WASTAC

Western Australian Satellite Technology and Applications Consortium

2001 ANNUAL REPORT

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2001 Annual Report

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Front Page
An NDVI/Biomass map and Pasture Growth Rate index map derived from NOAA/AVHRR imagery composited and processed by DOLA from WASTAC supplied data. The data assists in the management of rural land and supports decision processes of farmers and agribusiness.

Editors
R. Stovold DOLA , SRSS
A.F. Pearce, CSIRO

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CONTENTS

Improve the economy, society and environment through the acquisition of satellite observations of Western Australia and its oceans for research and near real-time applications.

WASTAC X-band Receiver Installation
Lifting the completed radome and X-band antenna assemby onto the top of the Environmental Sciences building at Murdoch University.

WASTAC CHAIRMAN'S REPORT 2001

WASTAC achieved three major milestones in 2001, with the extension of our reception capability to X-band, acquisition of data from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and the admission of Murdoch University and Geoscience Australia as members.

Thus WASTAC's collection of data on the spatial and temporal variability of our weather and renewable resource base has been significantly enhanced. Key variables derived from these new data increase the opportunity to revolutionise the way Australia manages significant parts of its renewable resource base by applying the key axiom " To Measure is to Manage" . Where high spatial-temporal variability exists in the resource base, remote sensing combined with conventional point measurements is the only way to truly apply this axiom.

" ...the opportunity to revolutionise the way Australia manages significant parts of its renewable resource..."

Capacity to achieve this has now taken a quantum leap forward. Compared with the current NOAA-AVHRR and SeaWiFS sensors, MODIS on TERRA provides six times more spectral resolution, four times greater radiometric resolution and up to sixteen times higher spatial resolution, thus enabling the simultaneous measurement of a wide array of atmospheric, oceanic and terrestrial variables in space and time. In 2002 data from the Atmospheric Infrared Sounder (AIRS) on AQUA with 2300 spectral channels will provide much higher resolution than currently provided by the Tiros Operational Vertical Sounder (TOVS) with 27 channels.

The collection of all these data is of little value if the information is not extracted and made widely accessible in near real-time. Thus the Bureau of Meteorology daily ingests the vertical sounder data from the TOVS sensor covering the Indian Ocean into meteorological models for weather forecasts essential for renewable resource management. Similarly other information is being used to forecast biomass outcomes resulting from the complex interaction between weather, a highly weathered land surface and historical management. Other applications of NOAA-AVHRR include location of Plague Locust breeding, Drought and Frost damage delineation, Wheat and Pasture Production Forecasts, Fire Hot Spots detection, Fire History Mapping, Seasonal Assessment of rangelands and Fishing Hot Spots to locate fish schools. Work with SeaWiFS data continues to indicate the potential to measure the spatial-temporal variability of the phytoplankton resource of the oceans, with an operational outcome now achievable with MODIS.

WASTAC's initiative to collect MODIS has created the momentum for a $111 million proposal for a Cooperative Research Centre for Application of Earth Observations to accelerate the capture of these opportunities for Australia's renewable resource sector. A total of 28 participants have combined to contribute $14.4 million of cash and $76.8 million of in-kind for the outcome of "To Measure is to Manage".

I thank the members for their ongoing support of WASTAC and welcome our new members for an exciting journey of discovery for, in the complex remote sensing business, another axiom of progress is "Partnership or Perish".

Richard Smith

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WASTAC BOARD

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WASTAC STRATEGIC PLAN

VISION

Improve the economy, society and environment through the acquisition of satellite observations of Western Australia and its oceans for research and near real-time applications.

MISSION

The mission of WASTAC is to :

- Provide high speed access to NOAA (TOVS and AVHRR) and SeaWiFS satellite data to members on a non-profit basis
- Contribute these data for national and international initiatives in remote sensing
- Adopt recognised data formats to ensure wide access to WASTAC data
- Maintain the integrity of archived data for research and operational applications
- Promote the development and calibration of value-added products
- Ensure maximum use of NOAA, MODIS and SeaWiFS data in the management of renewable resources.

FUTURE STRATEGIES

- Develop internet quicklook and promote archived data.
- Update the communications, ingest and reception equipment by a process of planned asset replacement
- Review future satellite reception opportunities in both L and X-band and plan new assets (e.g. antenna) to capture these opportunities
- Expand acquisition and distribution of satellite data through high speed communication links
- Identify new national and state opportunities in environmental monitoring for sustainable development utilising WASTAC satellite data
- Identify new requirements for improved exploitation of WASTAC data.

FUTURE SATELLITE OPPORTUNITIES

- MODIS on Aqua (2002) (X-band)
- METOP (Replaces NOAA in 2005) (X-band)

Radome
Radome top being lowered onto the WASTAC X band receiver assembly.

OPERATIONAL STATUS

Don Ward , Regional Computing Manager
Bureau of Meteorology(BOM): Perth
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WASTAC facilities now embrace both L Band and X Band reception. The X Band facility at Murdoch University was commissioned on the 21st November 2001.

WASTAC L

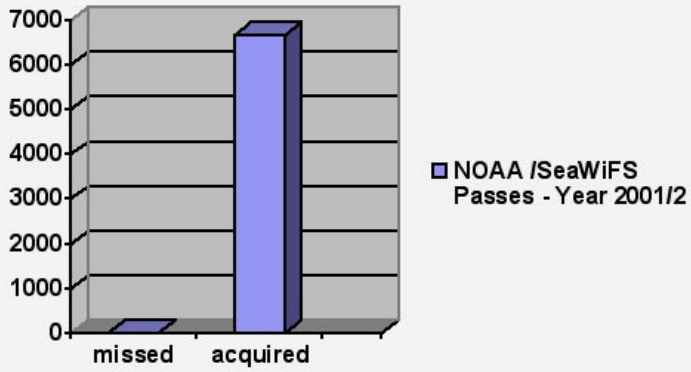
WASTAC L Band facilities consist of 2.4m antenna and antenna controller at Curtin University of Technology, ingest and display computers with hard disk storage and tape archive facilities, located at the Bureau of Meteorology premises at 1100 Hay Street, West Perth. A low speed uni-directional microwave link connects the antenna to the ingest computers. A high speed microwave communications system was installed in June 1996, allowing the transmission of raw and processed satellite data between the Leeuwin Centre, Curtin University, and the W. A. office of the BOM {Bureau of Meteorology}. The high speed microwave link was upgraded from 2 to 4 megabits per second in November 2001.

