ICEBERGS IN ERS-1 SAR IMAGES

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Abstract

The ERS-1 satellite is ideally positioned for the acquisition of synthetic aperture radar (SAR) imagery of the polar regions. These regions contain many hazards both for shipping and for drilling rigs. The IPAP project includes development of a demonstration system for the automatic extraction of ice feature products from ERS-1 SAR data. These products include sea ice extent, concentration and type; sea ice motion information both in the marginal ice zone and in open water; and iceberg detection and motion extraction. Results from the system, in chosen areas, may be sent by fax to operators in the field.

1. Introduction

Drifting icebergs represent a major hazard both to drilling rigs and to shipping operating in high latitudes and polar regions. They are formed when large pieces of a glacier break off the main mass into the sea, and are transported under the influence of currents, wind and tide. Icebergs appear in a wide variety of sizes from the largest icebergs and ice islands with diameters from 200 m (to several tens of kilometres) down to the smallest 'growlers' with an exposed surface area of only 6 m^2 or less. However, even growlers may weigh around 500 tons and pose a significant threat to operators in these areas. In order that ships may navigate successfully through iceberg ridden waters, the location of icebergs, and regions of high iceberg density must be identifiable. Similarly the Master of an oil rig will wish to be informed whenever icebergs enter alert zones surrounding the rig, or to assist in planning whenever the rig is too be placed in a region of high iceberg density.

ERS-1 is a near polar orbiting satellite operating at an altitude of approximately 780 km. Among other instruments ERS-1 carries a C-band SAR capable of producing images 100 km square at a resolution of 25 m. This satellite is ideally placed for the generation of images of the ocean at high polar latitudes.

Icebergs are imaged by ERS-1 SAR by virtue of two scattering mechanisms: surface scattering from the rough ice surface, and volume scattering from internal reflections within the bergs. These mechanisms tend to make icebergs appear as clusters of bright pixels against the dark ocean background. Allied to this there is often a region of dark sea pixels in the region of the berg which may be caused by a number of processes, including: wind shadows in the lee of the berg; wave suppression by the submarine component of the berg; and fresh water caused by melting of the berg surface. These bright and dark pixel cluster features make many icebergs identifiable in ERS-1 SAR images

2. The IPAP system

The ERS-1 Pilot Application Project for Polar Operations (IPAP) involves the development of techniques and algorithms for dealing with ERS-1 SAR images of polar oceans. The system has been designed to extract data from images for both sea ice and iceberg features using a range of processing and presentation techniques. These include:

- Preprocessing, to read the image in CEOS format from disk, average the pixels to produce an image of manageable size, transform to a map projection coordinate system (UTM or UPS), tiepoint to ground truth position if available and to mask out areas of land;
- Segmentation, of the image into different surface cover types, this leads into;
- Classification, of the segmented data into a range of classes including: water, first-year sea ice, multi-year sea ice, etc. Either supervised or neural net based classifiers may be used along with data from a range of training data sets;
- Sea Ice Concentration and Edge, to produce displayable and faxable products showing the effective position of the ice edge in the image and a range of contours showing the concentration density of the sea ice in the area from the lowest $^1/_{10}$ (passable by icebreakers) through to the highest $^{10}/_{10}$ (impassable even by icebreakers);
- Sea Ice Motion, tracking the movement of the sea ice both in the marginal ice zone and in pack ice, generated from a pair of images separated by a few days,

• Iceberg Detection, to detect clusters of features corresponding to icebergs in the open ocean;

• Iceberg Motion, tracking the movement of icebergs in a pair of images separated by a few days.

