

Availability of Remote Sensing Data for the Northwest Atlantic

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Abstract

The nature of remote-sensing data is briefly described, the satellite systems currently in use and those planned for future deployment are noted, and some satellite data products available from four suppliers are listed.

Remote sensing from space began with the deployment in the 1960's of meteorological satellites with low resolution optical sensors. Since then, there has been significant improvement in radiometric and geometric resolution, for both optical and microwave imaging systems. However, most of the satellites deployed to date have been oriented toward meteorological and land applications.

The primary operational systems are polar-orbiting and geostationary satellites deployed by the United States. The Advanced Very High Resolution Radiometers (AVHRR) aboard the NOAA-6 and NOAA-7 polar-orbiting satellites, with four channels (two visible and two infrared), have been used extensively for oceanographic research, resulting in the production of sea-surface temperature charts, ocean frontal and ocean current analysis charts, and ice charts. The GOES geostationary satellite provides frequent synoptic pictures of the eastern half of North America and the Atlantic Ocean for weather-forecasting purposes. Limited application of the GOES thermal infrared system for ocean temperature monitoring is developing, but the high latitudes of North America and the Atlantic Ocean are seen only at a very oblique angle. Generally, the polar-orbiting satellites are preferred for imaging the northern latitudes.

The greatest activity in the application of satellites for research has been the deployment by the United States of a series of experimental satellites. These are the LANDSAT series from 1972 to the present, the NIMBUS series from 1970 to the present, and SEASAT-1 launched in 1978 with a life span of only a few months. The main sensors on board LANDSAT-3 and NIMBUS-7 are optical imaging sensors. The polar-orbiting LANDSAT-3 Multispectral Spectral Scanner (MSS) provides four-channel line scanning in the visible range of the spectrum (500-1,100 nm). Data are framed in scenes of 185 × 185 km with a resolution of 80 m. LANDSAT has the highest resolution system, but it was designed mainly for land applications. The NIMBUS-7 satellite has a 6-channel Coastal Zone

Color Scanner (CZCS) for measuring ocean sediment and chlorophyll concentrations in the sea surface at a resolution of 800 m. In the Northwest Atlantic, optimum use of the sensors is often hampered by extensive cloud cover. A number of satellite passes over several days are often required to provide cloud free observations. The mosaicing of a time series of satellite images obscures many details of surface ocean color and circulation patterns. However, the combination of satellite data with observations transmitted from ships and buoys enables the weekly production and distribution of various types of oceanographic charts for the North Atlantic region. Such products include Global Sea Surface Temperature Charts (GOSSTCOMP) on 100 km grids, Gulf Stream Analysis Charts (GSAC), Great Lakes Ice and Sea Surface Temperature Charts, and Northern Hemisphere Snow and Ice Charts. The satellites currently in use are listed in Table 1.

Future satellite systems are being designed to provide all-weather data acquisition by deploying microwave sensors, such as Synthetic Aperture Radar (SAR), Scatterometer, and Scanning Microwave Radiometer. The SEASAT satellite, launched in 1978 was a proof-of-concept test of the microwave sensors, but,

TABLE 1. Operational and research satellites currently in use.

| Satellite | Sensors |
|-------------------------------|--|
| NOAA-6 & 7 (USA) | AVHRR — 4 channels, 800 m resolution TOVS — cloud temperature profile DCS — data collection system ARGOS |
| SMS/GOES (USA) | VISSR — 2 channels, 30 min intervals WEFAX — image retransmission |
| LANDSAT-3 (USA) | MSS — imagery from 4 channels, 80 m resolution RBV — B/W 40 m resolution DCS — 64 bit messages |
| NIMBUS-7 (USA) | CZCS — imagery from 6 channels, 800 m resolution SMMR — 5 freq. microwave radiometer |
| METEDSAT-2 (ESA) ^a | — 3 channels, cloud temp. profile |

^a European Space Agency

unfortunately, it failed after only about 3 months of operation, thus providing only a limited amount of experimental data for analysis. However, the value of all-weather sensing from satellites was demonstrated and has led to definition of at least two satellite systems (ERS-1 and RADARSAT) for future deployment. The microwave sensors will provide synoptic observations of oceans, winds and waves, as well as high resolution images of ice. These and other satellites planned for future deployment are listed in Table 2.

Remote-sensing instruments for measuring oceanic parameters continue to be developed at the same rate as *in situ* measuring systems, resulting in increasing amounts of data to be processed. The user communities, such as NAFO, can help in the development of the appropriate data-processing technology for oceanographic research by defining data-product requirements. In general, remote sensing has added a new dimension of information, which is potentially useful to NAFO fishery science studies. However, the high volume of accumulated data has saturated the ground-based data-handling facilities, thus resulting in many inadequacies in data distribution.

