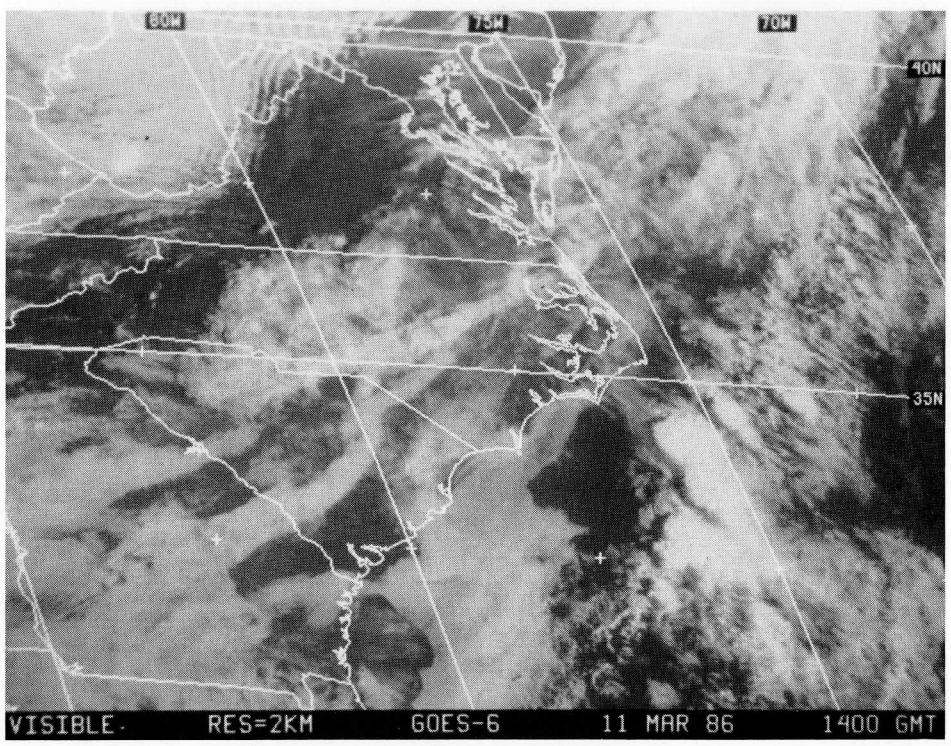
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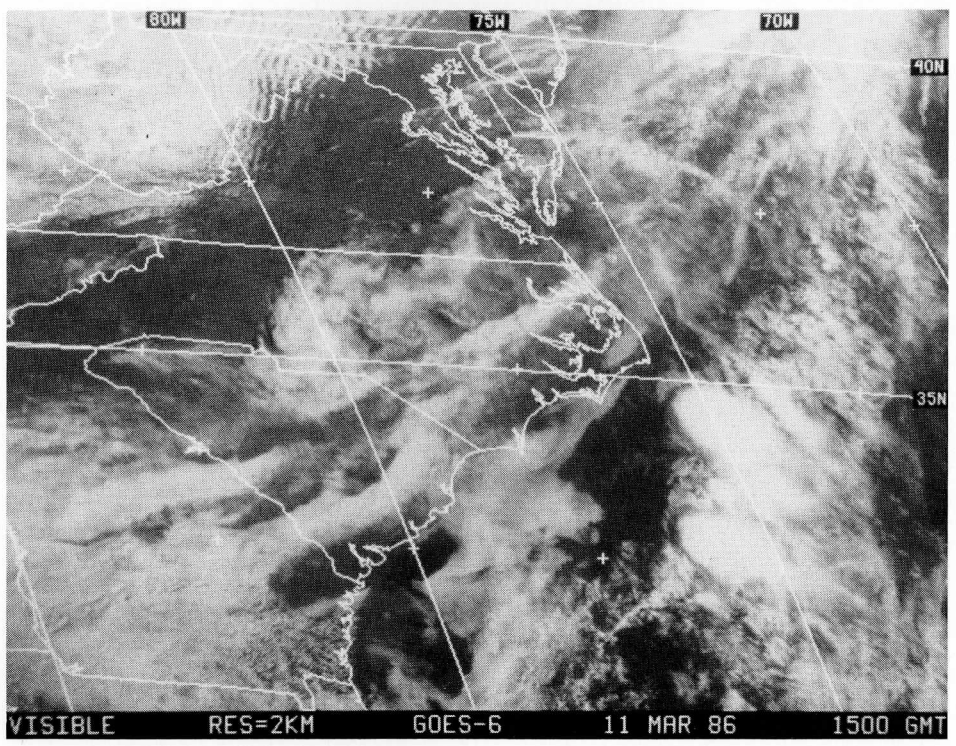
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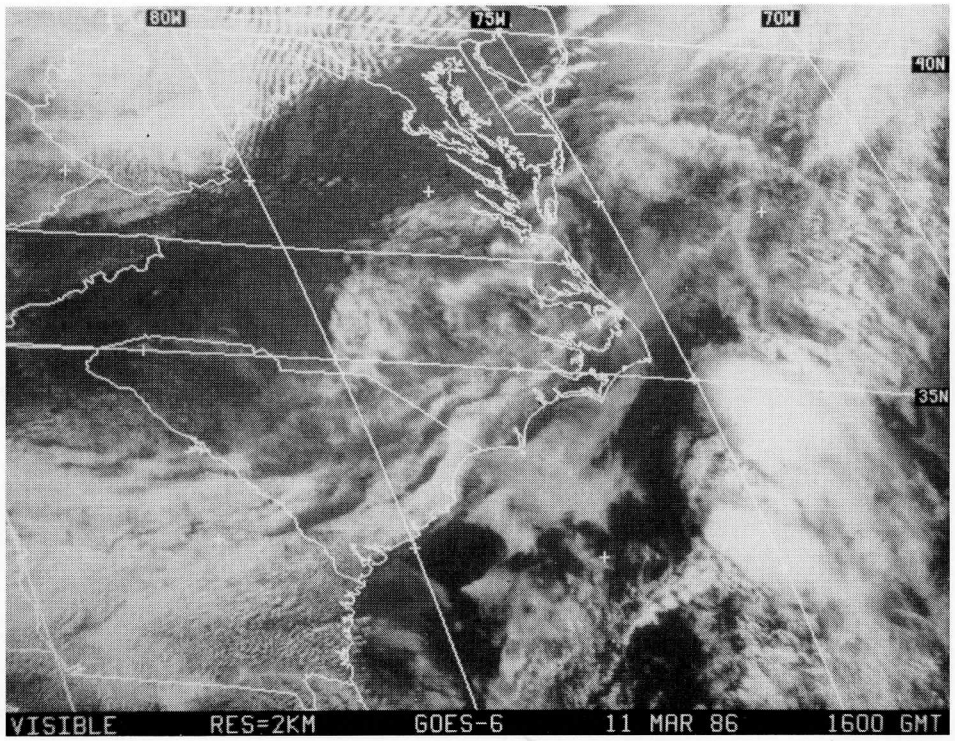
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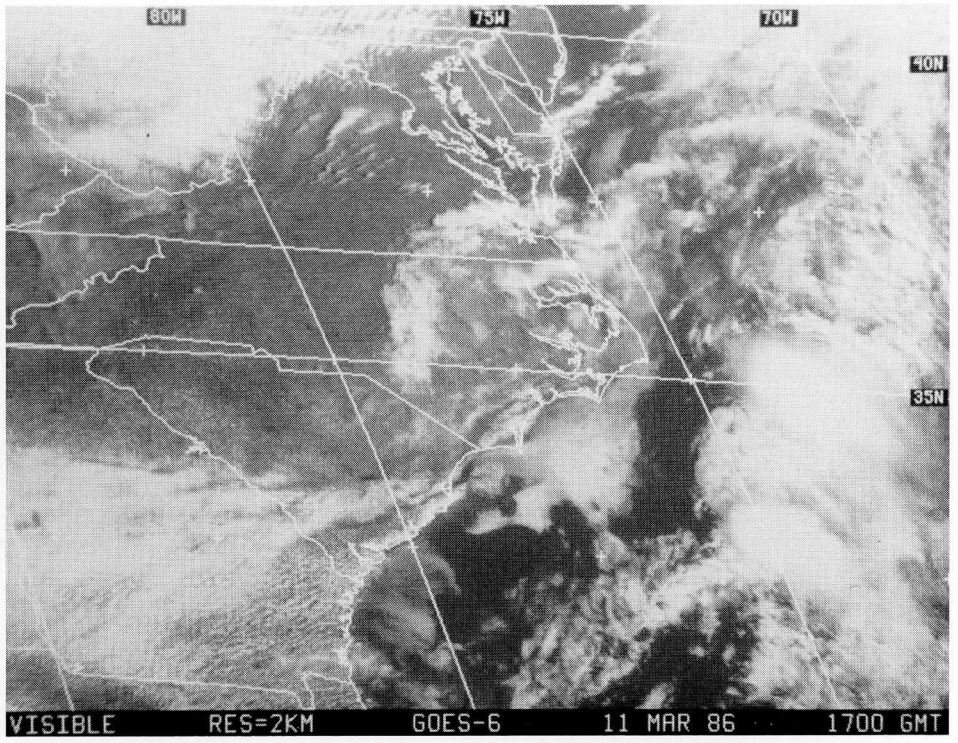
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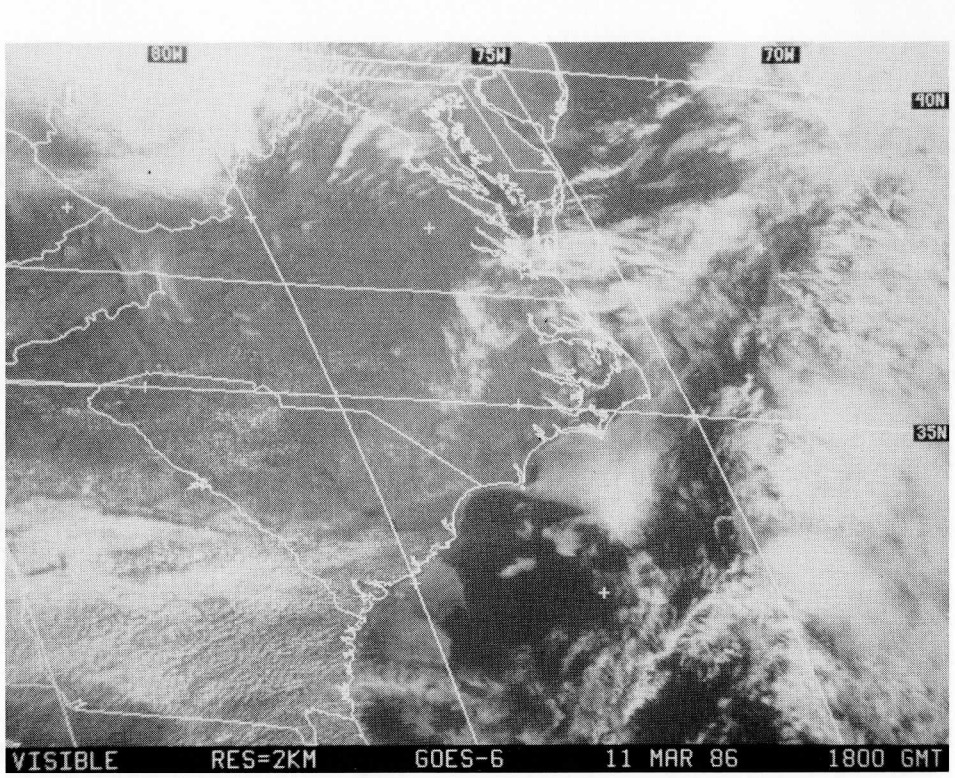
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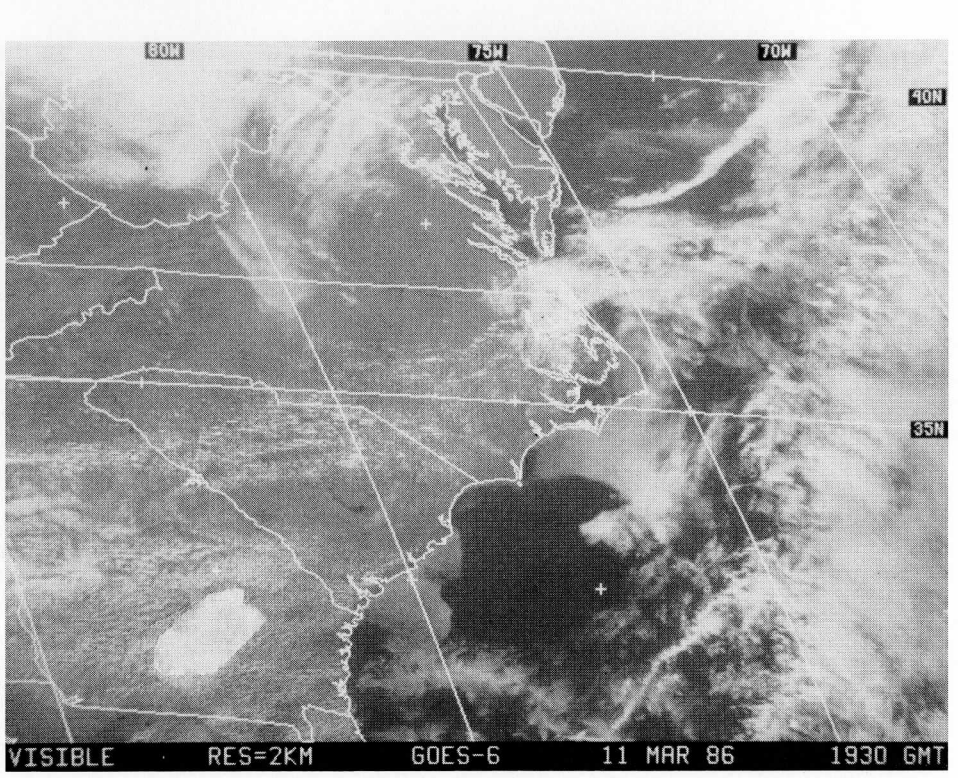
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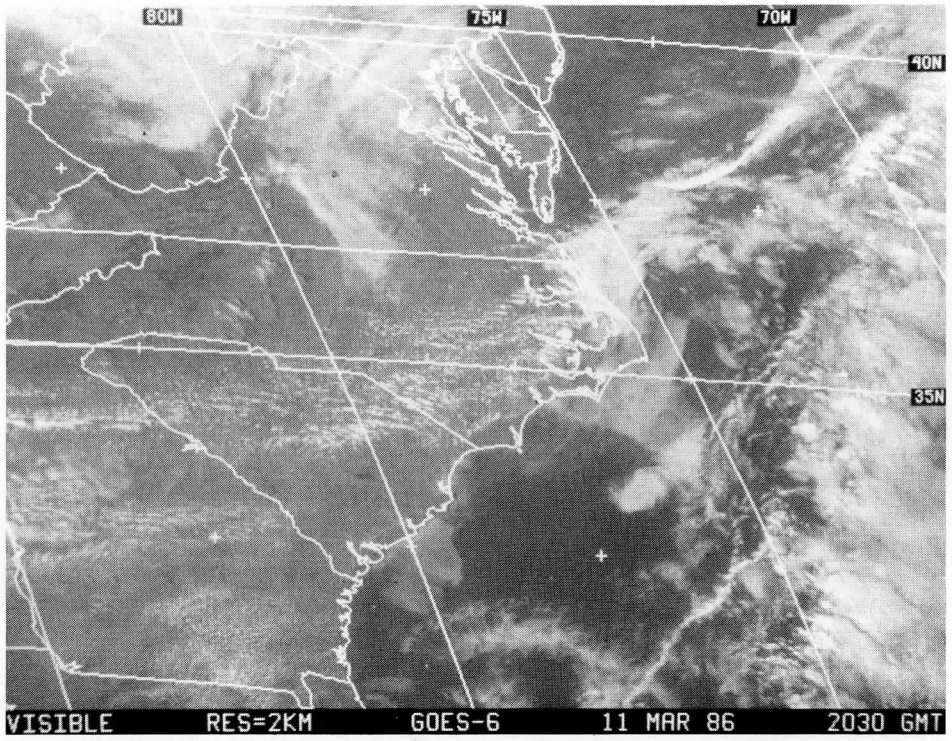
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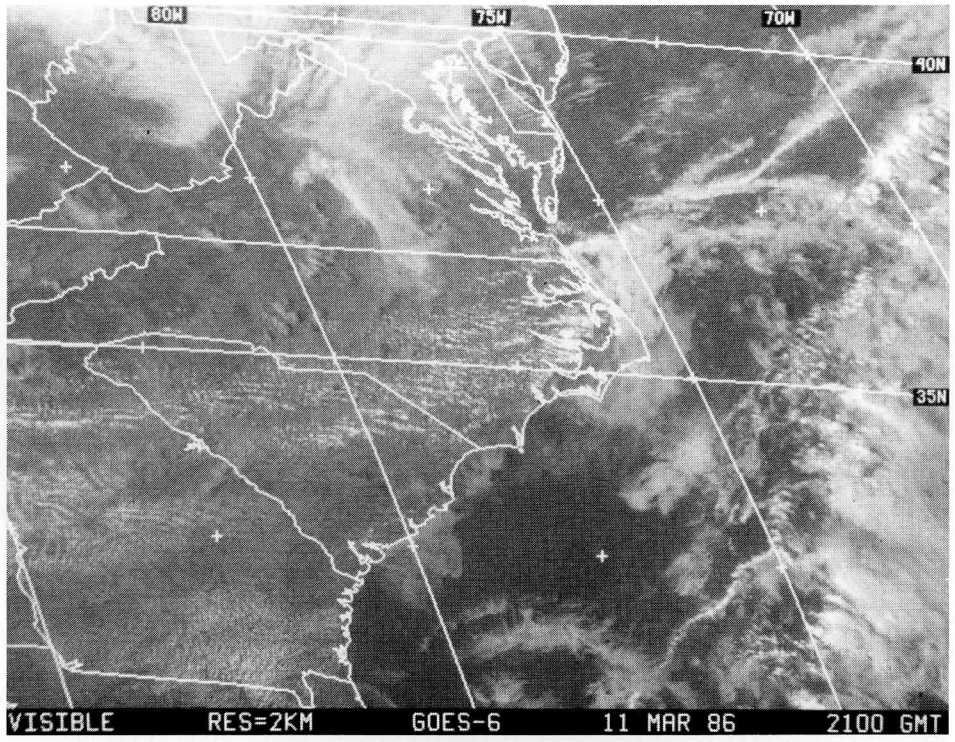