3. Iceberg detection

Figure 1 shows a small subimage of an ERS-1 SAR scene. The data displayed is at full resolution. This is

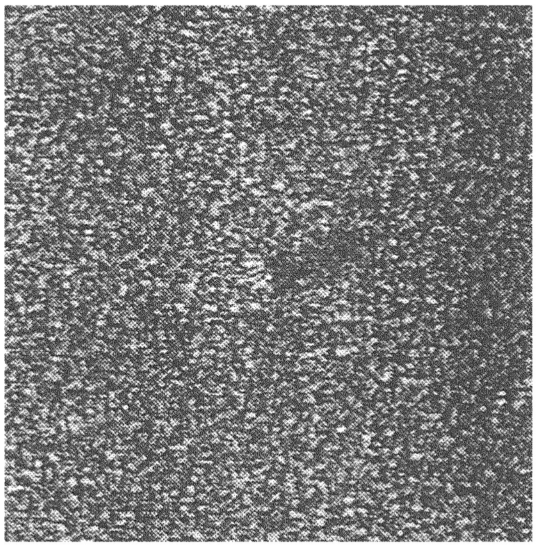

Figure 1. Iceberg in ERS-1 SAR image.

averaged from the original 12 5 metre square pixels to produce an image with pixels 100 metres square, i.e. by a factor of eight in each direction This has the effect of reducing the speckle inherent in all SAR images and also of reducing the magnitude of the data to be analysed. The backscatter signature of an iceberg is clearly visible in the centre of the figure as a cluster of bright pixels with a neighbouring cluster of dark sea pixels. Therefore an algorithm which detects clusters of bright pixels lying next to clusters of dark pixels will form a suitable basis for a system for the automatic detection of icebergs in SAR data This is the technique used in the IPAP system. Firstly, the image data is acted upon by the normalisation filter. This removes the background variations in the image and allows a constant threshold to be used everywhere The normalised image is then thresholded to pick out the pixels which are brighter than, or darker than, the user selected values. The two binary images are passed through morphological operators to cluster the pixels together, and to remove single pixel features The bright and dark binary images may then be merged to locate the features with the iceberg type signature

4. Faxable results

Production of results with the IPAP system is useful for improving interpretation of images at polar latitude, and for increasing knowledge of the sea ice and iceberg history in an area. However, if results produced with IPAP are to be useful to operators 'in the field' several constraints to the output results must be introduced

Firstly, if the data are to be relevant to the operator's current circumstances the results must be available as soon as possible. As far as the IPAP project is concerned this means fast processing by the system, and a high speed transmission of results to the operator. The former may be achieved by the use of powerful workstation systems, the later by various means.

The second constraint is that the results delivered to the operator should be in a highly interpreted state. The higher the level of interpretation provided by the IPAP system, the less interpretation is required by the operator. It is hoped that products provided to ships and rigs will not require an expert on sea ice and icebergs to understand them. Highly interpreted data also has the advantage of being considerably smaller in volume than data requiring significant further analysis. For example, the raw image data (the lowest form of interpretation) has a significantly larger data volume than an IPAP derived list of icebergs produced from the image.

The last major constraint is that the results produced by IPAP must be transmissible by standard means Operators required to invest heavily in sophisticated reception equipment for this data will be less easy to convince of its value.

The answer to all of these problems would seem to be provided by the production of facsimile (fax) output from the IPAP system. Most operators, both on ships and drilling rigs, already have access to this equipment. It is quick and easy to use, and provides monochrome line drawing and text transfer. The IPAP algorithms for iceberg detection and motion, and for sea ice classification and motion, produce this type of output. Figure 2 shows a typical faxable output for iceberg detection.