Lists of satellite data products available from four suppliers of data relevant to the NAFO region are given in Appendices I, II, III and IV. Potential users of the products should contact the suppliers directly for detailed information on the available data and costs.

TABLE 2. Satellites planned for future deployment.

| Satellite | Launch | Sensors | |
|--------------------------|---------|---------|---|
| LANDSAT-D (USA) | 1982 | TM | — 7 channels, 30 m resolution |
| | | MSS | — 4 channels, 80 m resolution |
| NOAA-E (USA) | 1982 | AVHRR | — visible and IR imagery |
| | | TOVS | — cloud temperature profile |
| | | DCS | — data collection and storage |
| | | SARSAT | — search and rescue tracking |
| SPOT (France) | 1984 | MSS | — 3 channels with 20 m resolution, 1 channel with 10 m resolution, stereo imagery |
| ERS-1 (ESA) ^a | 1986-87 | SAR | — 30 m resolution sensors |
| | | ALT | — ocean geoid |
| | | SCATT | — wind and wave data |
| RADARSAT (Canada) | 1987-88 | SAR | — 30 m resolution sensors, ice monitoring in north |
| | | SCATT | — wind and wave data |

^a European Space Agency

Suggested Literature

- GOWER, J. F. R. (ed.) 1981. Oceanography from Space. Plenum Press, New York, NY, *Marine Science*, 13, 976 p. (Monograph containing 109 papers.)
- MacLEISH, W. H. (ed.) 1981. Oceanography from Space. *Oceanus*, 24(3): 76 p. (Collection of 10 papers.)

APPENDIX I

Satellite Data Products of the United States Environmental Data and Information Service

Numerous satellite data products are available from the Satellite Data Services Division of NOAA, only some of which are summarized below. Interested users of such data should contact the supplier whose address is given in Section 4 below.

1. Standard Photographic Products (Black and White)

Paper print, 8 × 10 inch,
 Paper print, positive or negative film, 10 × 10 inch,
 Paper print enlargement, 16 × 20 inch,
 Paper print enlargement, 20 × 20 inch,
 Paper print enlargement, 30 × 30 inch,
 Slide 35 mm from positive, negative or print,
 Positive or negative 35 mm Microfilm,
 Positive or negative 16 mm film loop,
 Six, 12 or 24 hr of data, 16 mm movie loop,
 Duplicate transparent grid overlays (GOES),
 Duplicate transparent grid overlays (AVHRR),
 Geographic gridding on GOES imagery.

2. Special Photographic Products (Black and White)

- SEASAT synthetic aperture radar (SAR) digitally processed data: 10 × 10 inch, paper print, positive transparency, or negative.
- SAR 70 mm optically processed data, reproduced from original 70 mm negative strips of various lengths up to 200 feet. Requires 4 sub-swaths for entire 100 km swath width. Images of 1/4-swath width are available as follows: 70 mm contact paper print positive transparency, or negative.
- Briefing aids for environmental satellites, including document on systems, data interpretation and application, and illustrations on film strip or slides.
- Satellite Data Analysis Charts are available on subscription basis:
 Weekly GOSSTCOMP.

Monthly Mean GOSSTCOMP.
 Weekly Regional SST.
 Gulf Stream Oceanographic Analysis.
 Great Lakes Ice and SST Charts (2 per week).
 Northern Hemisphere Snow and Ice Charts (1 per week).
 NAVY-NOAA Joint Ice Boundary Charts (1 per week).
 River Basin Snow Coverage Charts (1 per week).

3. Digital Tape Products

- a) Direct one-for-one tape copy (CCT to CCT):
 7-track, 200, 566 or 800 bpi.
 9-track, 800, 1600 or 6250 bpi.
- b) AVHRR data sets (TBM to CCT):
 9-track, 800, 1600 or 6250 bpi.
- c) TOVS data sets (TBM to CCT):
 9-track, 800, 1600 or 6250 bpi.
- d) GOES full resolution data (cassette to CCT):
 9-track, 800, 1600 or 6250 bpi.

4. Availability and Cost of Products

Further information on the products listed above and other satellite data, including cost, may be obtained from the supplier:

National Oceanic and Atmospheric Administration (NOAA)
 Environmental Data and Information Service
 Satellite Data Service Division
 World Weather Building, Room 110
 Washington, D. C. 20233
 U. S. A.

APPENDIX II

Satellite Imagery Products of the Canada Centre for Remote Sensing

The satellite products listed below are available from the User Assistance and Marketing Branch of the Canada Centre for Remote Sensing whose address is given in Section 3 below.