Colour and grey scale quicklook pictures are produced at Department of Land Administration's (DOLA) Satellite Remote Sensing Service (SRSS) in near realtime for archive, indexing and distribution. The raw data archive is produced on 20 GB DLT tape and a duplicate copy is currently produced for a national NOAA data archive program that is coordinated by CSIRO Office of Space Science and Applications (COSSA) in Canberra.

The AVHRR ingest and display system, developed and installed by the Bureau of Meteorology in September 1996 consists of two HP UNIX workstations, one provided by WASTAC and the other by BOM. Software systems were upgraded late in 1999.

The ingest program runs on both workstations providing display, processing and backup facilities. The TOVS data, a subset of AVHRR, is automatically sent to the Bureau of Meteorology in Melbourne so that atmospheric temperature retrievals can be included in the global numerical weather prediction models. Sea surface temperatures (SST) are being produced by the BOM and DOLA. DOLA is able to produce vegetation maps and monitor fire scars in near realtime. NOAA and SeaWiFS archive information are posted to DOLA's World Wide Web page.

Equipment failures during the year resulted in the loss of 3 days of data.
Due to the dedicated efforts of DOLA and BOM staff, a total of 5844 NOAA and 811 SeaWiFS passes were recorded for the year.



WASTAC X

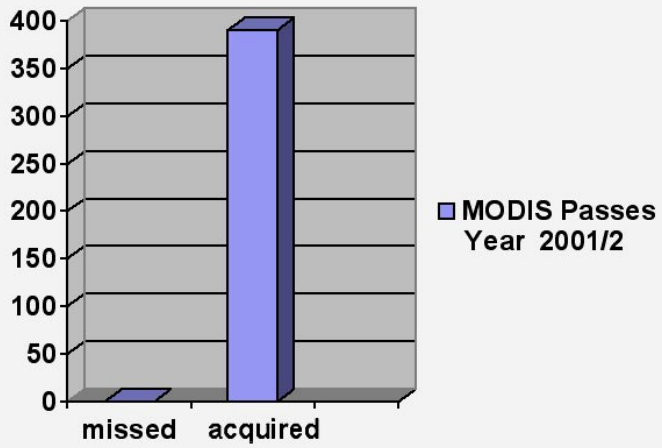
WASTAC X Band facilities consist of a 3.6m radomed autotracking antenna and antenna controller computer at the Environmental Science building at Murdoch University. The X band reception facility is directly connected to the high speed PARNET at the Murdoch University node which allows data transfer to DOLA and then via the internet to other members of WASTAC.

During installation in September 2001 a strong interfering source was located nearby. This was found to be a local microwave transmitter at Murdoch University. After the installation on the microwave transmitter of a 20 dB attenuator, on 1st December 2001, the noise level received was reduced dramatically, adding over 25% to the length and number of passes received.

Quicklook pictures are produced at SRSS in around 1 hour for archive, indexing and distribution. The raw data archive is produced on 35 GB DLT tape.

The X band ingest and display system, developed and installed by SeaSpace Corp. in September 2001, consists of a Sun Sparc 400 workstation, antenna and reception hardware at Murdoch University and a dual CPU LINUX processing computer at DOLA in Floreat.

There have been no days of data lost due to equipment failures during the year.
Due to the dedicated efforts of DOLA, Murdoch University and BOM staff, a total of 390 X band MODIS passes from the Terra satellite were recorded for the year.



ARCHIVE STORAGE

DOLA is currently holding the archive on 8mm exabyte and on DAT tapes.
20 GB DLT tape was introduced as archive media late in the year 2000 for L band data and, during 2001, 35 GB DLT for the X band data.

Orders for digital data can be provided via the internet or on 8mm data tape, DAT tape, DLT tape, CDRom or 6250/1600bpi magnetic tape.

RECENT DEVELOPMENTS AND FUTURE DIRECTIONS

WASTAC X consortium was formed and the WASTAC X band facility at Murdoch University was installed in September 2001.

An Internet connected Linux control computer was installed at the Curtin University Antenna site late in 2001.

WASTAC has setup an Internet site – www.wastac.wa.gov.au as a promotional vehicle for current and future WASTAC activities.

A proposal is being prepared that will provide backup NOAA L Band reception as an addon to the X Band ingest facility at Murdoch University.

AIRS and MODIS data will be received by the X band facility from the Aqua satellite due to be launched in 2002.

WASTAC DATA ARCHIVE

The WASTAC archive of NOAA and SeaWiFS satellite passes, managed and maintained by the Department of Land Administration (DOLA) Satellite Remote Sensing Services (SRSS) group, is held at the Leeuwin Centre in Floreat,W.A.

DOLA actively manages the daily archive and management systems which have been installed to ensure rapid and reliable delivery of WASTAC satellite data for research and wider community use.

A total of 5844 NOAA passes were archived for 2001. Passes comprised data from the NOAA 12, NOAA 14, NOAA 15 and NOAA 16 satellites.All passes were stored on 20 DLT tapes.

The archiving of SeaWiFS data onto 4mm data tapes commenced on 31 October 1997. During 2001, 811 SeaWiFS passes had been archived to 6 data tapes.

Following the successful installation of the X Band receiving facility at Murdoch 385 MODIS passes have been archived on 8 DLT tapes comprising 340 gigabytes of information.

We continue to maintain the near real time quick-look archive of NOAA-AVHRR data on the world wide web. The digital archive holds data from the present time back to 1983. A similar archive of SeaSiFS quick-look data is also held on the world wide web.