5. Acknowledgements

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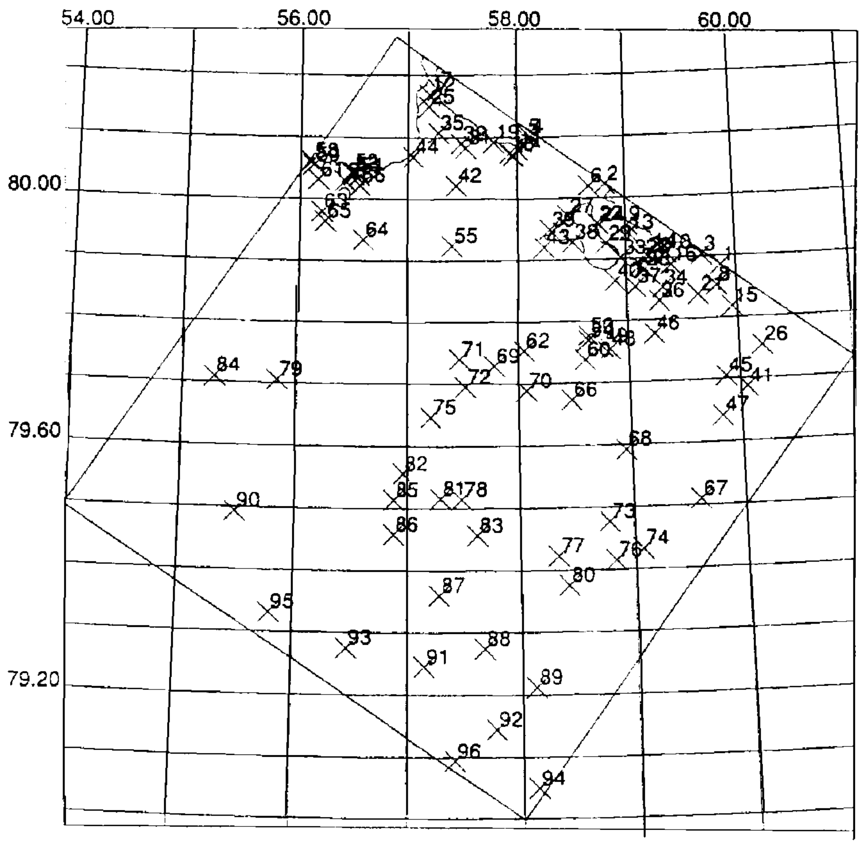

IPAP results for: Iceberg Detection

Image Acquisition Date: 16/09/1992
Image Acquisition Time: 08:54:48
Image Orbit Number: 0
Image Frame Number: 0
IPAP processing date: Mon Mar 7 14:40:12 1994

Figure 2. Detected icebergs plotted by IPAP.

GLOSSARY

ADPC	Asian Disaster Preparedness Centre
AIDAB	Australian International Development Assitance Bureau
ARTEMIS	Africa Real Time Environmental Monitoring Information Service
AVHRR	Advanced High Resolution Radiometer
AWS	Automatic Weather Station
BBC	British Broadcasting Corporation
CCD	Cold Cloud Duration
CEOS	Committee on Earth Observing Satellites
CGLR	Consultative Group on Locust Research
CNES	Centre National d'Etudes Spatiales (French space research agency)
CNN	Cable Network News
COSPAR	Congress for Space Research
DEM	Digital Elevation Model
DHA	Department of Humanitarian Affairs (of United Nations)
ENSA	El Nino Southern Oscillation
EOS(DIS)	Earth Observing System (Data and Information System)
ERS-1	European Remote Sensing Satellite
ESA	European Space Agency
EUMETSAT	European Organisation for the Explotation of Meteorological Satellites
FAO	Food and Agriculture Organization of the United Nations
FD	Fast Delivery
FIRE	Fire In global Resources and Environmental monitoring
GAC	Global Area Coverage
GIEWS	Global Information and Early Warning System
GIS	Geographical Information System
GISSIZ	Geographic Information System in Slope Instability Zonation
GMS	Japanese Geostationary Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
GTS	Global Telecommunications System
HIROS	High Resolution Optical Satellite
HRPT	High Resolution Picture Transmission
IAEG	International Association of Engineering Geologists
IAF	International Aeronautical Federation
ICAO	International Civil Aviation Authority
ICSU	International Commission of Scientific Unions
IDNDR	International Decade for Natural Disaster Reduction
IGBP	International Geosphere Biosphere Program
INPE	Brazilian National Institute for Space Research
IPAP	ERS-1 Pilot Application Project for Polar Operations
IPCC	Intergovernment Panel on Climate Change
ITC	International Institute for Aerospace Surveys and Earth Sciences
JERS-1	Japanese Environmental Research Satellite (Fuyo-1)
JPL	Jet Propulsion Laboratory
LANDSAT	American commercial earth observation satellite
LARST	Local Application of Remote Sensing Techniques
METEOSAT	European meteorological satellite
MSS	Multispectral Scanner (sensor on Landsat)
NASA	National Aeronautical and Space Adminstration
NASDA	Japanese space agency
NDVI	Normalised Difference Vegetation Index
NMHS	National Meteorological and Hydrological Services
NOAA	National Oceanic and Atmospheric Administration