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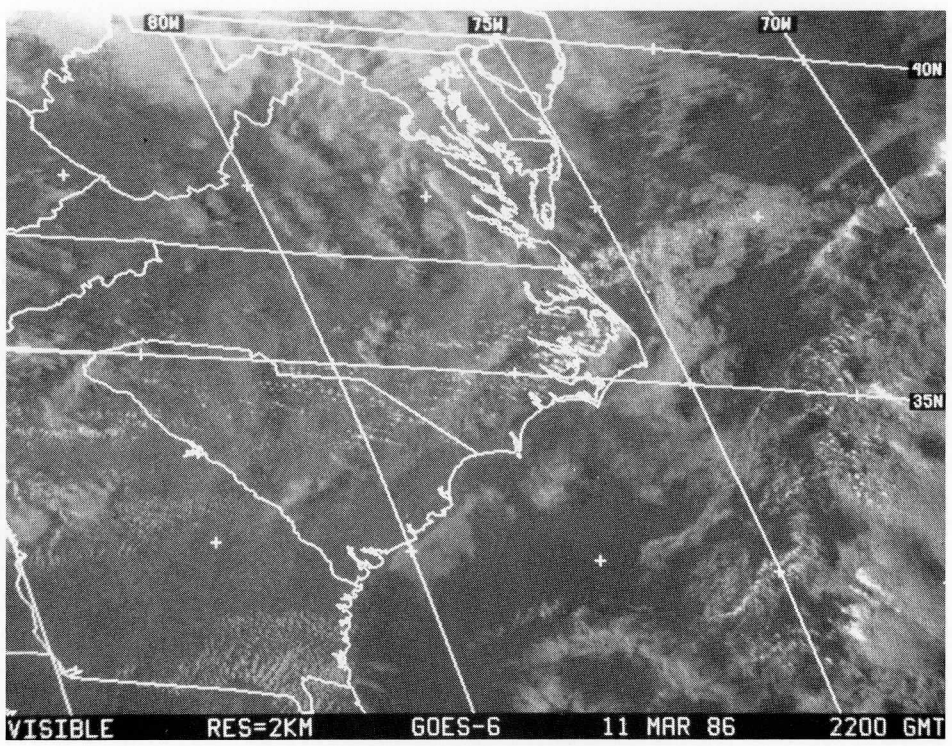
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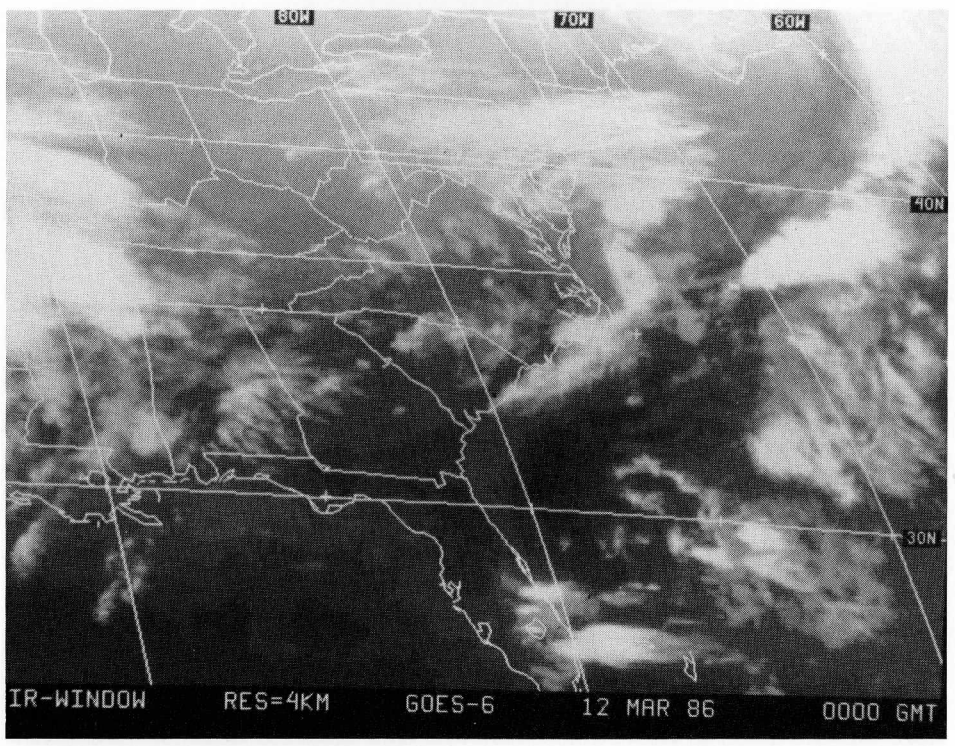
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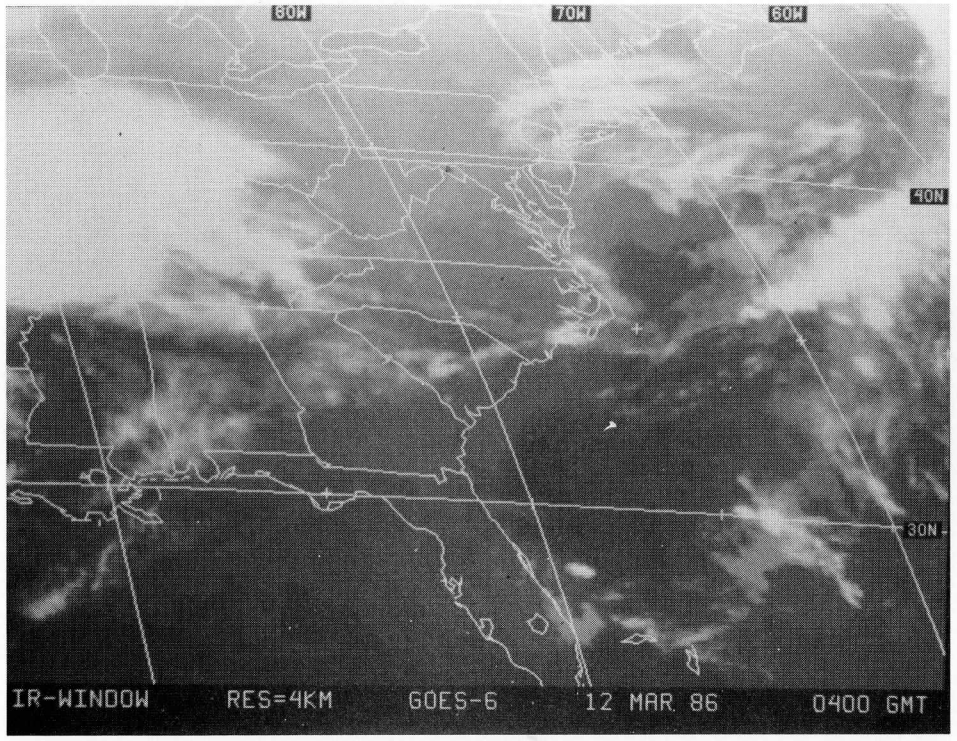
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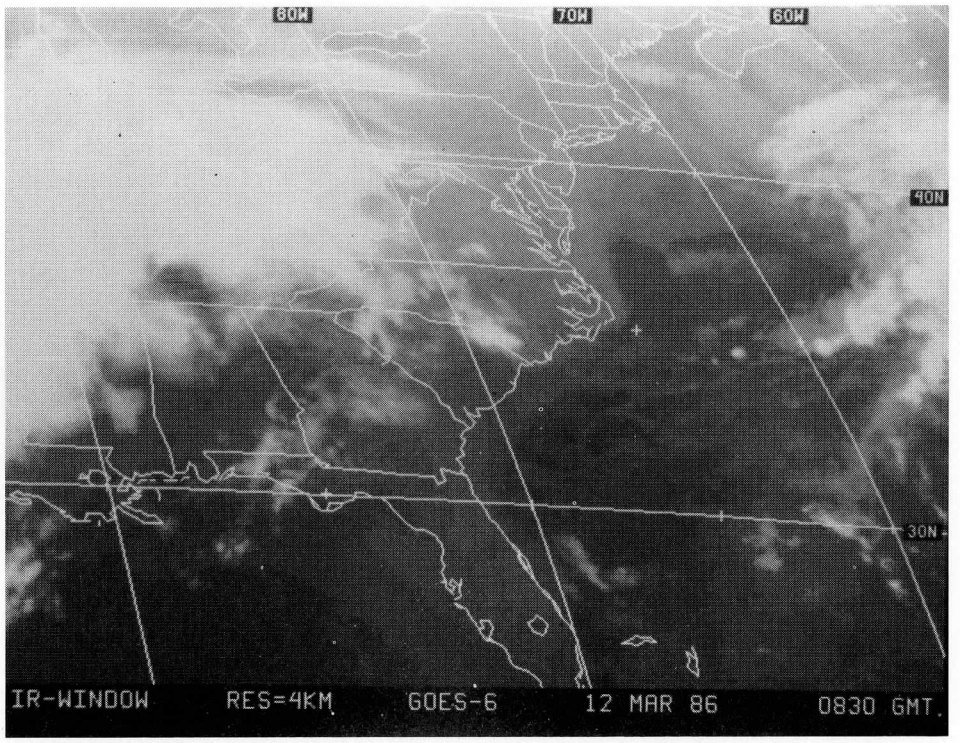
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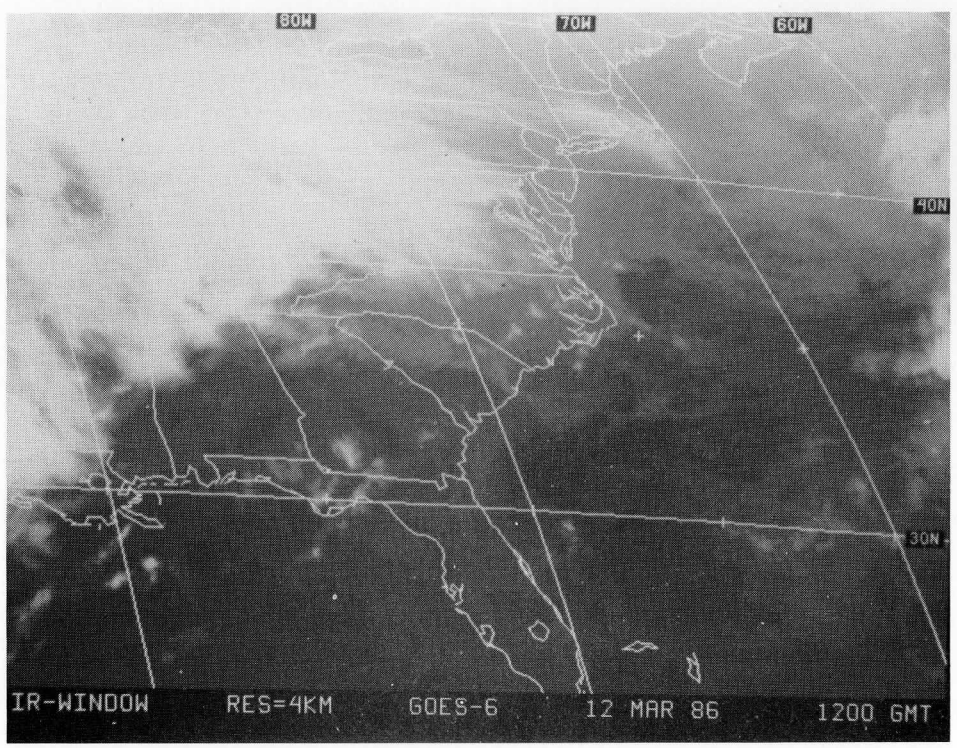
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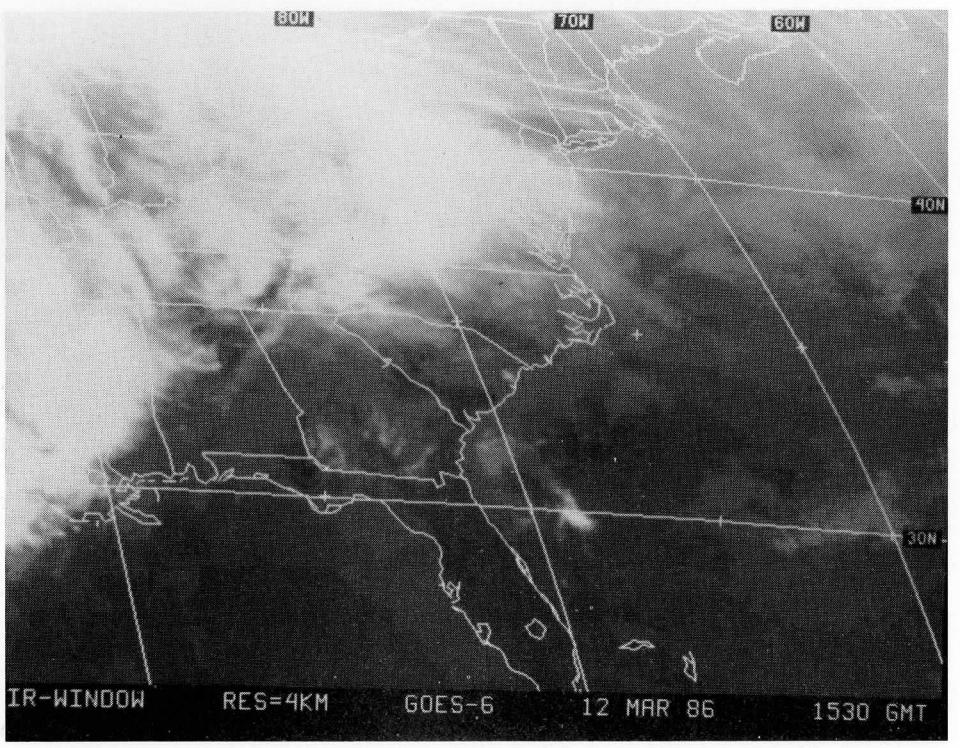
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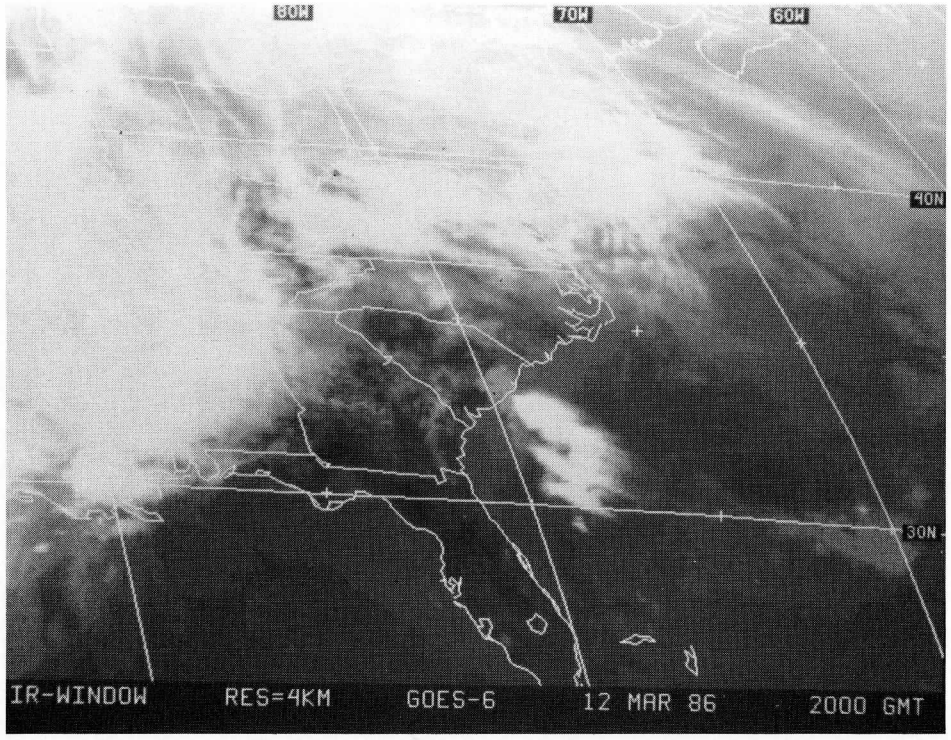
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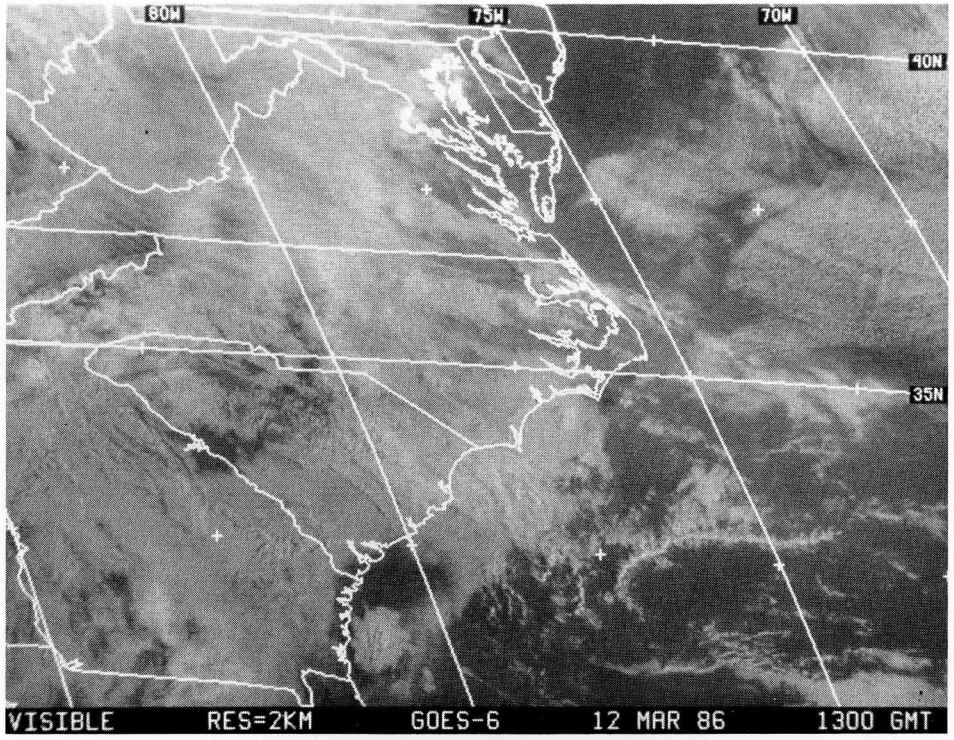