Email addresses to view this archive are

NOAA
http://www.rss.dola.wa.gov.au/noaaql/NOAAql.html

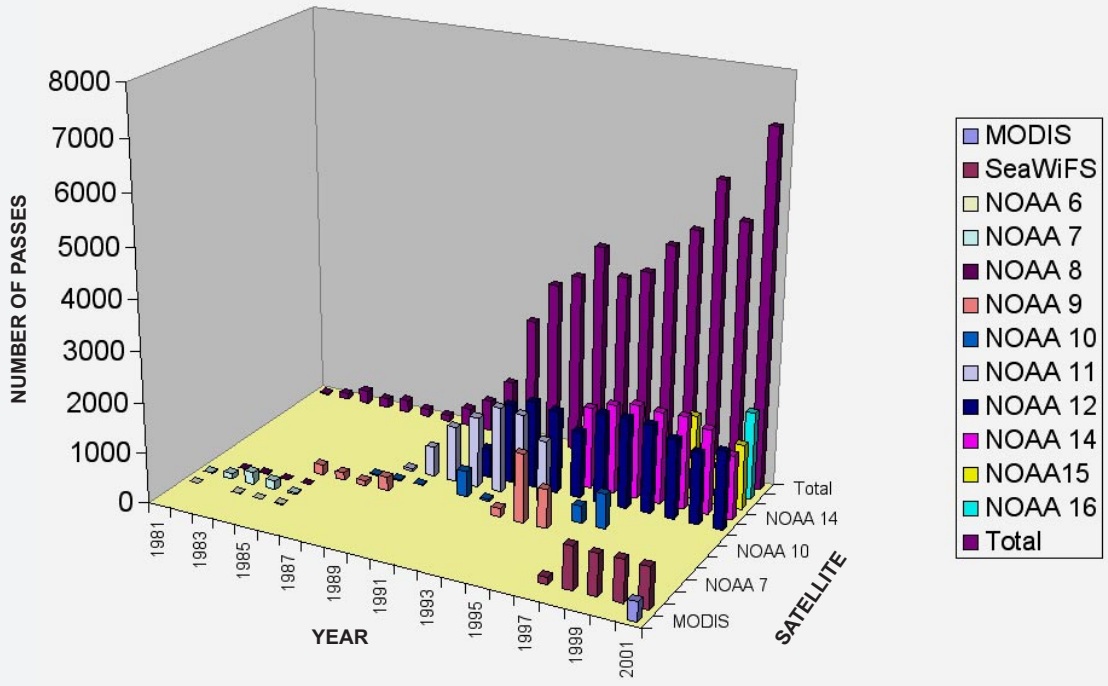
SeaWiFS
http://www.rss.dola.wa.gov.au/seawifsql/SeaWifSQl.html

MODIS
http://www.rss.dola.wa.gov.au/modisql/MODISql.html

TOTAL NUMBER OF SATELLITE PASSES HELD IN WASTAC ARCHIVE AT THE LEEUWIN CENTRE

	MODIS	SeaWiFS	NOAA 6	NOAA 7	NOAA 8	NOAA 9	NOAA 10	NOAA 11	NOAA 12	NOAA 14	NOAA15	NOAA 16	Total
1981			5	22									27
1982				115	1								116
1983			12	244	12								268
1984			7	179	4								190
1985			7	33	4	212							256
1986						151							151
1987						97	18						115
1988						280	25	53					358
1989							21	601					622
1990								1103					1103
1991							506	1399	575				2480
1992							47	1693	1571				3311
1993						183		1656	1720				3559
1994						1362		1227	1641				4230
1995						770			1326	1615			3711
1996							354		1780	1776			3910
1997		142					694		1797	1876			4509
1998		859							1763	1828	432		4882
1999		822							1589	1839	1663		5912
2000		843							1427	1681	905	341	5197
2001	390	811							1548	1271	1292	1733	7045

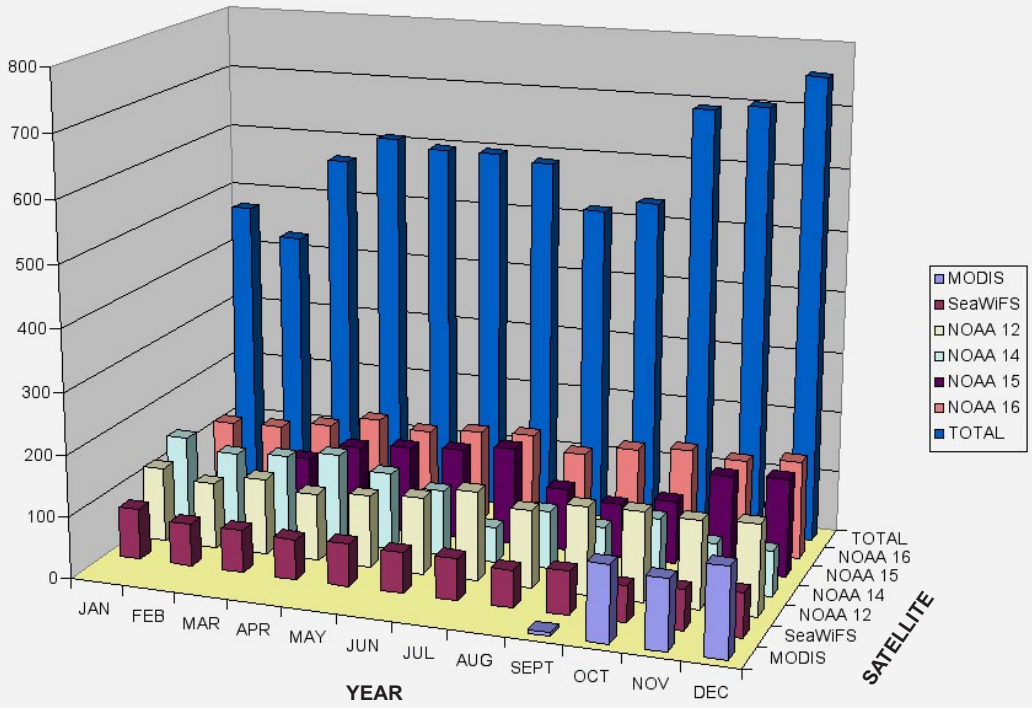
Held as: 57 Curtin archive 8mm tapes
1282 WASTAC archive 6250 bpi tapes (copied to 44 8mm tapes)
835 WASTAC archive 8mm tapes
427 WASTAC archive 4mm tapes
39 WASTAC archive DLT tapes



WASTAC SATELLITE DATA ARCHIVE FOR 2001

	MODIS	SeaWiFS	NOAA 12	NOAA 14	NOAA 15	NOAA 16	TOTAL
JAN		83	122	147		119	471
FEB		68	107	129		123	427
MAR		69	124	135	103	134	565
APR		65	110	147	133	153	608
MAY		69	117	125	142	143	596
JUN		66	124	107	148	151	596
JUL		68	145	57	160	156	586
AUG		60	126	94	102	133	515
SEPT	6	70	142	78	87	151	534
OCT	123	58	144	104	103	159	691
NOV	113	64	141	74	154	151	702
DEC	143	71	146	74	160	160	754

	NOAA	SeaWiFS	MODIS
Tapes	5844 passes on 20 DLT	811 passes on 6 4mm tapes	385 passes on 8 DLT
DATA ARCHIVED:	363 gigabytes	45 gigabytes	340 Gigabytes



RESEARCH AND OPERATIONAL APPLICATIONS
CSIRO MARINE RESEARCH

AVHRR-DERIVED SEA TEMPERATURES AROUND ROTTNEST ISLAND

Alan Pearce and Fabienne Faskel (Edith Cowan University)

The occasional mortality of corals at Rottnest Island has led to an increased interest in water temperatures around the Island. As so little temperature information exists in that area, Advanced Very High Resolution Radiometer (AVHRR) sea-surface temperature (SST) data were used to examine seasonal temperature variability over the 7-year period 1995 to 2001 and to assess whether temperature extremes were in any way related to observed coral bleaching episodes in 1996 and 1998/9 (Faskel, 2001).