NRI	Natural Resources Institute
NRFD	Number of Rainfall Days
NWP	Numerical Weather Prediction
ODA	Overseas Development Agency
PC	Personal Computer
RADARSAT	Canadian radar satellite
RAMSES	Reconnaissance and Management System of the Environment of Schistocera (Desert Locust)
SAR	Synthetic Aperture Radar
SPOT	Systeme Probatoire d'Observation de la Terre (French remote sensing satellite)
SSMI	Special Sensor Microwave Imager (passive microwave)
SST	Sea Surface Temperature
SWIR	Shortwave infrared
TAMSAT	Tropical Applications of Meteorology using SATellites and other data
TCC	Tropical Cyclone Committee
TCWC	Tropical Cyclone Warning Centres
TIMS	Thermal Infrared Multispectral Scanner (JPL sensor)
TIR	Thermal Infrared
TM	Thematic Mapper (sensor on Landsat)
TMU	Terrain Mapping Unit
TOPSAR	Topographic SAR
TOVS	Tiros Operational Vertical Sounder
TREES	TRopical Ecosystem and Environmental observations by Satellite
TRMM	Tropical Rainfall Mapping Mission
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNDP	United Nations Development Programme
UNDRO	United Nations Disaster Relief Organization (now DHA)
UTM	Universal Transverse Mercator
UPS	Universal Polar Stereographic
VIS	Visible
VMS	Vanuatu Meteorological Service
VNIR	Visible and Near Infrared
WMO	World Meteorological Organisation
WOVO	World Organization of Volcano Observatories
WWW	World Weather Watch

Existing and planned remote sensing satellites and instruments with application or potential use in disaster mitigation[1]

[1]Satellites are listed in order of their launch dates. Only existing and planned satellites are listed. Up-to-date information is difficult to obtain because of satellite loss and launch delays. Furthermore, information on sensors and satellite parameters is sometimes incomplete.

Some of the acronyms under "Sensors" are:

AVHRR	Advanced Very High Resolution Radiometer
MSS	Multispectral Scanner
SAR	Synthetic Aperture Radar

Under "Status", O = Operational, C = Commercial and EX = Experimental
The designation "O" was used for the SAR instruments. The large number being launched in the early 1990's probably signifies a continuing commitment so these systems may be considered operational.

"Resolution" is the instantaneous field of view (IFOV) and is generally much less than the size of the smallest object which can be identified.

SATELLITE	SENSOR	SOURCE	LAUNCH	STATUS	COVERAGE	RESOLUTION	BANDS	APPLICATIONS
GMS		Japan	1984	O continuing	Geosynch. hemispher, continuous			Geosynchronous meteorological observation of the Pacific and its rim, tracking severe storms, rainfall estimation
Landsat	Thematic Mapper	US	1984	C, continuing	16 day, 185 km swath	30 m (120 TIR)	4 visible/near infrared 2 mid infrared 1 thermal	Landuse, vulnerability assessment hazard assessment, flood plain mapping, etc
NOAA 9 through J	AVHRR	US	1984	O continuing	Global 1/day, 1 1 km 2400 km swath	1 1 km	2 visible, near infrared 1 mid infrared 2 thermal	Visible and infrared imagery, infrared atmospheric sounding and ozone measurements. Rainfall estimation, snow mapping, flood mapping, drought assessment
Meteor-2	Scanner	USSR	1986	O, continuing	Global 1/day	2- and 8 kilometres	Visible infrared	Polar orbiting meteorological observations Rainfall estimation, snow mapping, flood mapping
SPOT	HRV	France	1986	C continuing	Every 3 or 4 days (60 km swath)	10 (pan), 20 (spectral)	4 visible bands or panchromatic	Landuse, vulnerability assessment, hazard assessment, flood plain mapping, damage assessment, landslide warning, etc.
DMSP	OLS	US	1987 (5D-2/FB)	O, continuing	Global 1/day	620 metres	1 visible 1 thermal infrared	US Defence Dept. meteorological satellites, older imagery broadly available
GOES	Imager	US	1987 (GOES-7)	O, continuing	Geosynch. hemispher., continuous	51 km visible, 4/8 km IR	5 bands from visible to thermal infrared	Geosynchronous observations by (nominally two) satellites stationed at equator over US east and west coasts Useful for severe storm tracking, rainfall estimation, etc
Feng Yung	AVHRR scanners (2)	China	1988	O, continuing	Global 1/day	1 1 km	4 visible 1 thermal infrared	Operated by State Meteorological Administration Useful for rainfall estimation, monitoring drought, snow mapping, flood mapping etc