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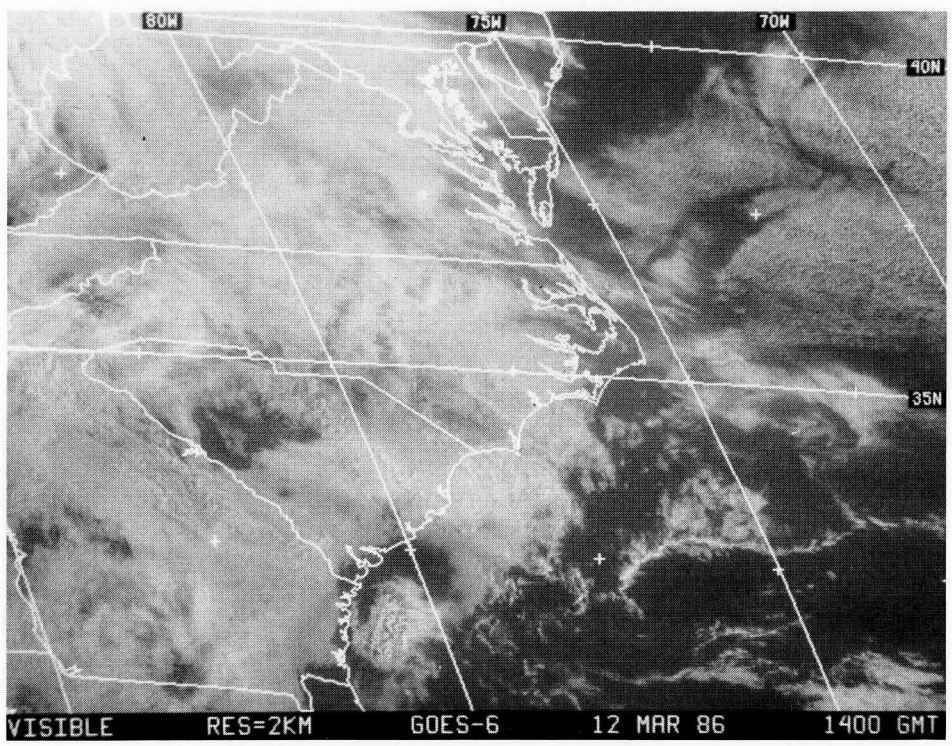
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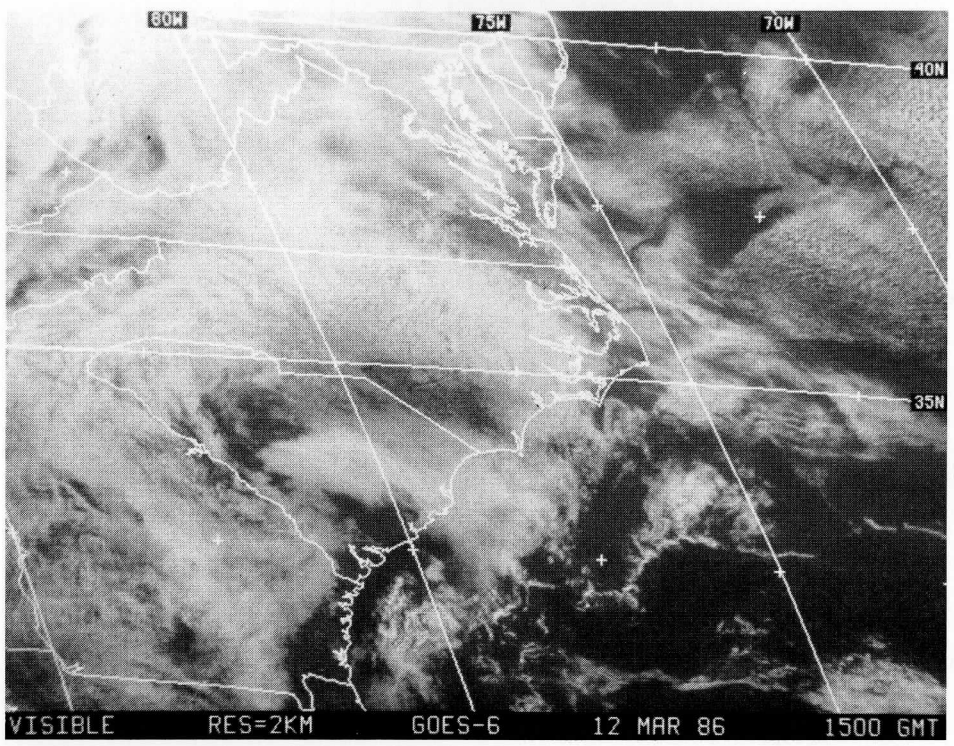
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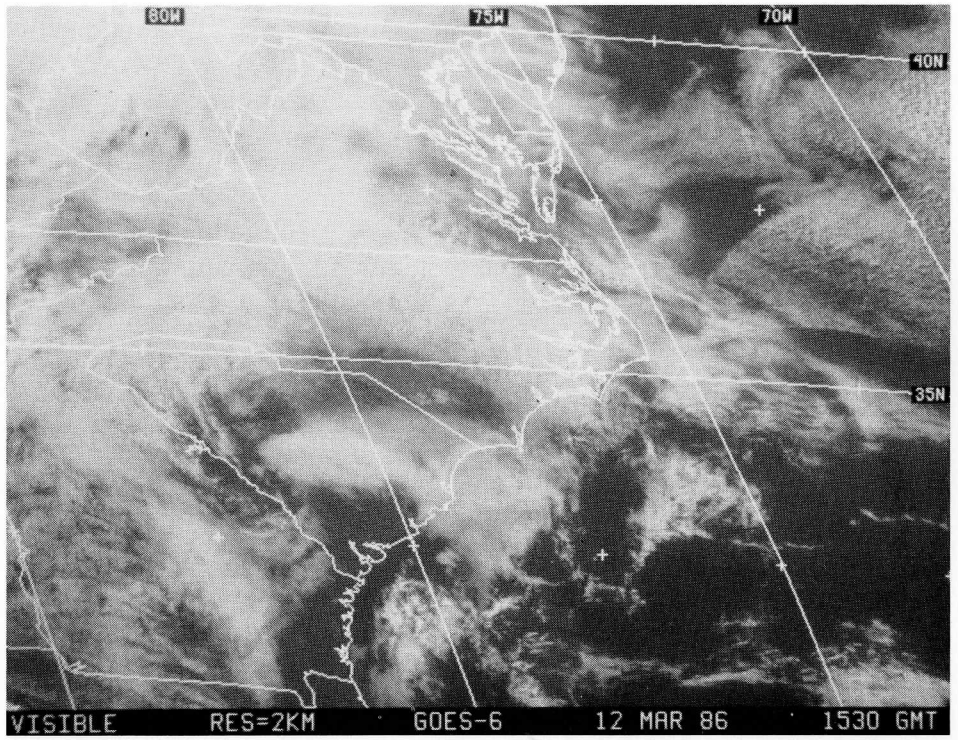
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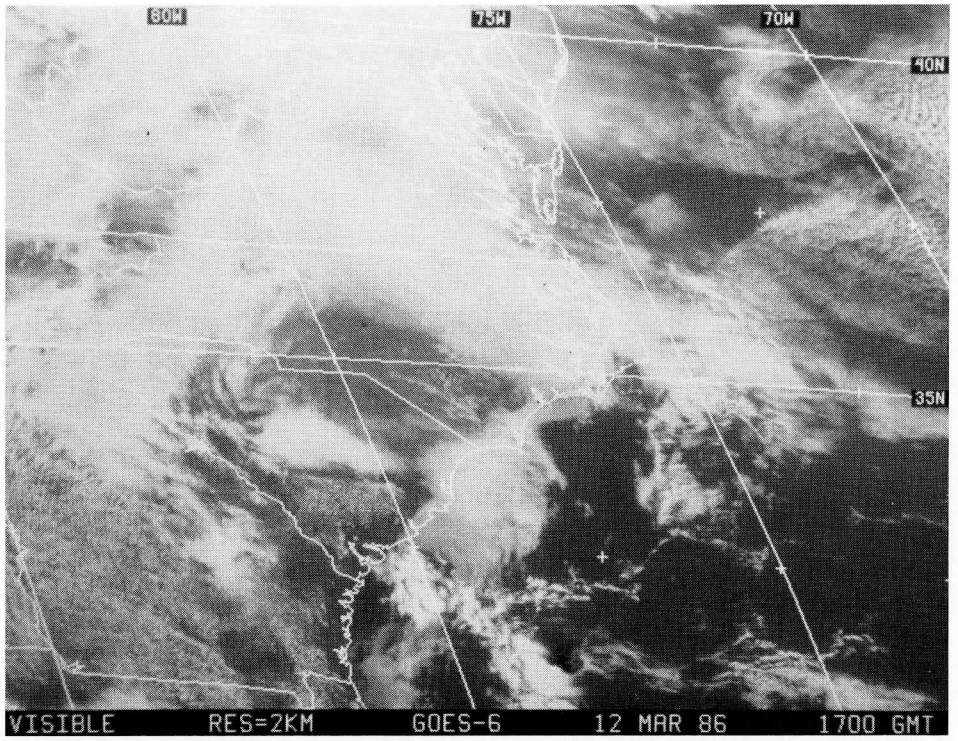
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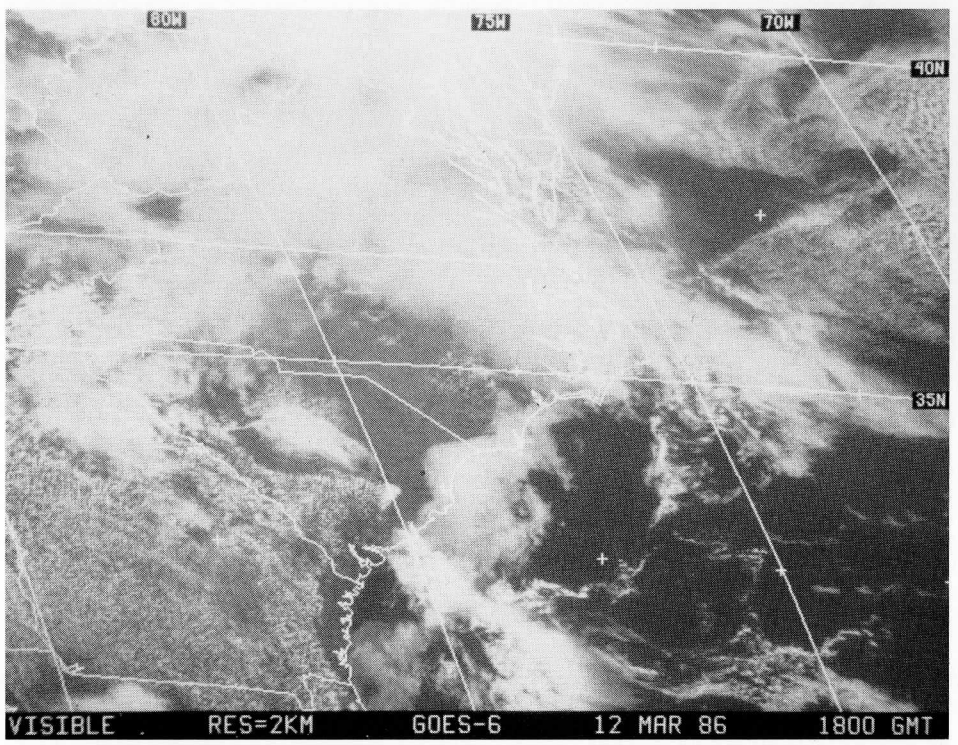
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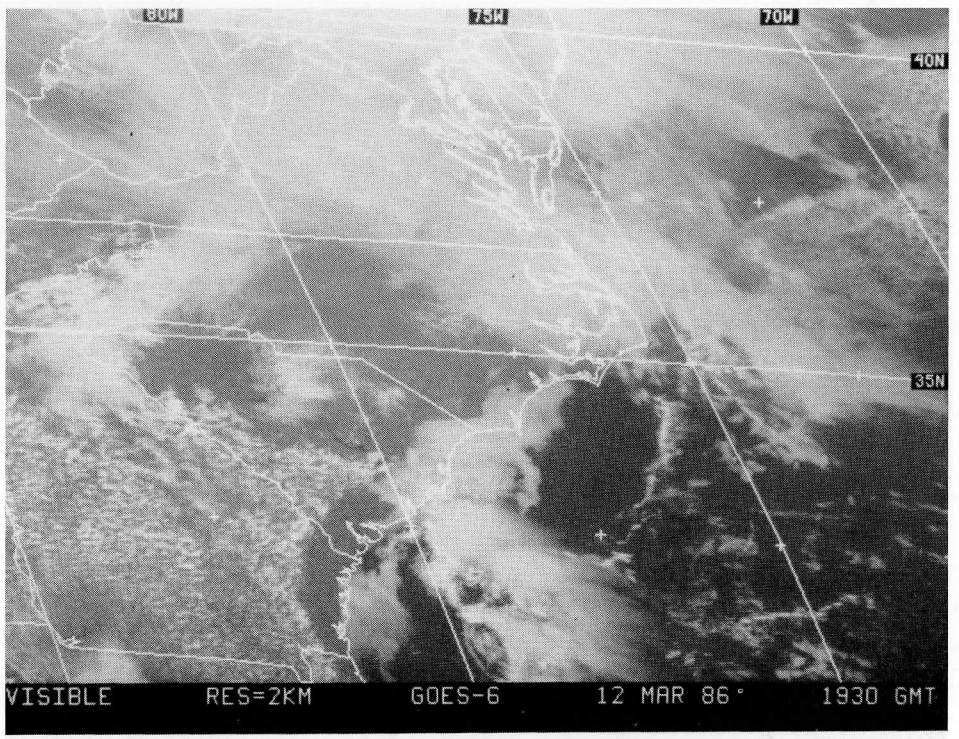
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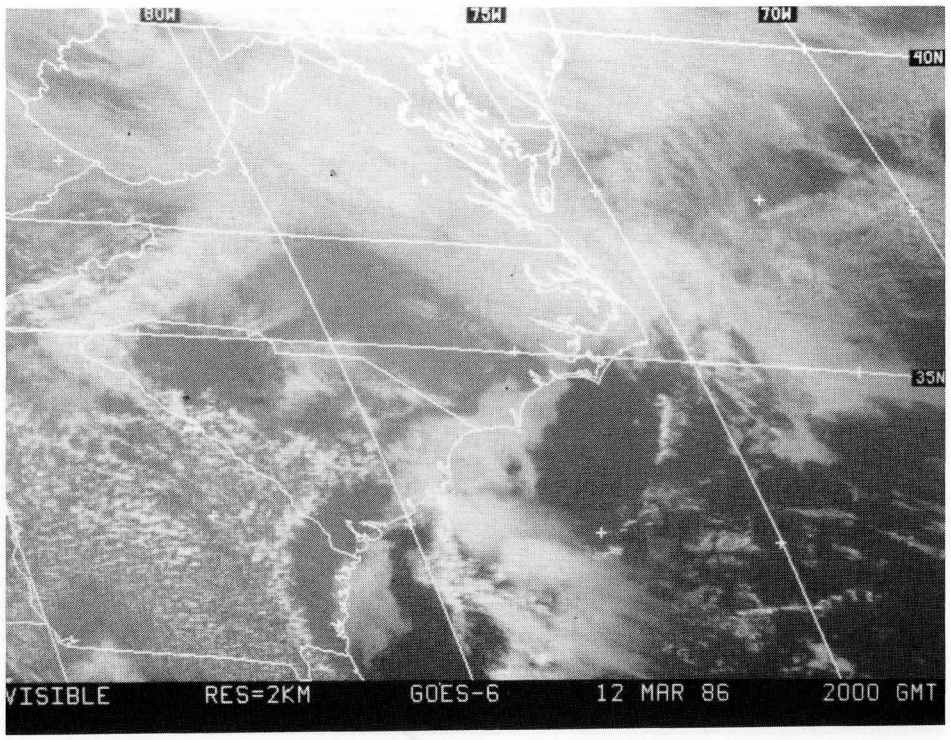
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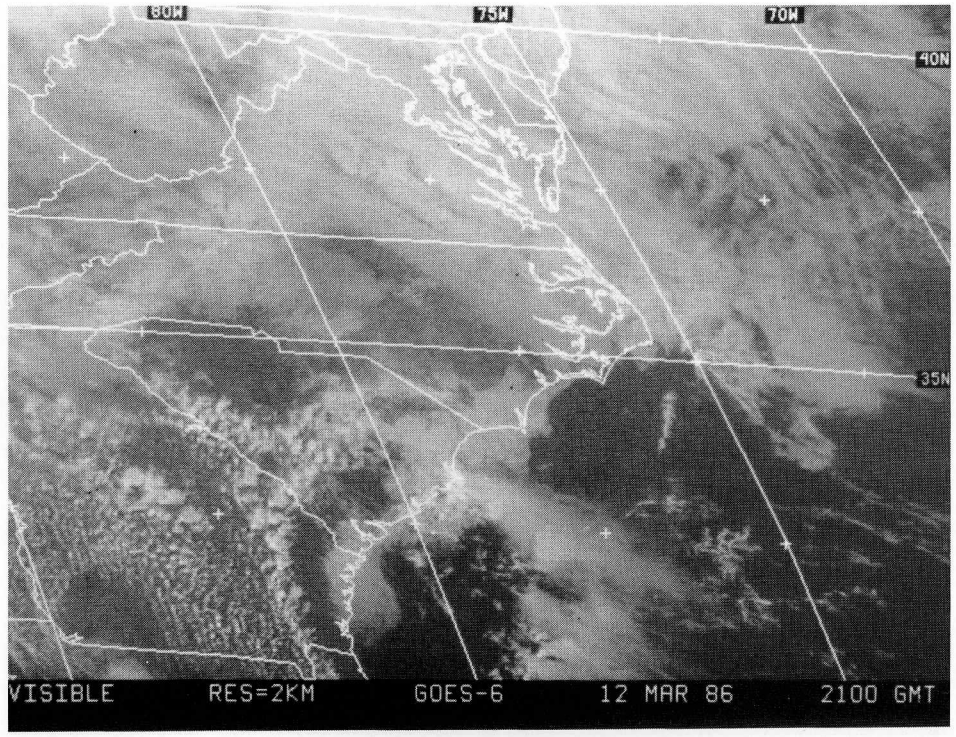