The 6-year time-series included data from both NOAA-14 and NOAA-16, clearly showing the seasonal cycle and some interannual variability (**Figure 1**). Summer peaks were generally around 23°C and the winter troughs about 19°C; the warmest summer was in 1998/99 when temperatures exceeded 24°C (coinciding with a record strong Leeuwin Current for that time of year), and the coolest winters were in 1995 and 2000. At the monthly time-scale, there was little regional variability between the three selected sites, although the water in shallow Thomson's Bay was slightly warmer in summer and cooler in winter than at the other two sites. While the thermal stress tolerance of *Pocillopora damicornis* is not known, this coral species is believed to be near the southern limit of its distribution and elevated local temperatures are therefore unlikely to be significant; the temperature data suggested, however, that the bleaching was not associated with cool episodes either, and the observed mortality events must therefore be due to other non-thermal causes.

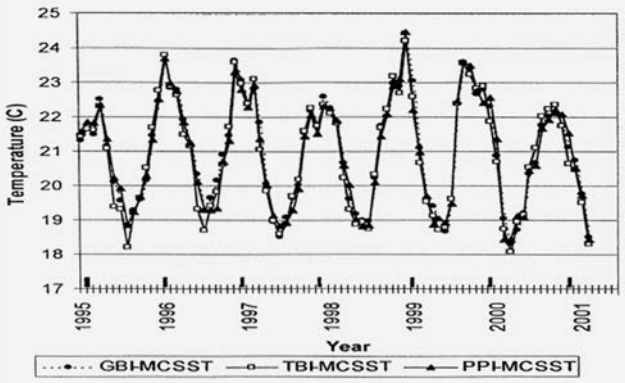


Figure 1: Satellite-derived water temperatures at 3 sites off Rottnest Island between 1995 and 2001: Geordie Bay (filled circles), Thomson's Bay (open squares) and Parker Point (filled triangles), from Faskel (2001).

Because of uncertainty about using 1-km resolution satellite data so near the coast, the AVHRR-SSTs were compared with *in situ* (temperature logger) measurements during 2001. The temperature loggers were installed at 3 selected sites (Geordie Bay, Thomson's Bay and Parker Point), with both a nearshore and an offshore (about 1 km from the coast) mooring. Some data were unfortunately missing from the Parker Point sites (where the main reef of *Pocillopora damicornis* coral is found) because of loss of the loggers, but reasonably good coverage was received for the two northern sites. As may be expected, the satellite-derived temperatures agreed better with the offshore loggers than with the nearshore measurements where "land-contamination" of the satellite pixels was more of a problem and also because of much higher spatial and temporal temperature variability in the coastal bays than further offshore.

Satellite images of the area assisted in interpretation of the temperature changes (**Figure 2**). On occasion tongues of warm Leeuwin Current water (shown in red) penetrated across the continental shelf towards the coast (cool coastal water in blue), sometimes bathing the north shore of the Island and at other times appearing to "wrap-around" the southern coast of Rottnest, matching surface observations undertaken by Dr Barry Hutchins (WA Museum).

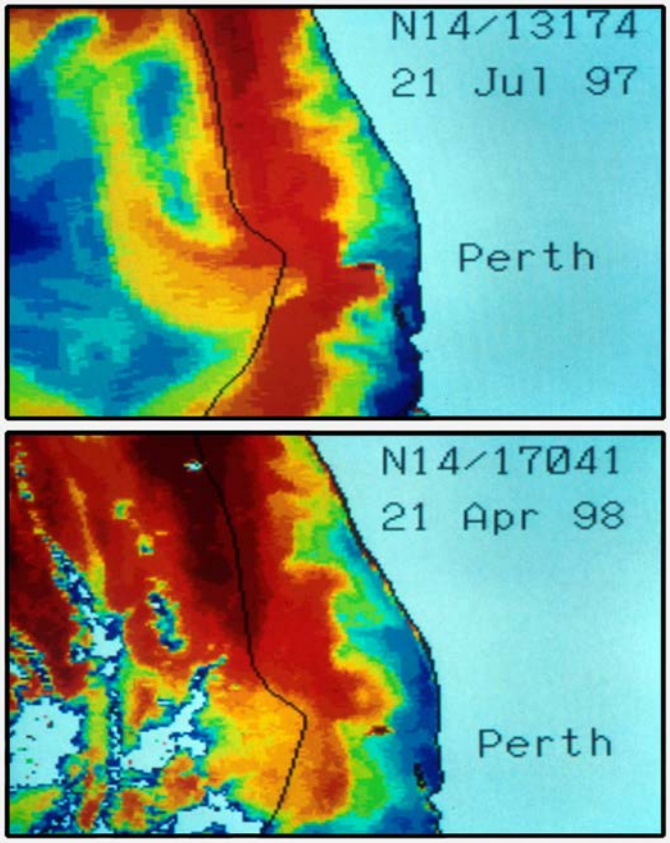


Figure 2: Satellite images of the Leeuwin Current off Perth in July 1997 (upper image) and April 1998 (lower image), showing modes of Leeuwin Current interaction with Rottnest Island. Warmest water is shown in red and the coolest in blue; the black line marks the edge of the continental shelf. NOAA-AVHRR data courtesy of WASTAC.

THE TEMPERATURE REGIME IN SOUTHERN GEOGRAPHE BAY

Alan Pearce, Ross Bromell (Busselton Jetty E & C Association) and Wendy Green (Murdoch University)

Sea temperatures are being monitored at the end of the Busselton Jetty to complement marine ecological studies in southern Geographe Bay, using small TidBit temperature loggers recording at 15-minute intervals. The project commenced in February 2001 and is scheduled to continue for at least two more years to show the seasonal and some interannual variability of the nearshore water temperatures. The highest monthly mean temperature recorded so far was 21.4°C in February and the lowest 15.5°C in August; the extreme recorded temperatures were 14.7°C in both July and August and 23.9°C in March. **Figure 3** shows seasonal AVHRR-SST images of Geographe Bay, illustrating the change between coastal heating in summer and the pronounced heat loss from the shallow nearshore waters to the atmosphere in winter. The warm Leeuwin Current was evident flowing southwards along the outer continental shelf.