INSAT		India	1988	O	Geosynchr hemispher , continuous	2 75 km visible 11 km IR	1 visible 1 thermal infrared	Geosynchronous meteorological and communications satellite over the Indian sub-continent. Geosynchronous meteorological observations of the region, tracking severe storms, rainfall estimation
IRS (Indian Remote Sensing)		India	1988	O		70 and 35 metres	3 visible 1 infrared	Polar orbiting satellite; data not generally distributed Landuse, vulnerability assessment, hazard assessment, flood plain mapping, etc.
Meteor-3	Scanner	USSR	1988	O	Global 1200 km orbit	1 and 3 km	Visible and infrared	Visible and infrared imagery, infrared atmospheric sounding and ozone measurements Rainfall estimation, snow mapping, flood mapping, drought assessment
N-2 (Resource Series)	MSS-E	USSR	1988	O?	-10 days, 900 km swath	45 x 33 metres	2 visible 1 near infrared	Question of availability May be used for landuse mapping, vulnerability assessment, hazard assessment, flood plain mapping, etc
N-2 Resource Series)	MSS-SC	USSR	1988	O?	-10 days, 600 km swath	170 x 245 m	2 visible 2 near infrared 1 thermal (600x820 m res)	Question of availability May be used for landuse mapping, vulnerability assessment, hazard assessment, flood plain mapping, etc
Meteosat		EUMETSAT (Europe)	1988 (P2)	O, continuing	Geosynch hemispher , continuous	2 5 and 5 kilometres	1 visible/near infrared 1 mid infrared 1 thermal infrared	Geostationary observations of meteorological phenomena from station over European longitude at equator, tracking severe storms, rainfall estimation
Ocean-01	MSS-L	USSR	1990	EX	Global	2 km	2 visible 2 near infrared	
Ocean-01	MSS-M	USSR	1990	EX	Global	370 metres	1 visible 1 infrared	
Ocean-01	Radar (Side looking)	USSR	1990	EX	Global	1 5 km	3 2 cm	
ERS-1	Microwave altimeter	ESA	1991	O*				For monitoring ocean currents
ERS-1	SAR	ESA	1991	O*		30 metres	C-Band	Cloud-penetrating radar for improved frequency of coverage at good spatial resolution Monitoring dynamic phenomena
ERS-1	Scatterometer	ESA	1991	O*				Determine wind speeds in range 4 - 24 m/s with 20% accuracy, +/- 20 degrees in direction. For improved storm tracking and warning
Almaz	Radar imagery	USSR	1991 Mar	C	Global	15 m		High resolution imagery available for purchase
JERS-1	SAR	Japan	1992, Feb	O*	44 days, 75 km swath	18 metres	L-band	High resolution cloud-penetrating imagery with potential use for flood plain mapping, land cover, land use and vulnerability mapping
JERS-1	Scanner	Japan	1992, Feb	O	44 days, 75 km swath	18 x 24 metres	3 visible and near infrared 4 shortwave infrared 1 stereoscopic band	Landuse, vulnerability assessment, hazard assessment, flood plain mapping