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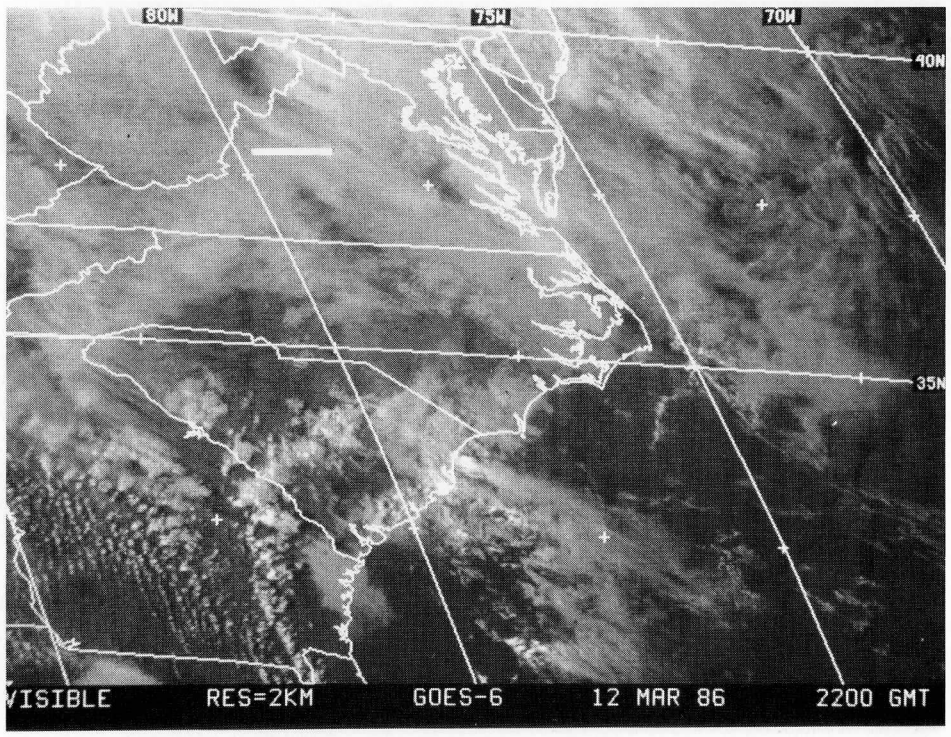
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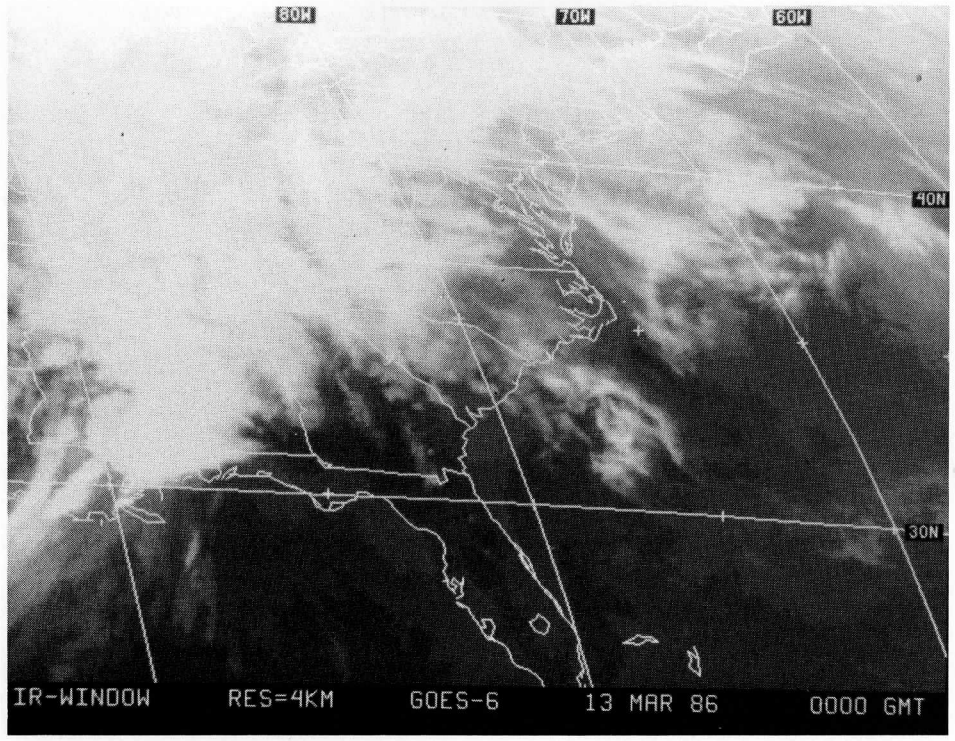
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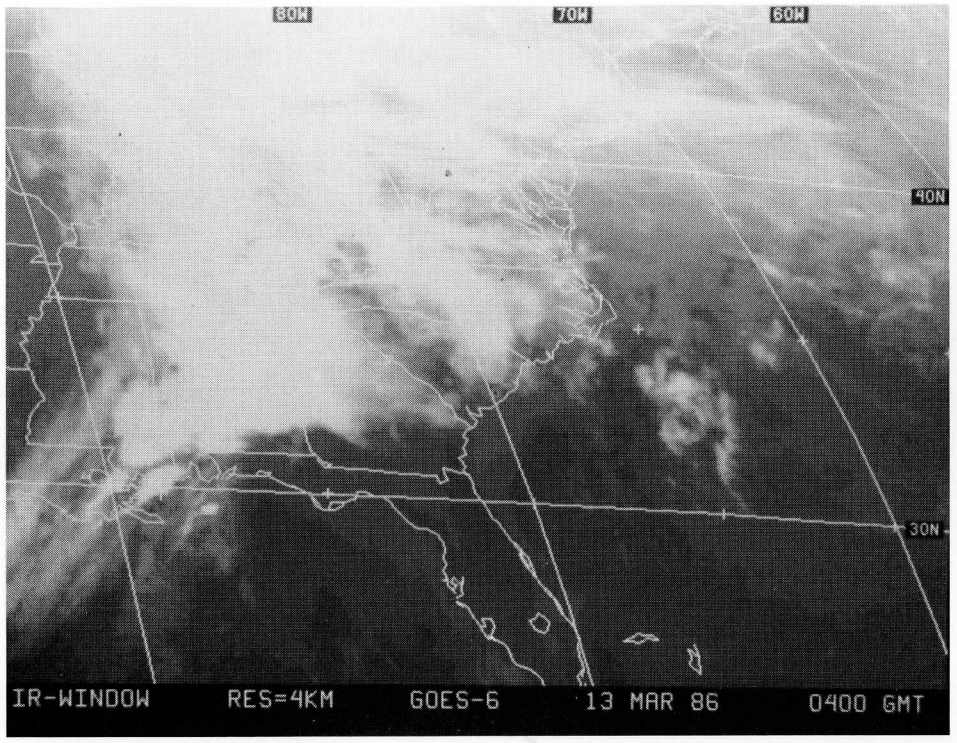
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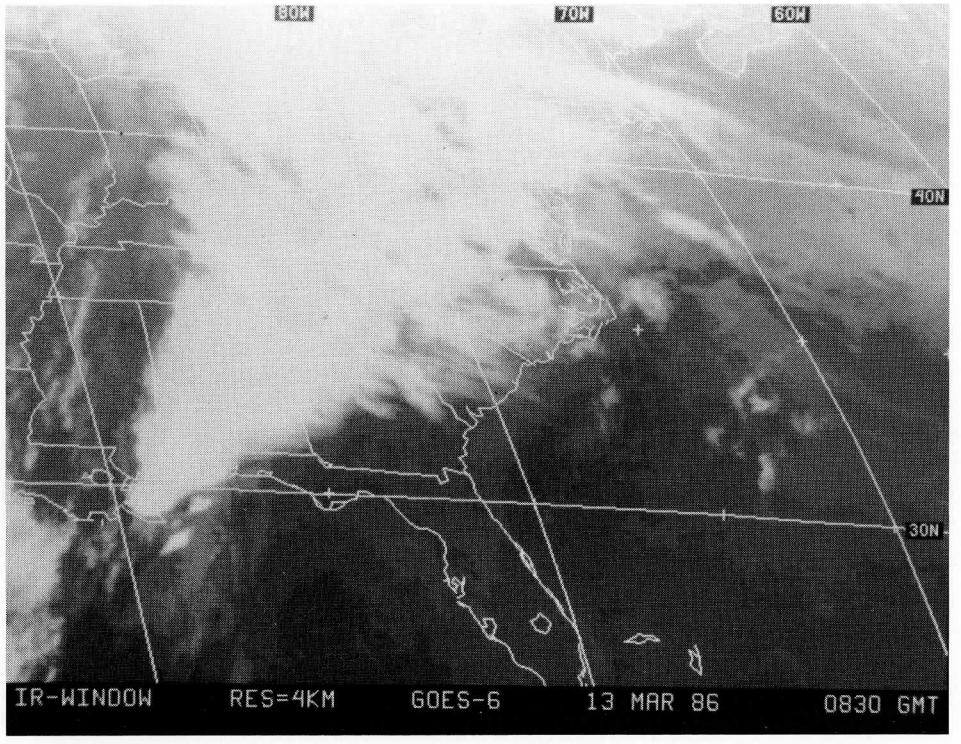
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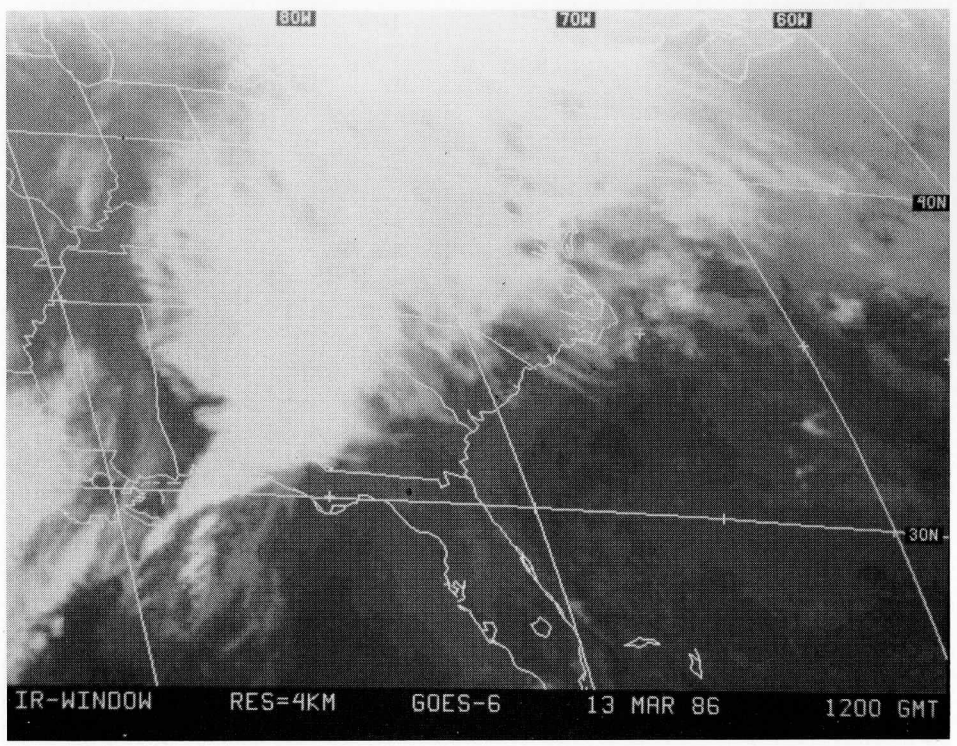
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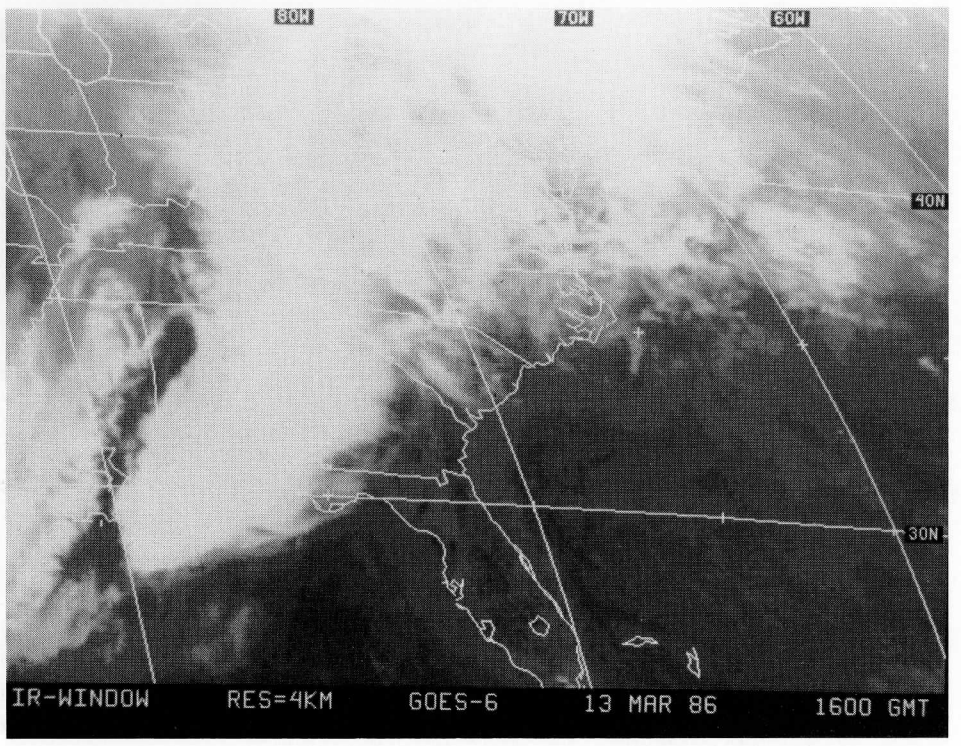
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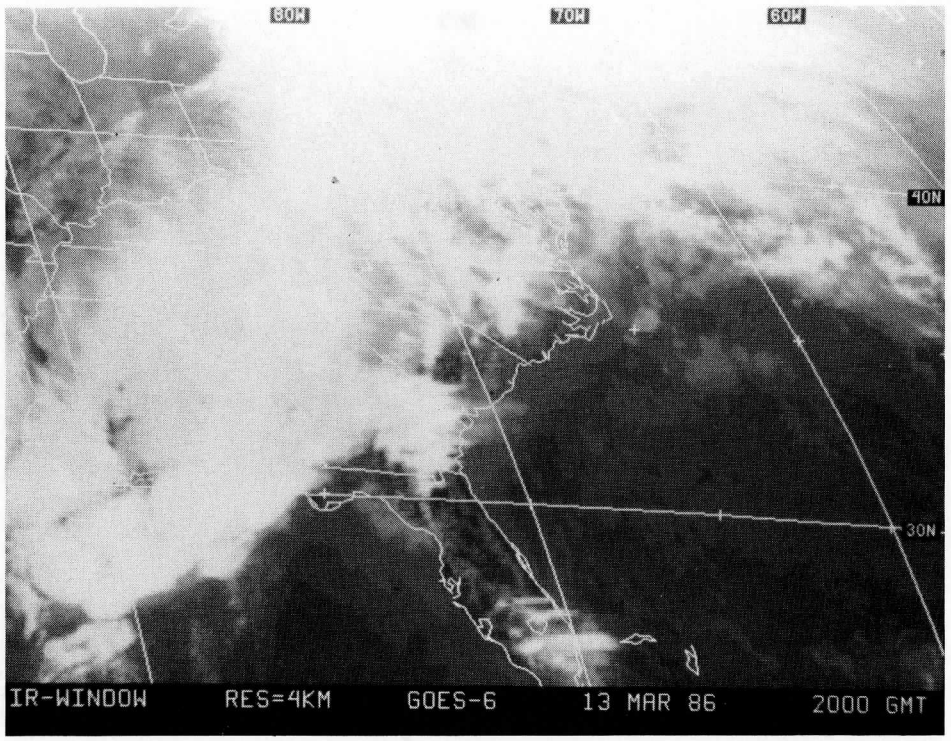
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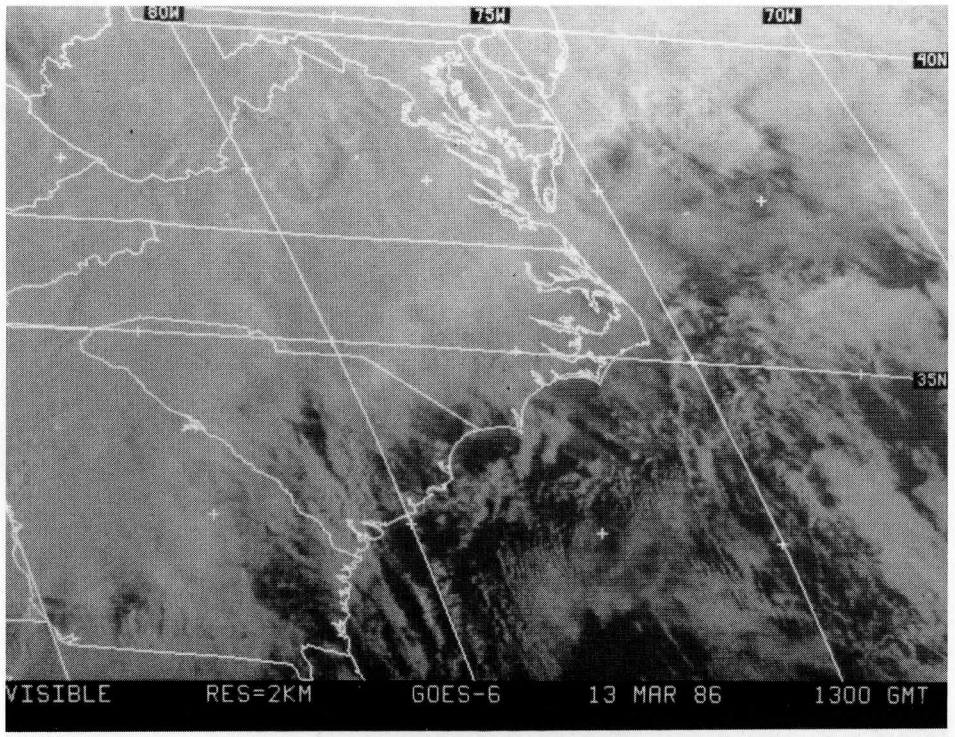