The Jetty water temperatures are also being used to validate AVHRR sea-surface temperatures (SSTs). Comparison between the AVHRR-SSTs and the logged values (**Figure 4**) indicates that the main temperature variations were generally reproduced by the satellite data although there were occasions when the satellite value differed from the *in situ* measurements by up to 2°C -- these instances will be

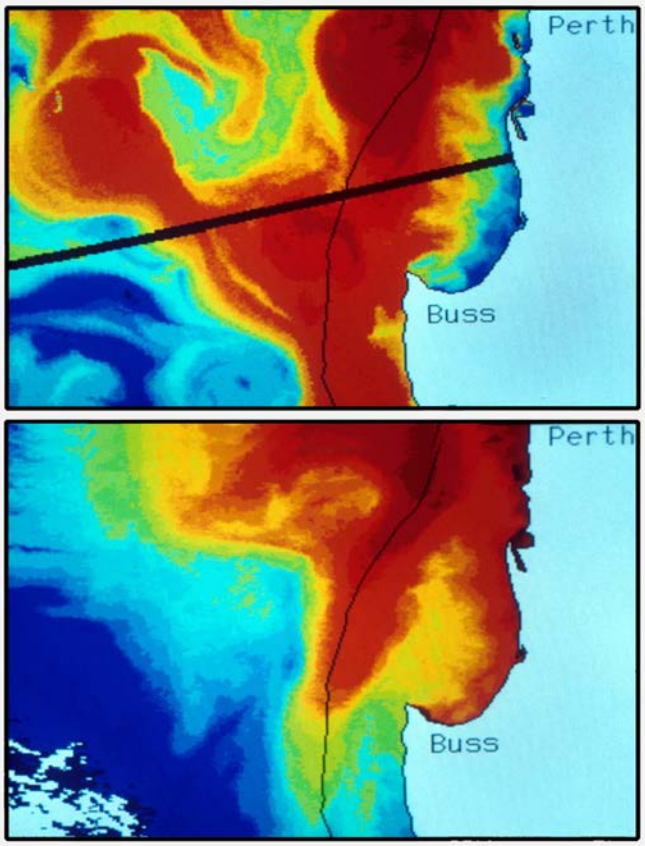


Figure 3: AVHRR images of water temperatures in and around Geographe Bay in March (upper image) and July 2001 (lower image). Other details as in Figure 2; the thick diagonal black line represents a data drop-out. NOAA-AVHRR data courtesy of WASTAC.

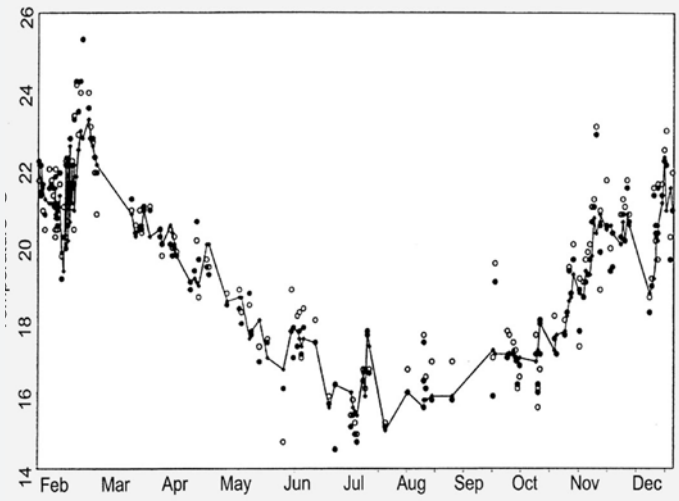


Figure 4: Time series of satellite temperatures off Busselton (filled circles are MCSST and open circles are the McMillin and Crosby algorithm) in 2001 compared with the recorded temperatures on the same days (solid line) .

examined in more detail. Overall, the correlation between the AVHRR-SST and the Tlogger was 0.95 for the MCSST algorithm and 0.93 for the older McMillin and Crosby algorithm; 76% of the MCSST temperatures were within ±0.5°C (and 90% within ±1°C) of the *in situ* measurements -- these are encouraging results bearing in mind proximity to the coast and the high variability of such nearshore waters.

This study is being complemented by similar temperature measurements at Woody Island off Esperance where recording commenced in May 2001, courtesy of McKenzie Island Cruises who operate the daily ferry across to Woody Island. As yet, the satellite data for that area have not been analysed.

AVHRR TRANSECTS ACROSS THE LEEUWIN CURRENT

Alan Pearce and Chris Ten Seldam (Murdoch University)

Following some earlier work on surface temperature gradients across the Leeuwin Current, monthly digital SST transects were extracted from AVHRR data over the period 1996 to 1999 to derive gradient indices which may represent the strength of the Current and also yield information on the width and position offshore of the Current boundaries. The latitude selected was 31°54'S, just north of Perth to avoid Rottnest Island, between longitudes 112°E and the coast. The surface temperatures were smoothed to reduce small-scale variability, and the along-transect SST gradients were computed.

The distinction between summer transects (when the Leeuwin Current is traditionally weak) and the winter plots was generally clear, with very much stronger SST gradients along the offshore boundary of the Current during the winter months. The gradients for each 1-degree longitude band across the Current clearly followed the expected seasonal pattern with higher indices between about April and September. However, interannual variability (which has been previously associated with sealevel changes and *El Nino*/Southern Oscillation (ENSO) events) was not evident despite the intense 1997/98 ENSO event which was sandwiched between two strong *La Nina* periods.

Analysis of the "width" and position of the Leeuwin Current relative to the shelf-break proved unreliable because of difficulties in unambiguously identifying the boundaries of the Current, particularly the coastal boundary where localised SST gradients obscured the larger-scale pattern.

REFERENCES

Faskel, F. (2001).
The assessment of satellite remote sensing as a tool for determining sea surface temperatures in nearshore environments. Unpublished B.Sc (Hons) thesis, Edith Cowan University, 67pp.

Pearce, A.F., F.Faskel & G.Hyndes (in prep).
Nearshore sea temperature variability off Western Australia derived from satellite data. To be submitted to the Journal of the Royal Society of Western Australia.

Pearce, A., W.J.Skirving, I.J.Barton, M.J.Lynch and K.J.Michael (2001).
Validation of satellite derived sea surface temperatures in Australian tropical, temperate and polar waters. International Geoscience and Remote Sensing Symposium (IGARSS 2001), Sydney, July 9-13.

Ten Seldam, C. (2001).
Seasonal variability of SST across the Leeuwin Current. Unpublished Industry Practicum report, Murdoch University, 22pp + Appendix.

CSIRO ATMOSPHERIC RESEARCH

COMMON AVHRR PROCESSING SOFTWARE (CAPS)

Harvey Davies

CAPS development began in 1997 and the software is now a mature, stable product. The following describes developments since the last report on CAPS in the 1998 WASTAC Annual Report.