1. Computer Compatible Tape (CCT)

| Type | Tracks | BPI | Format |
|----------------|--------|-----------|----------|
| MSS (4 bands) | 9 | 1600 | Tape set |
| DICS | 9 | 1600 | Tape |
| NOAA (5 bands) | 9 | 1600 | Tape set |
| SEASAT | 9 | 1600/6250 | Tape set |

2. Prints and Film (Black and White)

| Type | Image Size | Scale | Format |
|-------|---------------------|-------------|------------------|
| MSS | 70 mm | 1:3,369,000 | Pos. & Neg. Film |
| | 185 mm ^a | 1:1,000,000 | Paper, Pos. Film |
| | 371 mm ^a | 1:500,000 | Paper, Pos. Film |
| | 742 mm ^a | 1:250,000 | Paper |
| RBV | 185 mm | 1:500,000 | Paper, Pos. Film |
| | 371 mm | 1:125,000 | Paper, Pos. Film |
| | 742 mm | 1:125,000 | Paper |
| NOAA/ | 185 mm | Any | Paper, Pos. Film |
| TIROS | 371 mm | Any | Paper |
| | 742 mm | Any | Paper |

^a Also available in color.

3. Availability and Cost of Products

Further information on the products listed above and other satellite data, including costs, may be obtained from the supplier:

Canada Centre for Remote Sensing
 User Assistance and Marketing Branch
 2464 Sheffield Road
 Ottawa, Ontario K1A 0E6
 Canada

APPENDIX III

Earthnet User Service Satellite Data Products

The satellite data products summarized below are available from the Earthnet User Service, whose address is given in Section 5 below.

1. LANDSAT Data

- a) Digital products:
 MSS raw data CCT.
 MSS S/C data CCT.
 RBV set of CCTs.
- b) Photographic products:
 Quick-look prints MSS.
 Quick-look microfiche MSS.
 MSS and RBV images (black and white), print or film (240, 480 and 960 mm).
 MSS color composites (3 bands), print or film (240, 480 and 960 mm).

2. SEASAT Data

- a) Digital products:
 Non-SAR individual sensor data.
 Raw SAR data on CCT in CCRS-MDA format, 100 km in range, 15 km in azimuth.
 SAR image CCT in MDA format, digitally processed, source DFVLR, 40 km in azimuth, 40 or 50 km in range.

SAR range compressed data CCT, digitally processed, source RAE, area, orientation and resolution variable.

SAR final image CCT, digitally processed, source RAE, area, orientation and resolution variable.

- b) Photographic products:
 Survey processed SAR film, optically processed, up to 1,500 mm long, 2 sub-swaths.
 Full resolution SAR film, optically processed, up to 1,200 mm long, 2 sub-swaths.
 Digitally processed SAR data, print or film (240 and 480 mm).

3. HCMM Data

- a) Digital products:
 Radiometrically corrected data, day (VIS or IR) and night (IR).
 Radiometrically and geometrically corrected data, day (VIS or IR) and night (IR).
 Night/day registration and temperature difference, superposition of night and day IR.
 Thermal inertia map.
- b) Photographic products:
 Quick-look prints, day (VIS and IR) and night (IR).
 Radiometrically or geometrically corrected data, prints or film (240 mm).
 Night/day registered image, prints or film (240 mm).
 Temperature difference image, prints or film (240 mm).
 Thermal inertia map, prints or film (240 mm).

4. NIMBUS-7 CZCS Data

- a) Digital products:
 Raw data TRLI CCT, all 6 channels.
 Raw data and radiometric tables, all 6 channels.
 Raw data, radiometric tables and geometric location information.
- b) Photographic products:
 Quick-look prints, station pass, 3 bands.
 Radiometrically corrected data, all 6 bands, prints or film (240 mm).
 Geometrically located data, all 6 bands, prints or film (240 mm).

5. Availability and Cost of Products

Further information on the products listed above and other satellite data services, including costs, may be obtained from the supplier:

ESA-Earthnet Data Services
 C. P. 64
 00044 Frascati
 Italy

APPENDIX IV

University of Dundee Satellite Image Data Acquisition and Archiving Facility

With financial support from the National Environment Research Council, Dundee University has been recording scanning radiometer data for several U. S. meteorological polar-orbiting satellites every day since August 1976. All image data are recorded unprocessed on magnetic tape and will be kept indefinitely. Also, at least data from one channel from each pass is placed on full size negative, used for producing contact prints.

Very High Resolution Radiometer (VHRR)

Recording commenced on 23 August 1976 and continued daily until the end of the second generation series on 28 February 1979. At least two recordings were taken per day, one during the morning closest to the overhead pass and one during the evening. On some days, two successive passes were taken during the morning.