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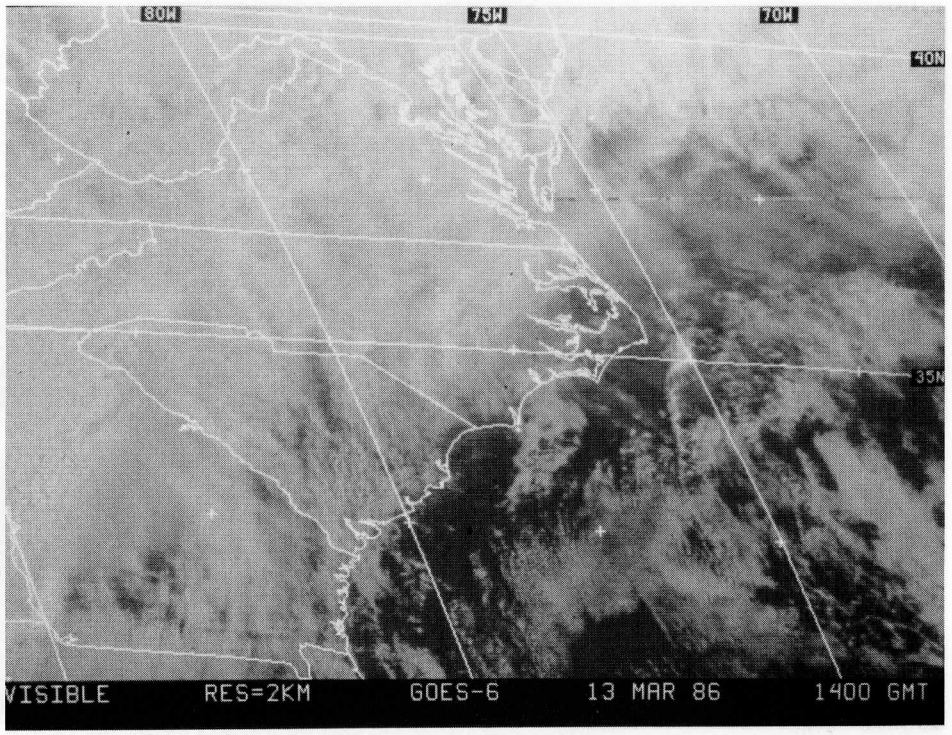
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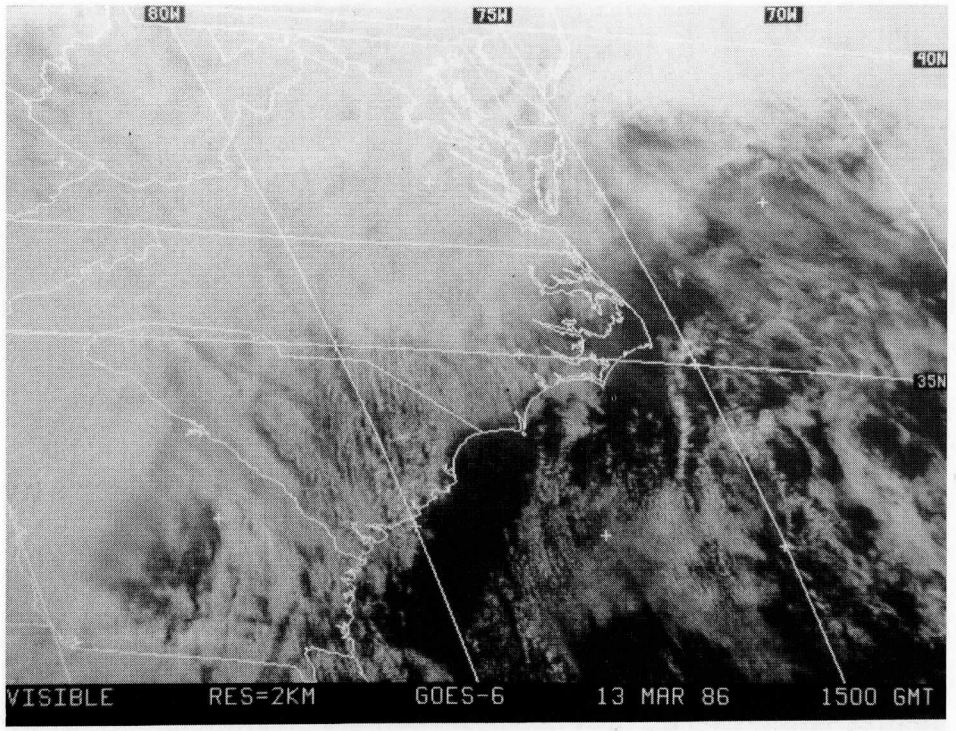
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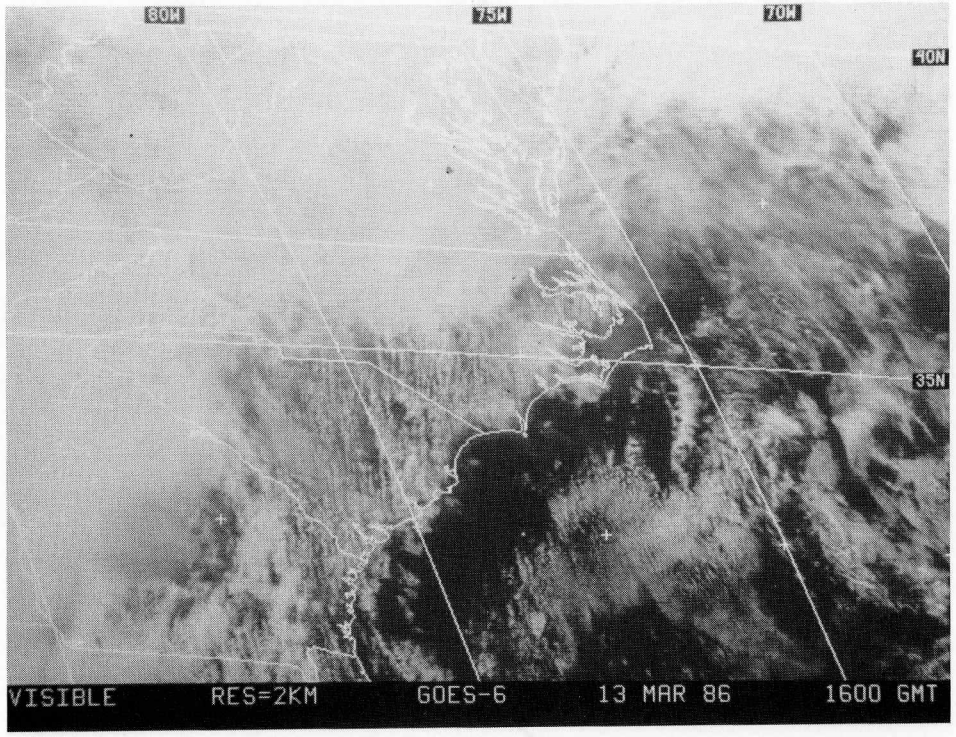
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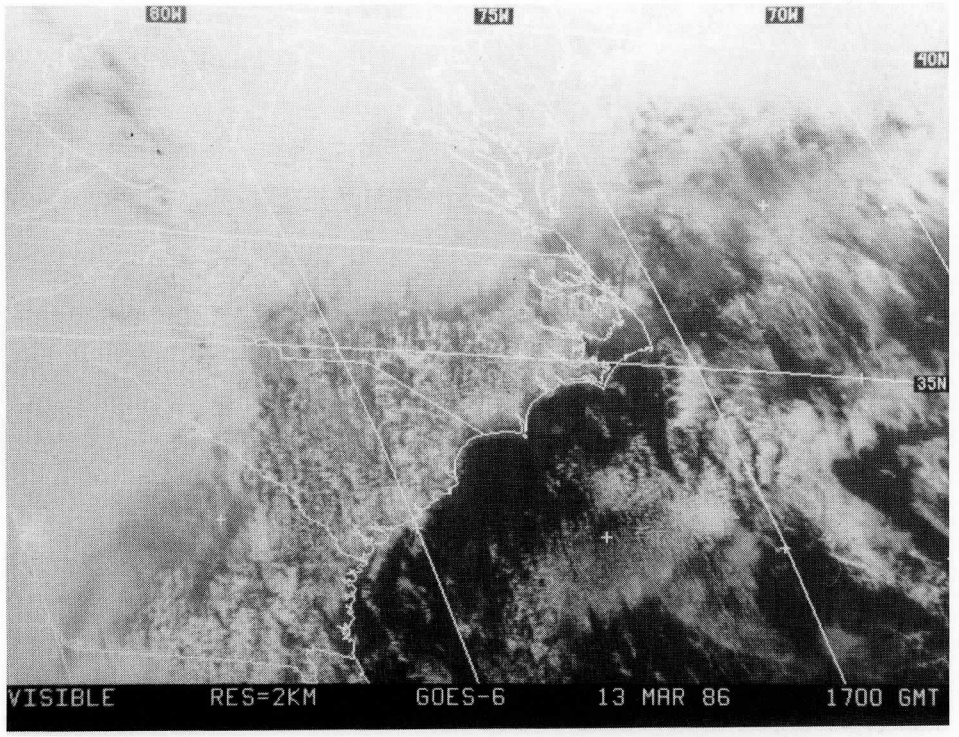
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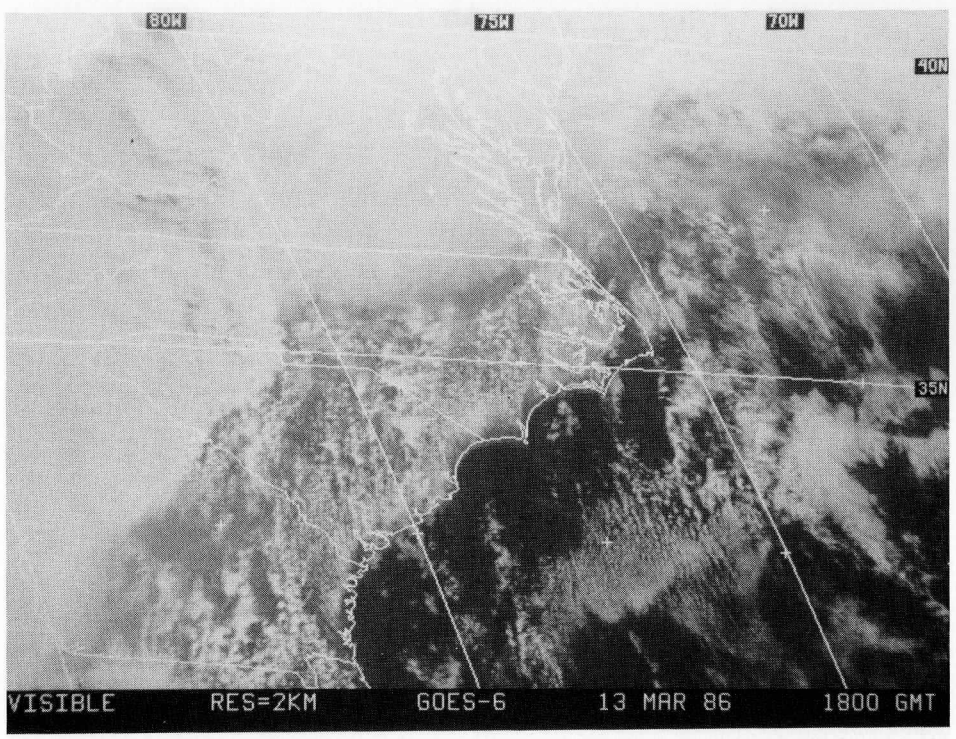
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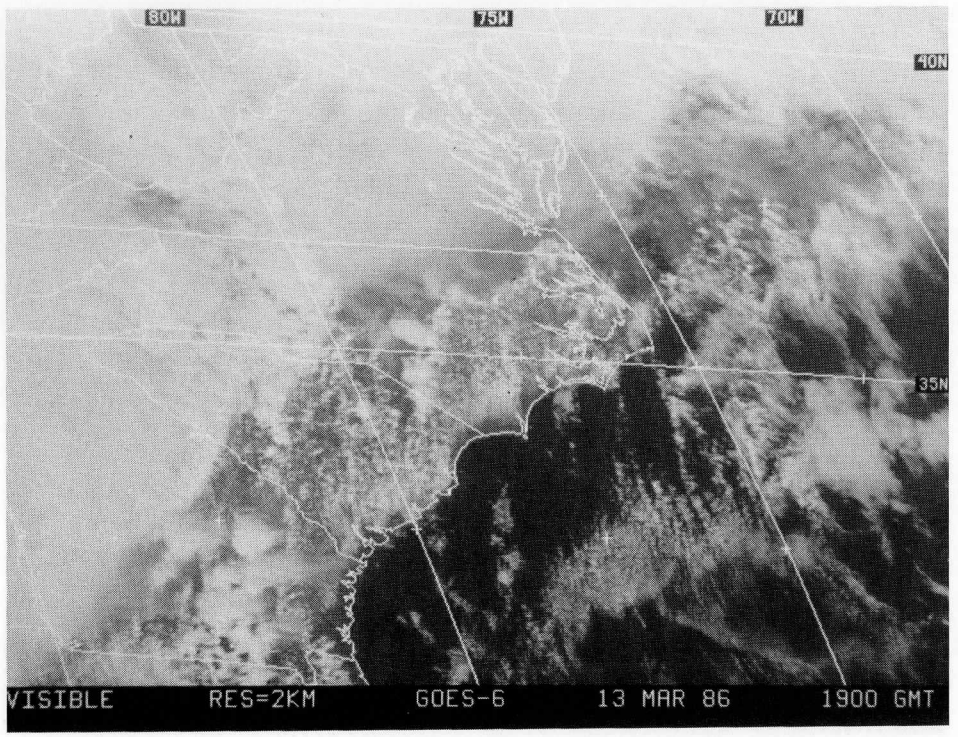
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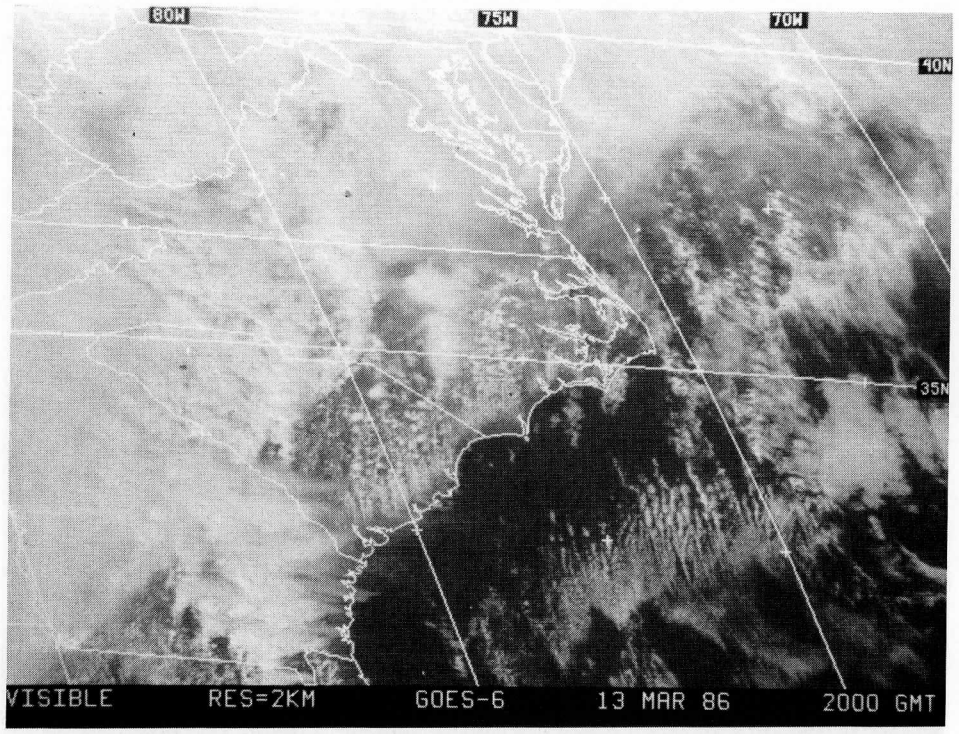