As well as the previously supported Linux (for PC), Solaris (Sun) and Irix (Silicon Graphics), CAPS now runs under the Microsoft Windows operating system and on Hewlett Packard Unix systems. CAPS is now able to read data in all the known formats in which AVHRR data have been archived in Australia. There is support for the NOAA-16 satellite, which was launched in September, 2000. A cloud detection module (based on the CLAVR algorithm) has been developed. There is a new Graphical User Interface (GUI).

CAPS is used by DOLA to calculate and map hot spots (fires), fire scars, grassland curing index, sea surface temperatures, land surface temperatures and NDVI. CAPS is used by CSIRO Marine Research in Hobart for 'warping' of SeaWiFS data onto a latitude/longitude grid. Both the input and output files are in HDF format. There have been successful tests of warping of MODIS data, which is also commonly stored using HDF.

Ancillary data are required for calibration and navigation. Data for calibration of each satellite are provided by CSIRO Atmospheric Research. CSIRO Marine Research generates navigation data (position, velocity and attitude of the satellite) soon after each pass is received. This aspect of the system has worked well over a number of years, although there have been occasional errors and other problems.

The NAP (N-dimensional Array Processor) package was developed as part of the CAPS project. NAP provides a powerful and efficient arithmetic and input/output facility in the Tcl/Tk environment in which CAPS operates. A number of new features have been added to NAP. There are new unsigned integer data-types, which are needed to read MODIS HDF files. There is support for netCDF (as well as HDF) input/output. There are facilities to read and write binary data. These were used by the Bureau of Meteorology to develop an interface to the McIDAS file format. There is a new library of statistics functions. The new function for calculating spatial correlations can be used to correct for errors in navigation by matching small areas (called 'chips') whose position is known. There is a new graphing facility 'plot_nao' for the display of data as XY graphs and images. The facility to load modules compiled from C and Fortran has been used to produce land/sea masks based on data and a modified version of software obtained from Rutherford Appleton Laboratory.

The CAPS Developers' Group has been created and includes several members from WASTAC. Members have signed a legal agreement, which is designed to promote the sharing of software while protecting Intellectual Property.

It is planned to replace the main CAPS processing script 'avhrr2hdf' with a new modular system that will facilitate the integration of new processes including cloud detection, atmospheric correction and BRDF.

DEPARTMENT OF LAND ADMINISTRATION (DOLA)

MODIS - FIRST IMAGES FROM WASTAC

Jackie Marsden

In October 2001 WASTAC began acquisition of data from the Moderate Resolution Imaging Spectroradiometer (MODIS) which is one of five instruments onboard the NASA satellite platform TERRA. The MODIS sensor views the entire surface of the Earth every 1-2 days making observations in 36 spectral bands. It has a viewing swath of 2300 km and provides high radiometric resolution images of both reflected solar and emitted thermal radiation. The Terra satellite passes over Perth at approximately 10:00 am. Its spatial resolution ranges from 250m in the visible to 1 km in the infrared - the spatial resolution in the visible is greater than that currently available from the NOAA AVHRR sensor. In May 2002 a second NASA platform known as AQUA, was launched, also carrying the MODIS sensor but flying in an afternoon orbit passing over Perth around 1:00 pm. Using both morning and afternoon overpasses we may be able to establish the diurnal variability of many atmosphere-ocean-land processes.

The data are acquired via direct broadcast using the X-band antenna which was installed at Murdoch University in October 2001, and are pre-processed using the Seaspace Terascan software. The International MODIS-AIRS Processing Package (IMAPP) from the University Of Wisconsin is used to geolocate and calibrate the data. The geolocation is done using the platform ephemeris and altitude information which is contained in the pre-processed datastream of each individual overpass.

Once remapped, a variety of products may be generated from the 36 bands of data. Many of the products which have been developed from NOAA AVHRR may be applied using MODIS, and there is also the opportunity to develop new products. Of particular interest to DOLA is the Normalised Difference Vegetation Index (NDVI). MODIS provides several advantages over NOAA AVHRR. Firstly, it has a spatial resolution of 250 m in the visible giving better detail. MODIS has onboard calibration so the sensor drift which showed up as a bias in the NOAA-AVHRR NDVI over time may not be present. The high quality of the IMAPP geolocation is of operational significance. The fortnightly continental NDVI product is a composite of some 24 MODIS overpasses. With accurate geolocation, the remapped data are easily composited and products are available to clients more rapidly.

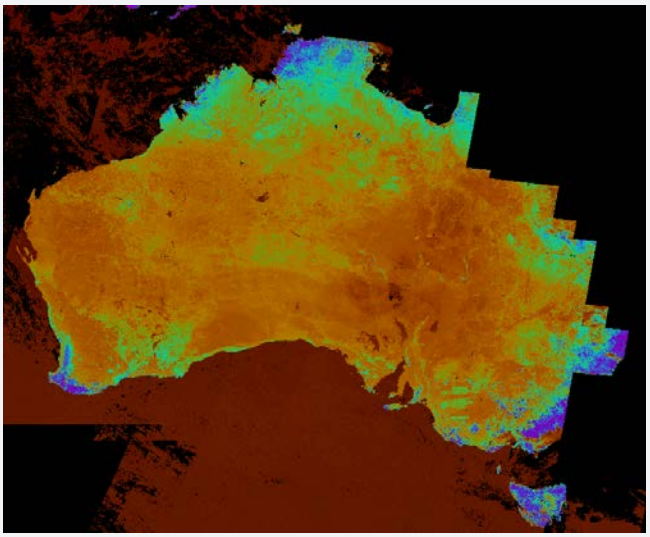


Figure 1: MODIS NDVI composite at 250 m resolution using data from the WASTAC X-band receiver in Perth.

DOLA is now routinely creating semi-monthly NDVI composites at 250 m resolution for research and development, using data solely from the WASTAC X-band receiver in Perth (**Figure 1**). In the future, data from the ACRES X-band receiver at Alice Springs may be added to provide continental coverage.

NDVI AND PLAGUE LOCUSTS

J Adams and T Deveson (APLC)

The Australian Plague Locust Commission (APLC), part of the Commonwealth Dept of Agriculture, Fisheries and Forestry-Australia (AFFA), has been using DOLA's Normalised Difference Vegetation Index (NDVI) derived from WASTAC NOAA-AVHRR data for monitoring locust habitat since 1998. It has been receiving finalised composites as scaled 8-bit, single band image files from Environment Australia as part of the Vegetation Watch Project. Following discussions with the APLC and Environment Australia in late 2001, DOLA has commenced the supply of interim composites, created normally within one working day of the last overpass, directly to the APLC in the 8-bit format to trial assessment of the more timely interim data.