TOPEX/POSEIDON	Altimeter	US/France	1992, July	O				Mapping topography of ocean surface, ocean currents
TOPEX/POSEIDON	Scatterometer	US/France	1992, July	O				Mapping wind speed and direction at the ocean surface, useful for severe storm warning
SeaWiFS		US	1993, Aug	C				Mapping biomass in the oceans
ERS-2		ESA	1994	EX				Ozone mapping and monitoring
NOAA K - N	Various	US	1994 (start)	O			Visible/infrared/ mimicrowave imagery, infrared atmospheric sounding, ozone measurements	Microwave imagery at 10's of km resolution may be useful for soil moisture determination or flood mapping
Radarsat	AVHRR	Canada	1994, Dec	O*	Daily, 2900 km swath	1.1 km	5 visible to thermal infrared	Monitoring vegetation biomass, estimating rainfall rates (from clouds) snow mapping
Radarsat	SAR	Canada	1994, Dec	O*	100 km swath	15-30 metres	C-Band	High resolution cloud-penetrating imagery with potential use for flood plain mapping, land cover, land use and vulnerability mapping
Radarsat	Scatterometer	Canada	1994, Dec	O*	Daily (600 km 25 km swath)			Mapping wind speed and direction at the ocean surface; useful for severe storm warning
ADEOS	AVNIR	Japan/US	1995	EX	4 days 80 km swath	16 m spectral 8 m pan	3 visible 1 thermal 1 panchromatic (visible)	Landuse, vulnerability assessment, hazard assessment, flood plain mapping, damage assessment, landslide warning, etc
ADEOS	NSCAT scatterometer	Japan/US 1995	EX	Daily, 1200 km swath			14 GHz	Wind speed at ocean surface to within 2 m/sec and 20 degrees accuracy Useful for mapping wind speed and direction at the ocean surface, useful for severe storm warning
ADEOS	OCTS	Japan/US	1995	EX	Daily, 1400 km swath	700 m	6 visible 2 near infrared 1 mid infrared 3 thermal	Monitoring vegetation biomass, estimating rainfall rates (from clouds), snow mapping
TRMM	AVHRR imager	US/Japan	1997, Feb	EX	+/- 35 degrees latitude		Visible/infrared	Link other sensors on TRMM and other spacecraft observations Useful for monitoring vegetative biomass, estimating rainfall rates (from clouds), snow mapping
TRMM	Microwave radiometers (2)	US/Japan	1997, Feb	EX	+/- 35 degrees latitude		19, 37 and 85 GHz ("Moderate resolution" 19 GHz "High resolution"	Detect rainfall rates over oceans from 10 to 20 mm/hr Useful for predicting tracks and severity of storms.
TRMM	Scanning radar	US/Japan	1997 Feb	EX	+/- 35 degrees latitude	3 km		Rainfall rates over land and sea May be very useful for flood prediction
ADEOS-II		Japan/US	1998	EX			Visible, near infrared and microwave imagery	Global change measurements, scatterometry and laser atmospheric sounding
EOS-AM		US	1998	EX				Global change measurements, visible, near IR imagery, radiation budget, CO and CH_4

EOS-COLOR		US	1998	EX		Purchase of ocean colour data to monitor ocean productivity
POEM-1		ESA	1998	EX	Visible/infrared imagery	Global change and meteorological measurements scatterometry tropospheric and stratospheric chemistry etc
EOS-AERO		US	2000	EX		Global aerosols and stratospheric chemistry
EOS-PM		US	2000	EX		Global change measurements visible and infrared, radiation budget and hydrologic cycle
TRMM-2		Japan	2000	EX		Precipitation and related variables, Earth radiation budget in the tropics
NOAA O-Q	O	US	2001 (start)	O	Visible/infrared imagery, IR/ microwave soundings ozone measurements	
EOS-ALT	Laser radar altimeters	US	2002	EX		Ocean and sea ice altimetry
EOS-CHEM		US	2002	EX		Atmospheric chemistry and ocean surface scatterometry