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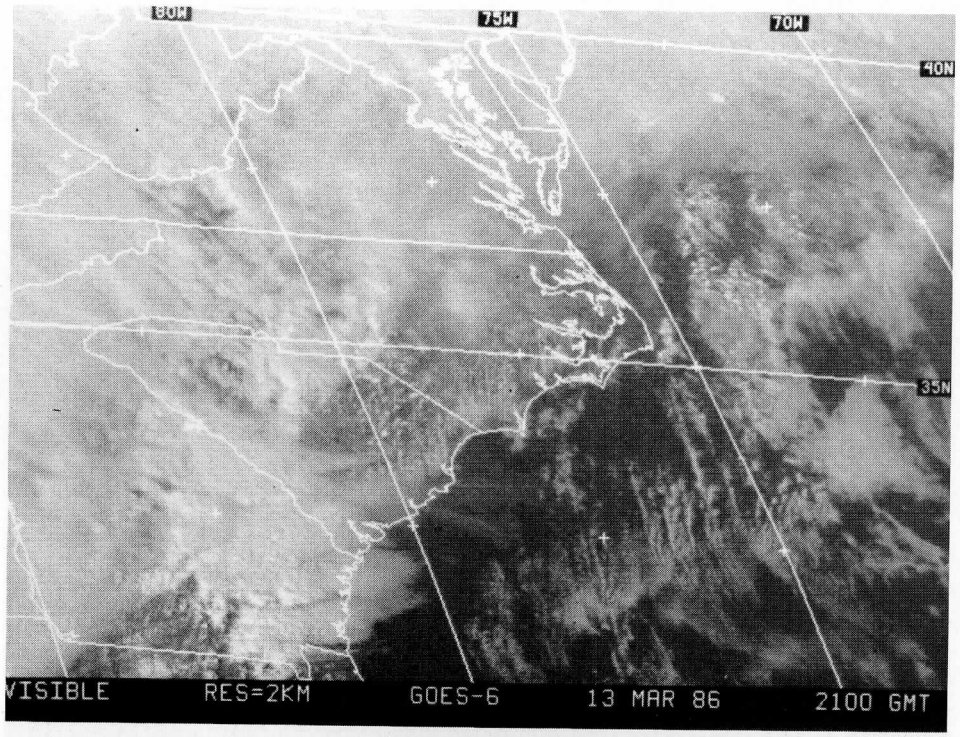
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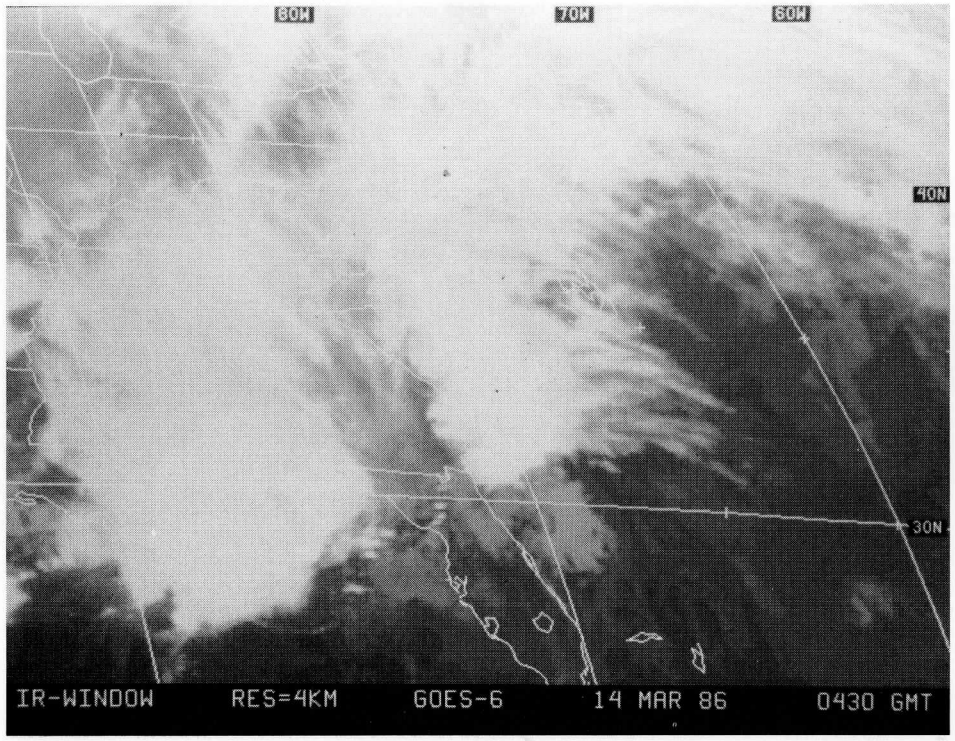
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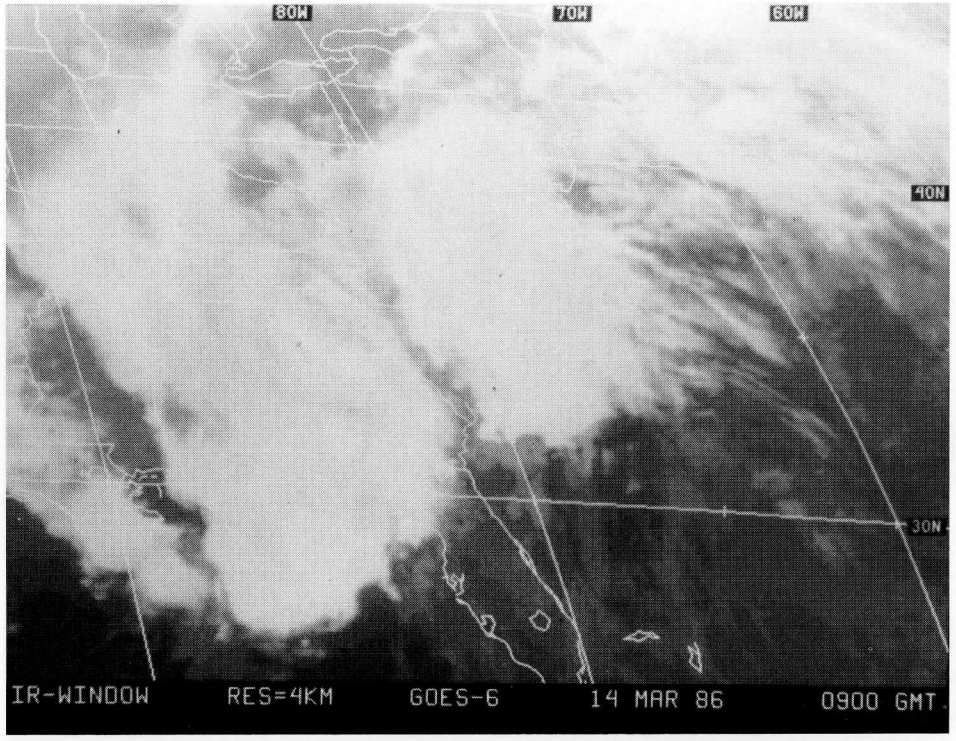
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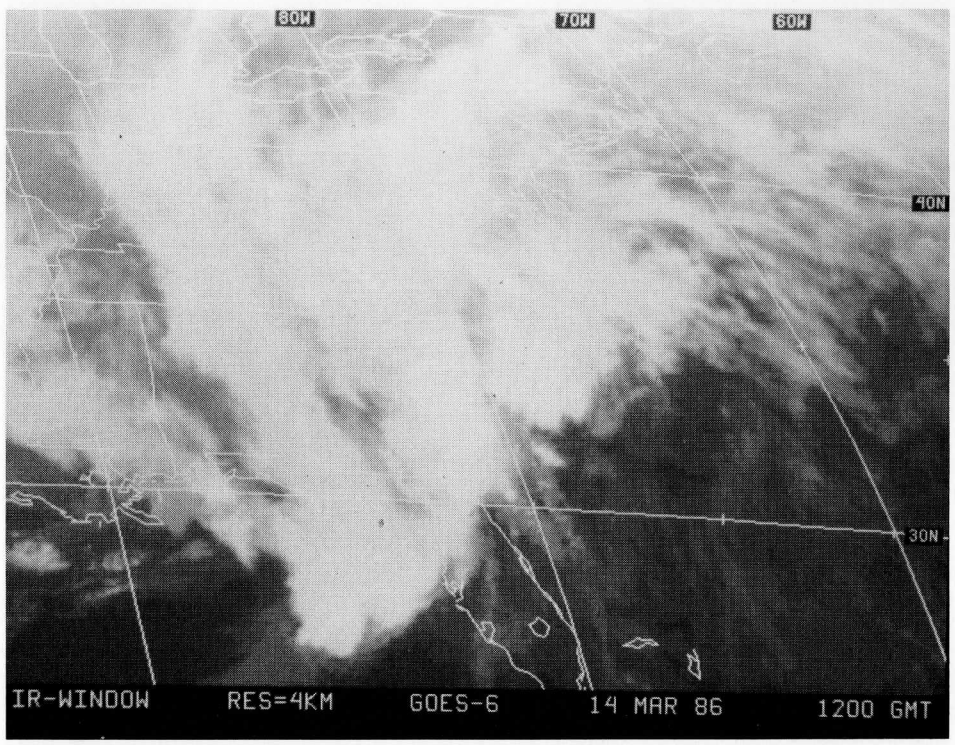
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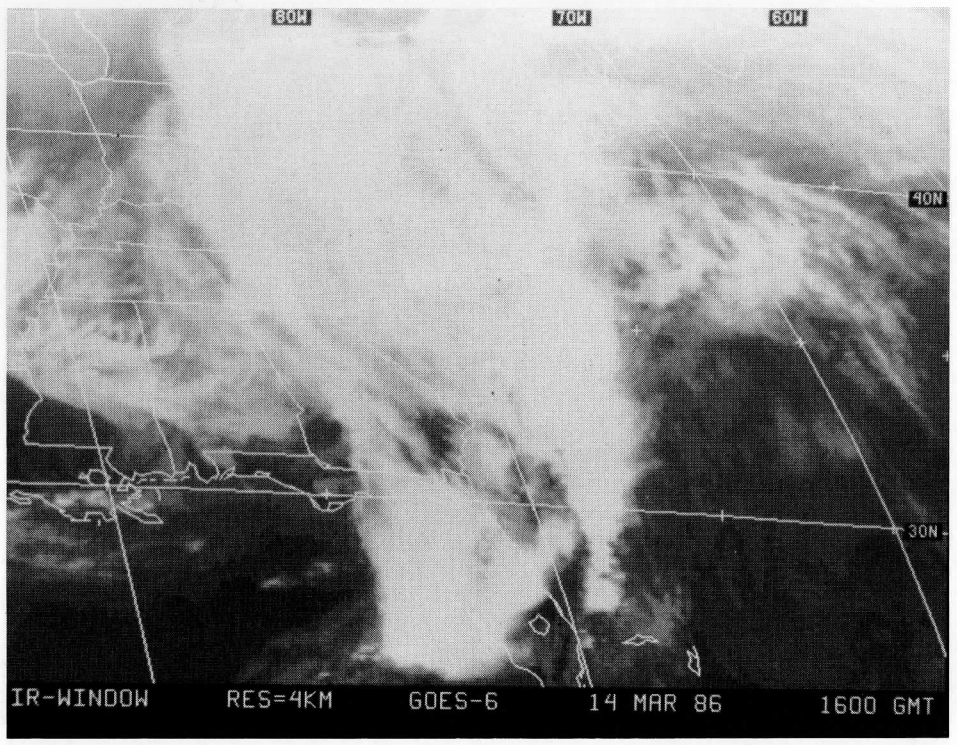
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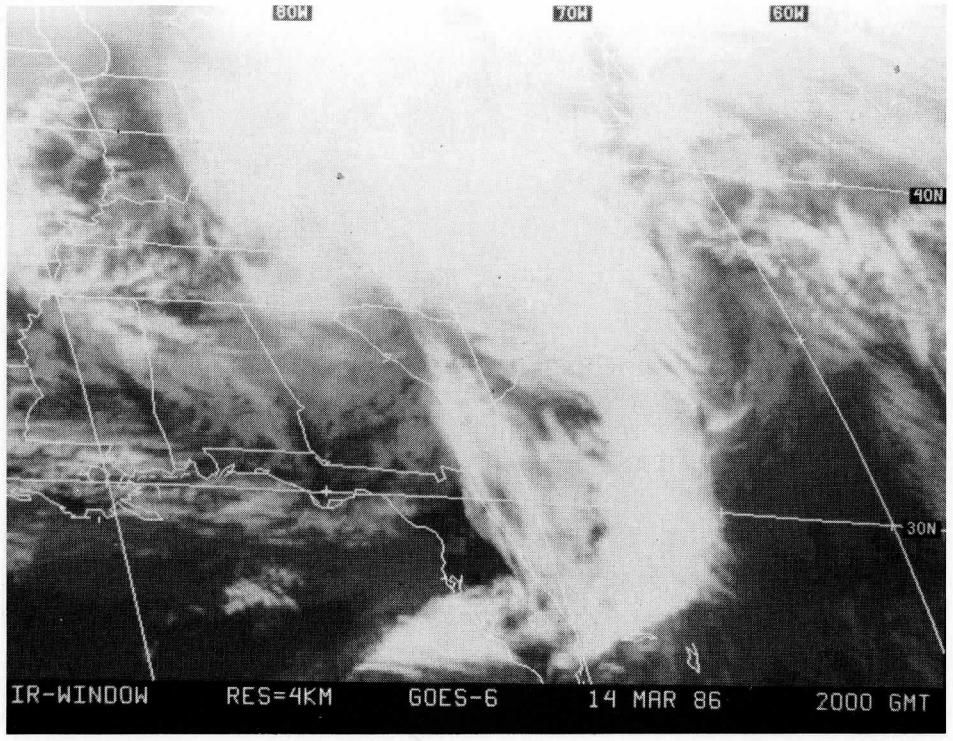
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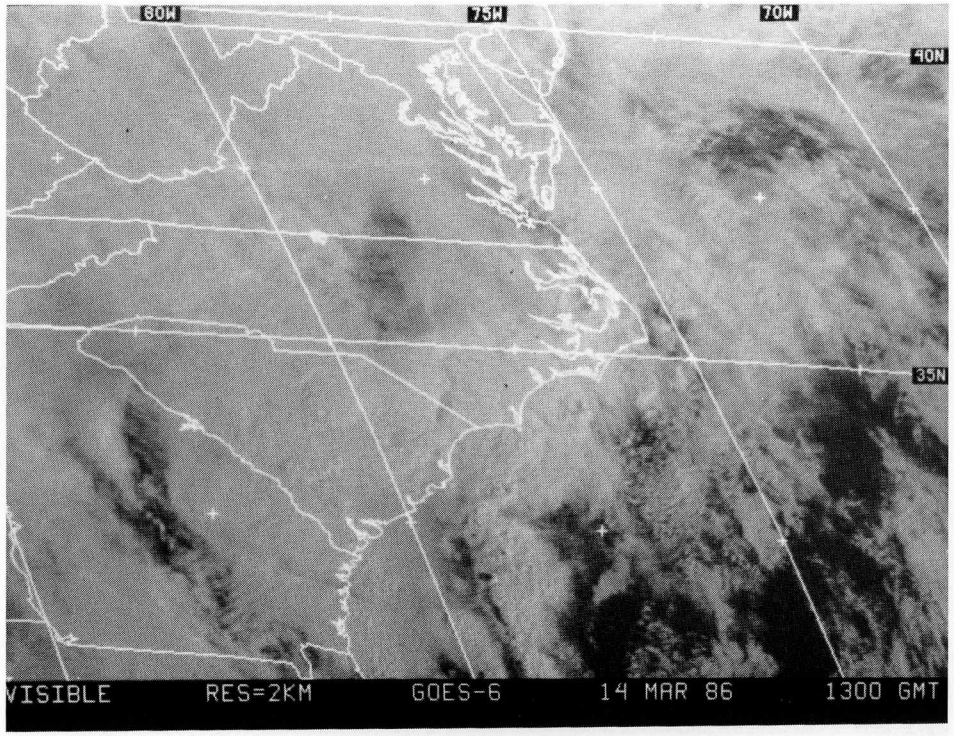
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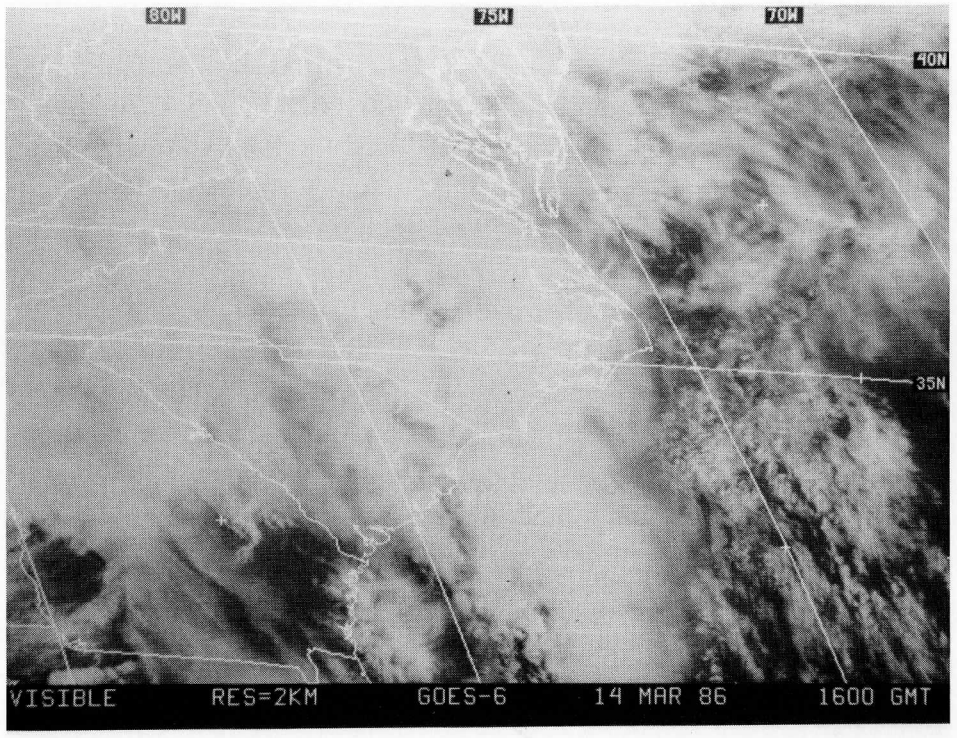