The APLC use the interim NDVI to detect areas of ground vegetation response to rainfall events to identify potential habitats where locust gregarisation and breeding are likely. A 14-day change index, calculated from the difference between current and previous composites, and a relative index of current NDVI as a proportion of local potential range are used to monitor ground vegetation condition. The increased timeliness of the NDVI supply is of particular importance for the APLC to assist in the rapid identification of likely areas of plague locust population increase for ground survey direction. Early detection of highly gregarious locust populations is essential because the opportunities for effective control of bands or swarms can be limited to a few weeks in each generation.

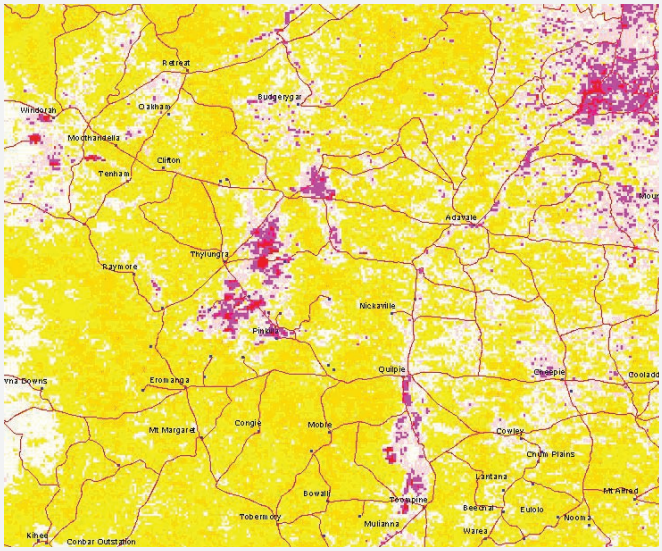
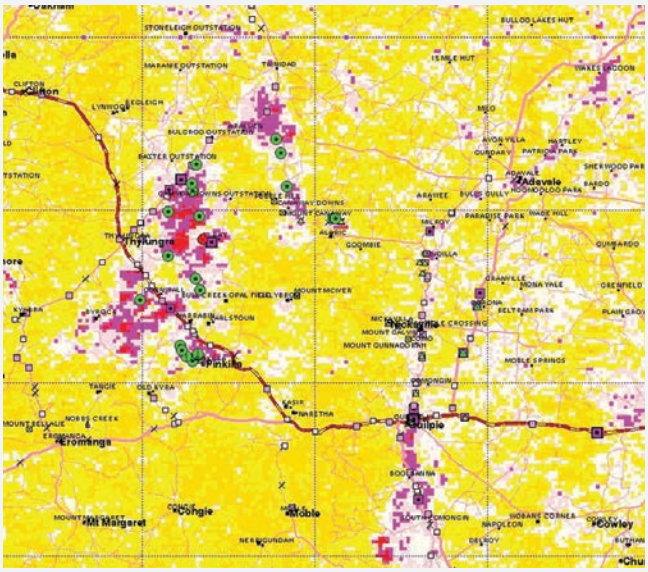


Figure 2: Regional overview around Thylungra in south-west Queensland showing change between the 14-day NDVI composite starting on the 19th of January 2002 and the previous 14-day composite starting on the 5th of January.

As an example of the usefulness of the NDVI data, the accompanying images (**Figures 2 and 3**) show the change between the 14-day composite starting on the 19th of January 2002 and the previous 14-day composite starting on the 5th of January.



Fiqure 3: Enlarged section around Thylungra. The NDVI change image indicates greener areas as pink, white as little change and yellow as drier compared to the previous image.

The increased vegetation response around Thylungra is primarily due to a single rainfall event on the 7th of January. The rainfall event was widespread but here the areas of Mitchell grass produced a strong response - assisted by run-on from adjacent higher scrub areas. The dots indicate the distribution of locust nymphal bands detected by ground and aerial survey during February. This image highlights vegetation habitats because of differential response to January rainfall. It also shows the habitat preference of gregarious adult locusts, the selection of egg-laying sites after rain and the high survival rate of nymphs in these areas.

AGRICULTURAL BIOMASS IMAGES

M.Tovar, R.Stovold

As part of the development of a new improved range of NOAA/AVHRR products, the Satellite Remote Sensing Services (SRSS) group of DOLA is providing fortnightly biomass images to CSBP futurefarm. The images cover the entire agricultural zone of the south west of Western Australia and show the growth rate of the green biomass of pasture and planted crops.

The satellite derived biomass image shown in **Figure 4** is combined with accumulated rainfall data (supplied by the Bureau of Meteorology) and local government boundaries. The information is being used as a strategic management tool to assist in the deployment of resources and to monitor the development of the crop growing season.

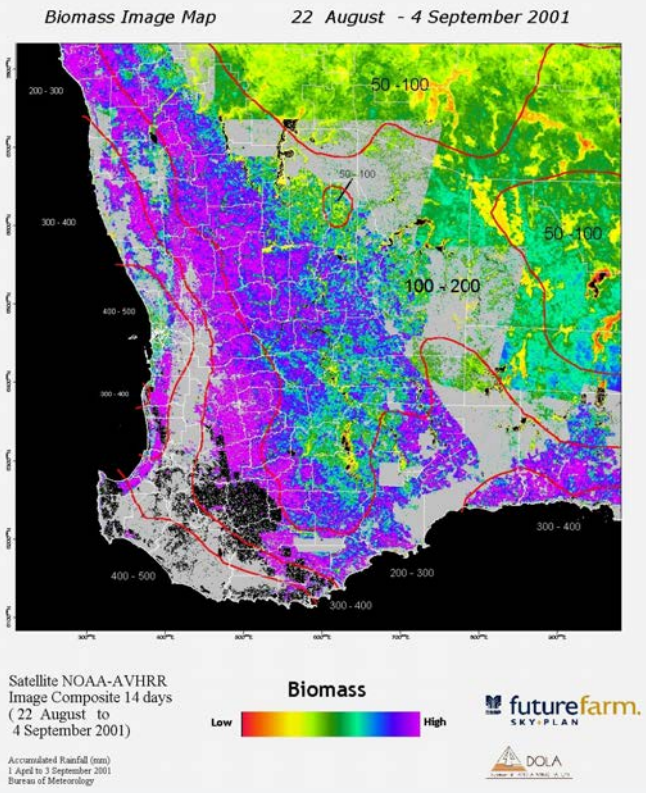


Figure 4: Biomass map of the south west of Western Australia with accumulated rainfall gradients.