Advanced Very High Resolution Radiometer (AVHRR)

First of the third generation spacecraft to carry AVHRR was TIROS-N, launched on 13 October 1978. Recordings at Dundee commenced soon after launch from two successive passes each afternoon and continued until the spacecraft failed on 1 November 1980. The second spacecraft in the series, NOAA-6, was launched on 23 June 1979. A single recording is taken each morning from the closest to overhead pass. After the failure of TIROS-N AVHRR, recordings from two successive evening passes have also been taken.

Products Available from VHRR/AVHRR Archive

- 1. Hard copy.** Primary output from the archive is hard copy photofacsimile imagery, linearized to correct earth curvature distortion. Linearization means that the scale of the images is very nearly (but not exactly) constant in all directions and at all points in the image. The images are basically in one of two categories:

- a) Full pass, with or without latitude/longitude and land outline grids. These images are contact printed from full size negatives. They can also be supplied as Xerox copies, of reduced quality, which are quite readable in terms of major weather features and are less costly.

| Magnification | Lines per cm | Size (cm) | Total lines | Grid | Coverage area |
|---------------|--------------|-----------|-------------|----------|------------------|
| VHRR × 1 | 246 | 25 × 21 | 6,250 | Optional | 5,625 × 4,400 km |
| VHRR × 2 | 118 | 25 × 25 | 3,000 | No | 2,800 × 2,700 km |
| VHRR × 4½ | 59 | 25 × 25 | 1,500 | No | 1,350 × 1,350 km |
| VHRR × 6¼ | 39 | 25 × 25 | 1,000 | No | 900 × 900 km |
| AVHRR × 1 | 177 | 24 × 16 | 4,275 | Optional | 4,700 × 3,000 km |
| AVHRR × 1½ | 118 | 25 × 25 | 3,000 | No | 3,300 × 3,300 km |
| AVHRR × 3 | 59 | 25 × 25 | 1,500 | No | 1,650 × 1,650 km |
| AVHRR × 4½ | 39 | 25 × 25 | 1,000 | No | 1,100 × 1,100 km |
| AVHRR × 9 | 20 | 25 × 25 | 500 | No | 550 × 550 km |

b) Sectorized electronic enlargements of selected sectors of the full pass image. These represent the best image quality available from the archive. Gridding of sectorized enlargements is not available, but they are linearized. Xerox copies can be supplied only if a photographic version is ordered first. Sectorized enlargements can be grey scale enhanced to bring out such features as sea-surface temperature in IR images. A summary of sizes and areas covered is given in the table above.

- 2. Browse file.** A full pass gridded image from at least one channel (usually IR) of every pass recorded in the archive is placed in the station browse file. It may be consulted by any data user. Periodically, the images in the file are photographed on 35 mm film negative. These are then contact printed on 20 × 25 cm sheets with 36 images per sheet. The sheets can be normal positives or positive transparencies. Despite the small size of the images, cloud features can be seen with the aid of a magnifying glass. These browse file sheets of miniature images are distributed regularly to users on the mailing list. Back copies are available. A complete set, with instructions, is maintained at the London Weather Centre for public access.
- 3. Computer compatible tapes (CCT).** Transcripts of raw data of selected scenes from the tape archive can be supplied. These data contain the output from all spacecraft instruments and all channels of the AVHRR. Documentation has to be performed by the user's software. The 10-bit words from the spacecraft are grouped in threes to form 4 8-bit words on the tape. Details of the tape format can be supplied on request. VHRR CCTs are not available.

Coastal Zone Color Scanner (CZCS)

The NASA experimental satellite NIMBUS-7,

launched in October 1978, carries the CZCS, which is often but not always switched on during daytime passes over European areas. Recordings at Dundee commenced on 3 August 1979.

Products Available from CZCS Archive

- 1. Hard copy.** Any of the six channels may be hard copied in a photo facsimile machine to produce an unlinearized image size of 25 × 25 cm covering an area of 1,200 km (N-S) by 1,500 km (E-W). Alternatively, 512 × 512 pixel scenes of any selected area can be produced on the same size photographic paper.
- 2. Computer compatible tapes (CCT).** Transcripts of raw data can be supplied, as for AVHRR, except that the data are already in 8-bit words.

Non-routine Recordings

Extra recordings from satellite passes to the east or west of the United Kingdom can be taken by prior arrangement, in support of scientific projects. These recordings are placed in the archive and products, as described above, are made available to the project scientists. Dundee also has a METEOSAT Primary Data User Station, which can be used to record data as required. METEOSAT data are not archived routinely.

Enquiries

Information on satellite data products and costs may be obtained from the supplier:

Department of Electrical Engineering and
Electronics
The University of Dundee
Dundee DD1 4HN
United Kingdom