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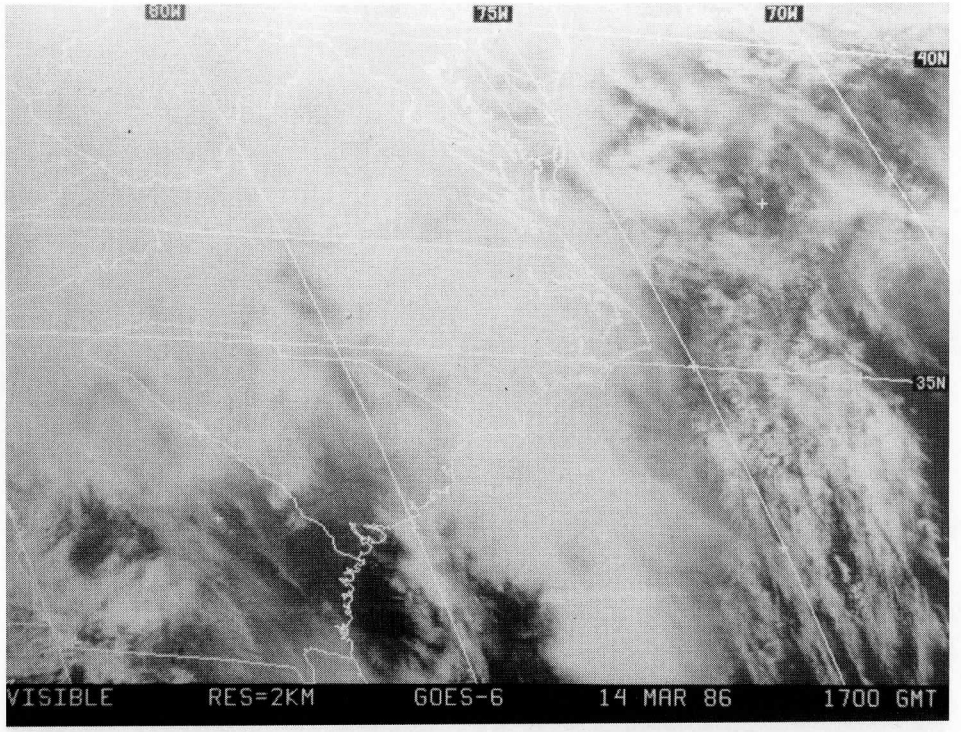
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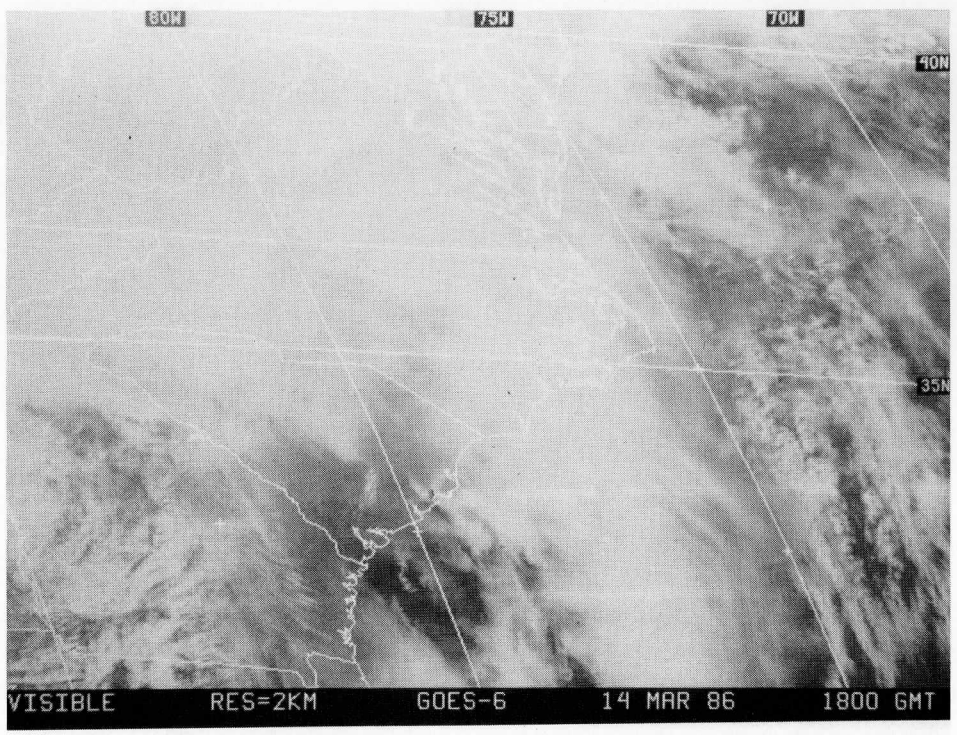
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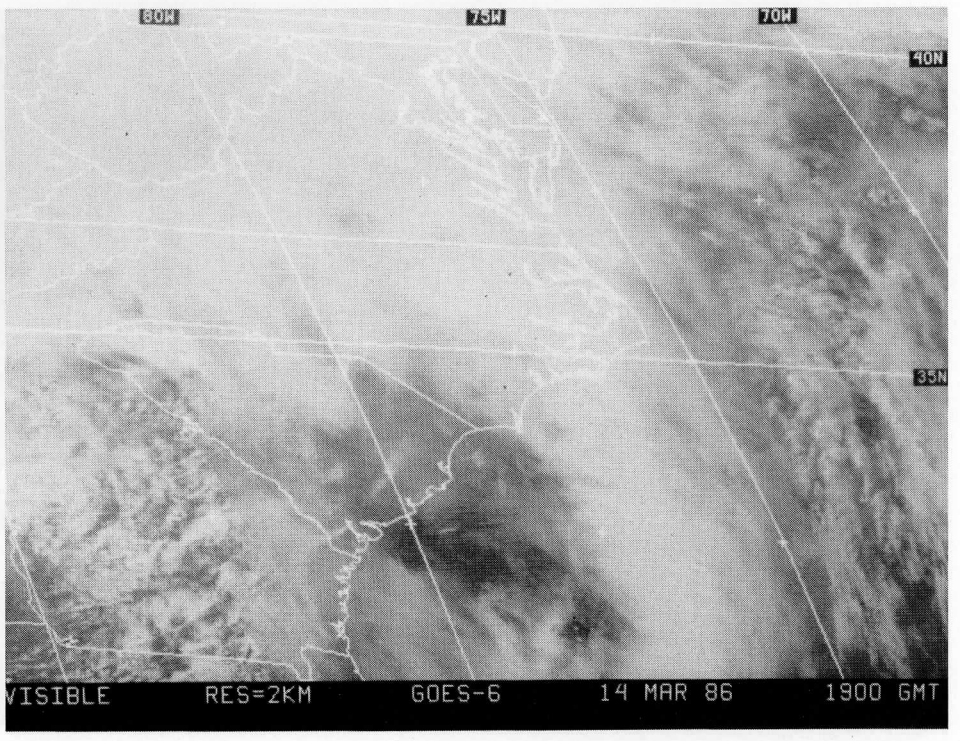
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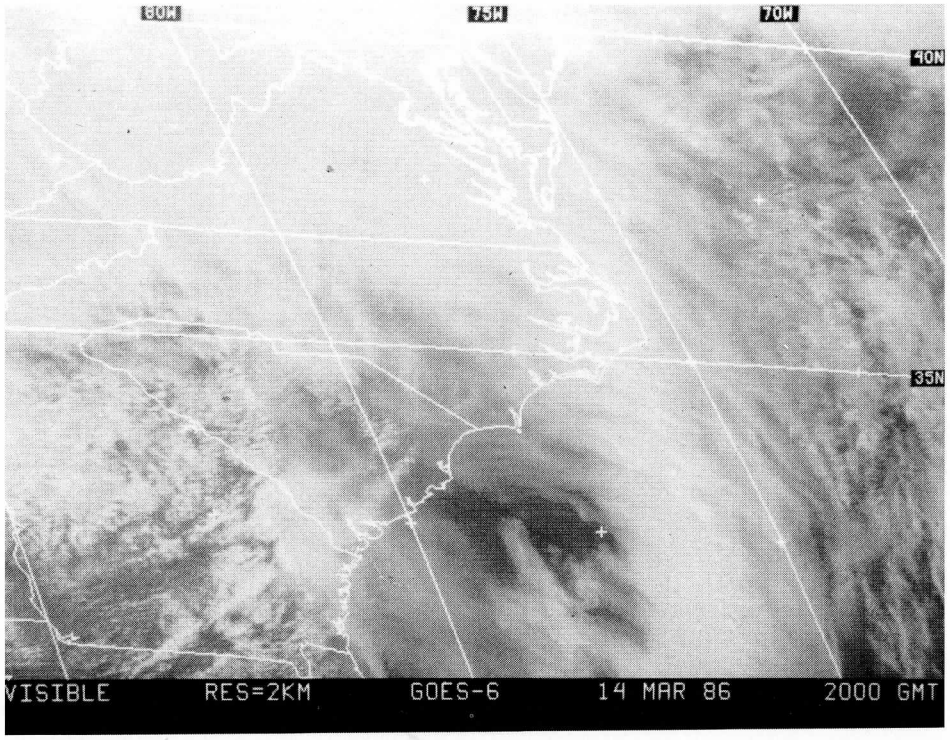
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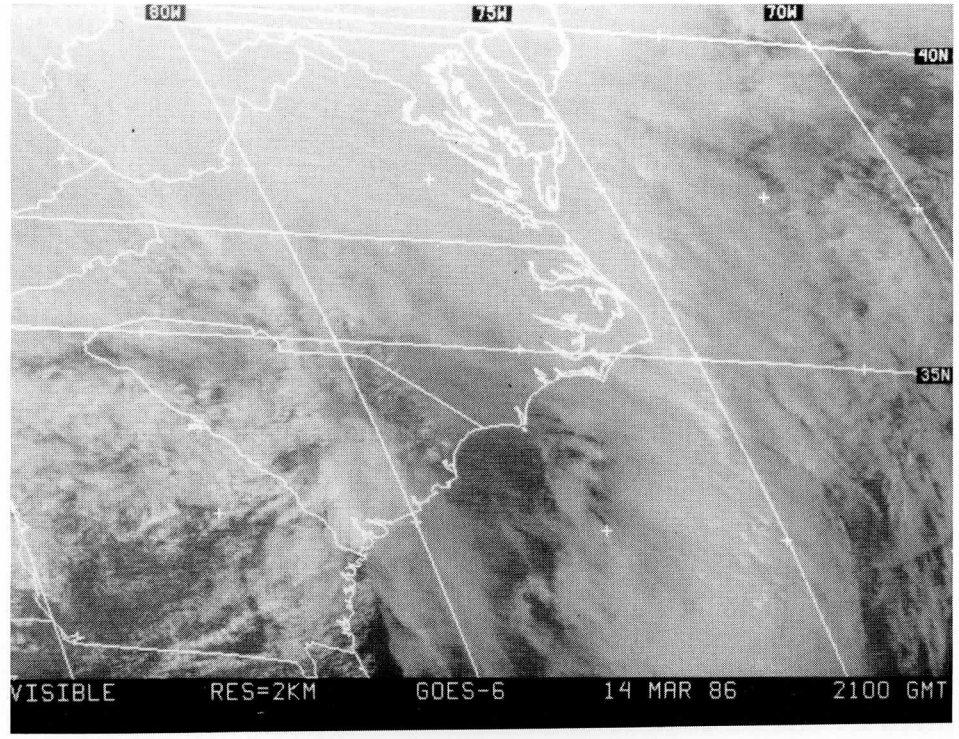
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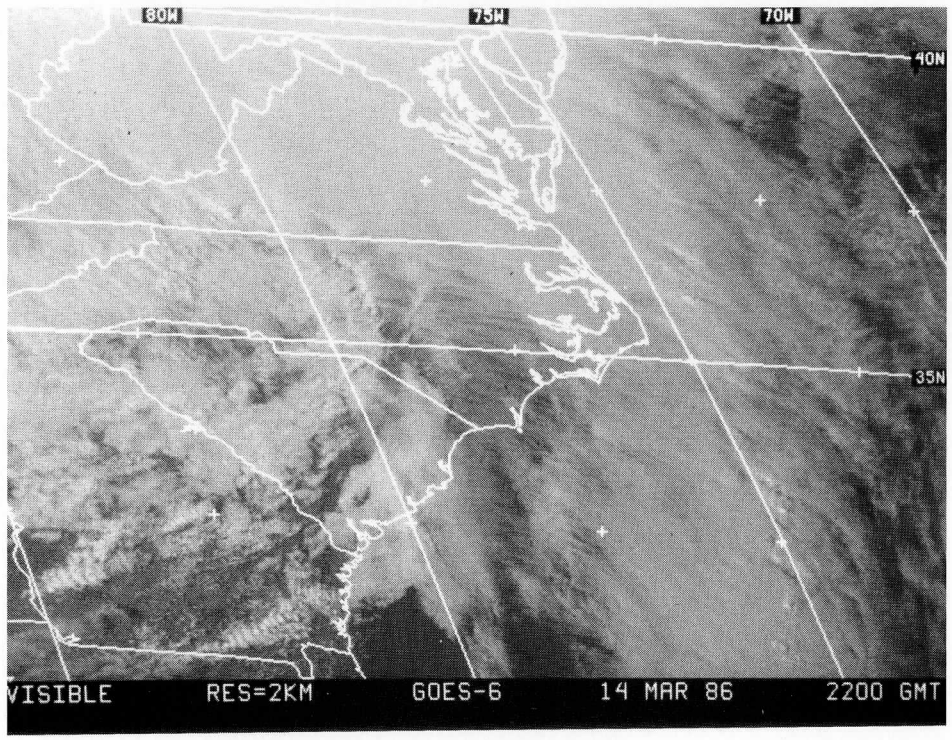
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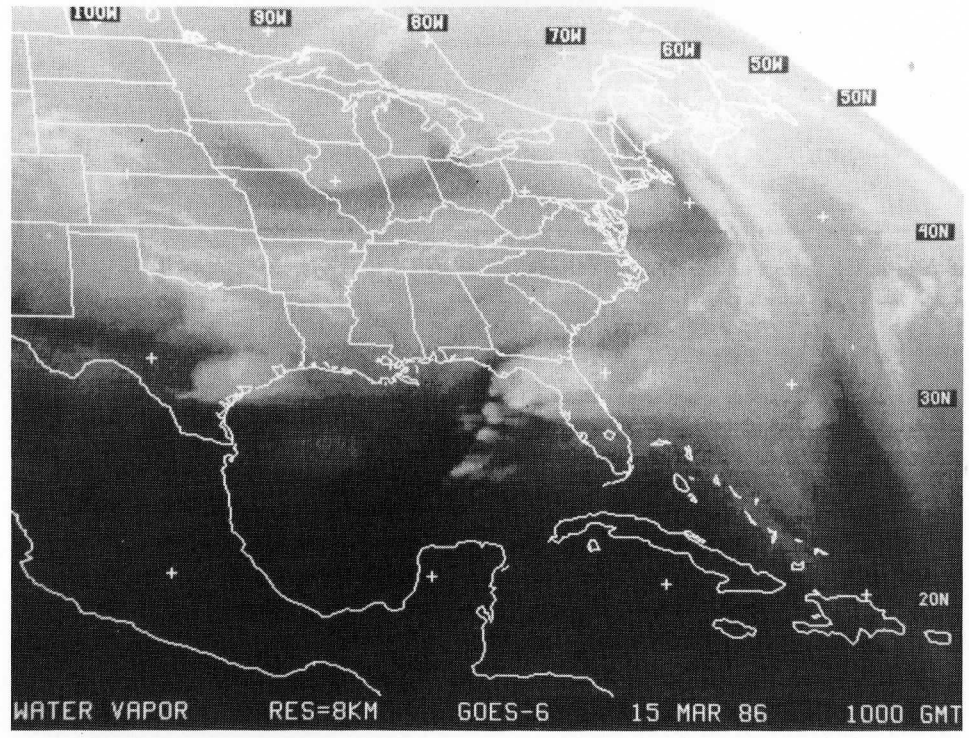
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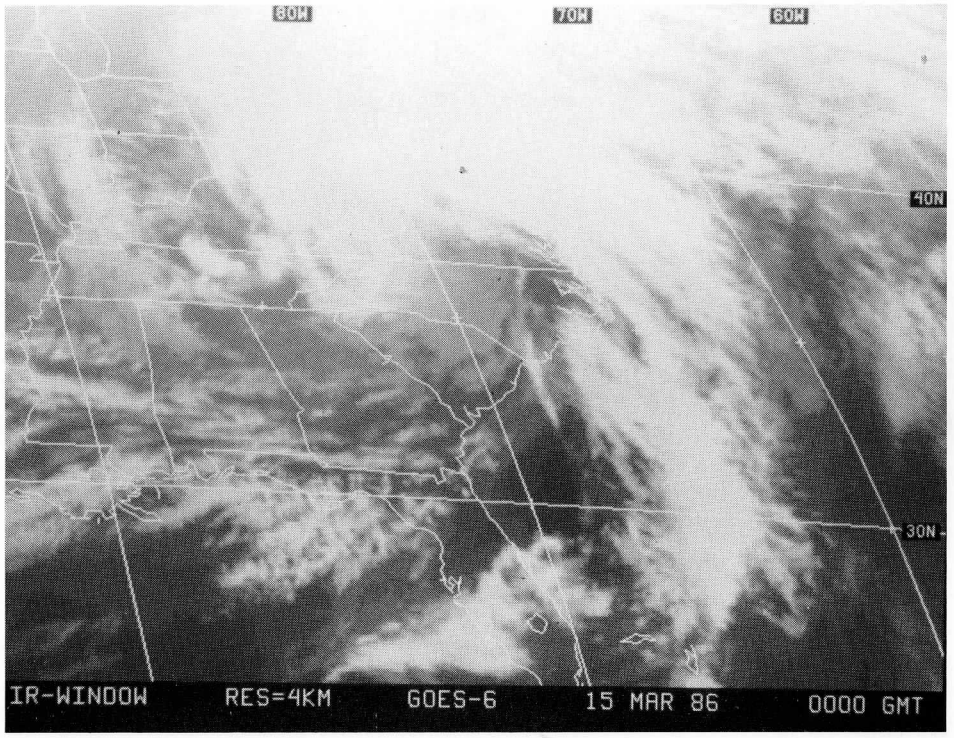

END OF IOP

4. Appendix

SUMMARY OF SATELLITE DATA, IMAGERY AND DERIVED PRODUCTS
AVAILABLE FOR GALE

In addition to standard satellite data, an effort was made to provide special satellite data products for GALE. The first table summarizes all satellite imagery available from the University of Wisconsin SSEC.

Satellite Imagery Available from CIMSS

GOES Stationary Platform

- Cassette archive (digital format)
    * 4 Km resolution IR (1/2 hourly)
    * 1 Km resolution visible (1/2 hourly)
    * 8 Km resolution water vapor (1/2 hourly, 08-01 GMT)
    * 8 Km VAS multi-spectral (3 hourly, 08-01 GMT)
- Magnetic tape archive (digital)
    * Selected imagery from above
    * 8 Km VAS derived (LI, PW) imagery (3 hourly, 08-01 GMT)
- Videotape
- Atlas

NOAA Polar-Orbiting Series Platforms

- Magnetic tape archive
    * 25 Km resolution IR, visible (selected NOAA-9 passes)
    * 110 Km resolution microwave (selected NOAA-6, 9 passes)

All GOES raw data is stored on the UW cassette tape archive. Requests for any of this data can be expected to take up to six weeks, with some possible expense involved. A subset of this data has been extracted and

stored on nine-track magnetic tape, including selected imagery from the cassette archive (four hourly IR and water vapor and one hourly visible imagery). Orders for any of this data can be processed quicker and cheaper.

A videotape of satellite data in animation is available from GDC. It includes IR, visible and water vapor loops (b/w and color enhanced), with special emphasis on IOPs.

Imagery is also available from the NOAA polar-orbiting satellites including microwave and 1 km IR, which is imagery unique to these platforms.

Examples of all the different satellite imagery discussed above were given at the GALE workshop in Monterey, February, 1987. Copies of these examples in 35 mm slide format can be obtained from GDC.

A summary of the satellite data gathering performance during GALE is given in the following table:

DATE	STATUS	EXPLANATION
1/15/86		
1/16	RISOP 9-14Z -- no VAS	
1/17	RISOP 8-14Z -- no VAS	
1/18	IOP	
1/19	IOP	
1/20	IOP	
1/21		
1/22		
1/23	IOP	
1/24	IOP	
1/25	IOP	
1/26	IOP	
1/27	IOP	RISOP 11-18Z
1/28	IOP	
1/29		
1/30		
1/31		
2/1		
2/2	IOP	
2/3	IOP	some data loss - equipment problems
2/4	IOP	
2/5		

DATE	STATUS	EXPLANATION
2/6	IOP	
2/7	IOP	
2/8		
2/9	IOP	
2/10	IOP	
2/11	IOP	
2/12	IOP	
2/13	IOP	data loss due to satellite maneuver
2/14	IOP	some data loss - equipment problems
2/15	IOP	
2/16		some data loss - equipment problems
2/17		some data loss - equipment problems
2/18		
2/19		
2/20		
2/21	IOP	some data loss - equipment problems
2/22	IOP	
2/23	IOP	
2/24	IOP	
2/25	IOP	Wallops SDB testing--17-00Z no VAS
2/26	IOP	Wallops SDB testing - no VAS
2/27	IOP	data loss (9-16Z) - equipment problems
2/28	IOP	Some data loss - equipment problems
3/1	IOP	
3/2	IOP	
3/3		data loss (17-00Z) no VAS - equipment problems
3/4		some data loss - equipment problems
3/5		no VAS - equipment problems
3/6	IOP	no VAS (18-00Z)-equipment testing
3/7	IOP	
3/8	IOP	some data loss - equipment problems
3/9	IOP	RISOP 18-00Z
3/10		RISOP 0-10Z -- no VAS
3/11	IOP	RISOP 16-00Z
3/12	IOP	RISOP
3/13	IOP	RISOP
3/14	IOP	RISOP 0-14Z -- no VAS
3/15		no VAS - equipment problems

In general, GOES data collection was fairly complete, except for some data loss (mostly VAS) due to equipment problems/testing later in the experiment. RISOP stands for Rapid Interval Scan OPerations, when IR and visible data are available every 15 minutes, and VAS is not available.

In addition to convectional satellite imagery, a number of other satellite products are available. These are listed in the following table:

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Satellite Derived Products Available from CIMSS

- GOES
    * VAS soundings and analyses
- Up to 5 times a day (3 hourly, 08-01 GMT)
- Mandatory level T, Td, ZT
- Some bias problems (recommend using gradients)
    * VAS sea surface temperature estimates
    * Cloudiness estimates (VAS CO_2 slicing method)
    * Cloud drift winds
    * VAS water vapor motion winds
    * Rainfall estimates
- NOAA-9
    * Soundings
- Better absolute accuracy

A more complete, detailed discussion of these products is given in the GDC GALE Data Users Guide. Examples can be obtained from GDC.

A set of maps of accumulated (24 hour) rainfall during IOPs derived from satellite IR image estimation techniques are available from GDC.

The Goddard Space Flight Center collected and processed TOMS ozone data from the NIMBUS-7 satellite. An atlas which contains daily maps of this data is available from GDC.

Soundings and imagery from the Air Force DMSP F-6 and F-7 satellites is available. Contact GDC for more information.

High resolution sea surface temperature data from polar orbiting AVHRR data is available on selected GALE days. This data is also available at GDC.

02/CSV1/03