PASTURE GROWTH RATE MAPPING

A.Tjalma, A.Allen, R.Stovold

In a collaborative project between the Department of Land Administration, CSIRO Livestock Industries and Agriculture Western Australia, two satellite-based measurement tools have been developed to measure the growth rate and amount of feed on offer of pastures. The tools are Pasture Growth Rate (PGR) and Food On Offer (FOO).

The PGR project provides farmers and decision makers with timely estimates of regional pasture growth rates for the south western corner of Western Australia.

The Satellite Remote Sensing Services (SRSS) group's role is to provide specialist services including data acquisition, image processing and web delivery. SRSS are accessing NOAA/AVHRR data at 1 km resolution from the WASTAC archive in Perth and processing the data into fortnightly NDVI composites. The NDVI is a measure of the greenness of pastures. The NDVI composites are then combined with weekly climatic data supplied by the Bureau of Meteorology to give estimates of PGR within Local Government Areas (LGA) as depicted in **Figures 5 and 6**. The model development and testing are being undertaken by CSIRO Livestock Industries in conjunction with Agriculture Western Australia which is supplying field validating information over the last 5 seasons.

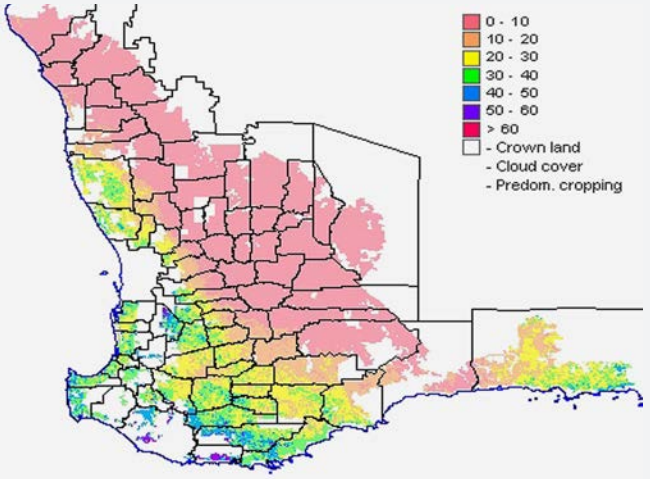


Figure 5: Map of south west Western Australia showing Pasture Growth Rate (PGR) on 1st May 2002 in kg/ha/day

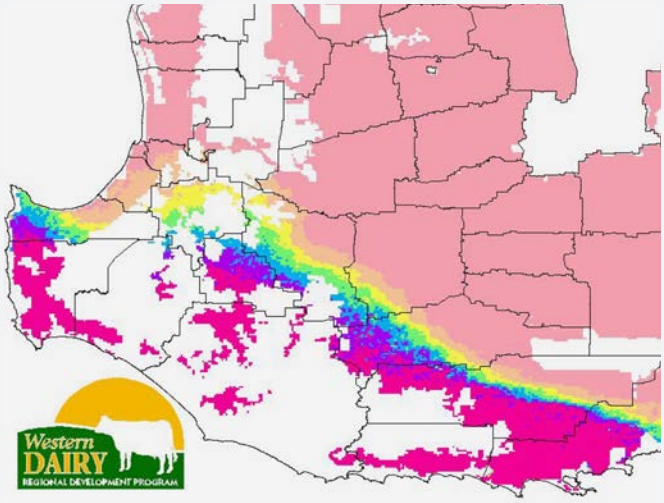


Figure 6: An enlarged PGR map of dairy areas in SW Western Australia on 7th November 2001.

The PGR files are posted to the website (www.pgr.csiro.au) every week throughout the pasture growing season. In addition to PRG maps at low and full resolution, a weekly mean PGR value per LGA is posted to the website for the farmer to assess (**Figure 7**). This provision of pasture information has assisted farmers to interpret the spatial and temporal variation of biomass and growth rates in paddocks. Using the PGR tool the land manager is able to better manage fertiliser use and to target grazing to improve fine wool production and achieve more efficient feed conservation.

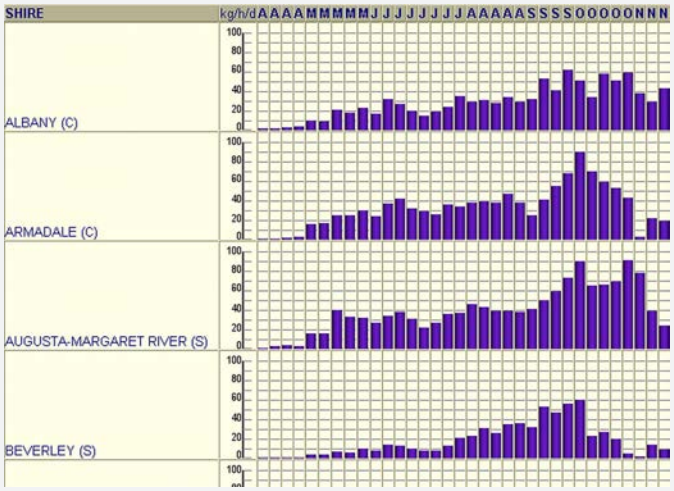


Figure 7: A chart of mean PGR values for four Local Government Areas areas during the 2001 season.

The PGR information also has important applications for agribusiness, regional shires, banking and finance sectors. Potential uses include rural strategic planning, insurance, land valuation and assessment and futures forecasting.

The pasture monitoring programme is currently being extended and verified across high winter rainfall areas of southern Australia. Further improvements of PGR products are expected with the use of the new MODIS 250 m resolution data.

Further information is available from the websites www.pgr.csiro.au and www.agric.wa.gov.au.

FLOOD MONITORING

M.Tovar

On the 27th of February 2002, the MODIS sensor on the Terra satellite was able to capture the extent of a significant flooding event along the Fitzroy River in Western Australia. The information was available to the relevant agencies and public on the following day. The area flooded was similar to the one experienced on 12 of March 1993. Landsat TM imagery was used to map the extent of flooding, however due to the 16-day orbit cycle of the satellite the information was not available in near real time. The daily access to MODIS imagery through the WASTAC consortium has permitted the timely delivery of these products

The MODIS image was downloaded at the Murdoch University facility. The image was then classified for flood-affected areas using the 250 m resolution bands 2 and 1. To improve the interpretation of the image, a shaded 9-second digital elevation model was used to highlight relief of the ground (**Figure 8**). Digital pictures of the flood were sent as e-mail attachments to the Fitzroy FESA offices on the 28th February and hardcopies were distributed. The flood maps were repeated on the 3rd of March as the water advanced to the sea.

DOLA is now able to offer MODIS near real time data at a spatial resolution never before achieved. The availability of this critical information will allow an efficient and faster response to emergency services in the future.

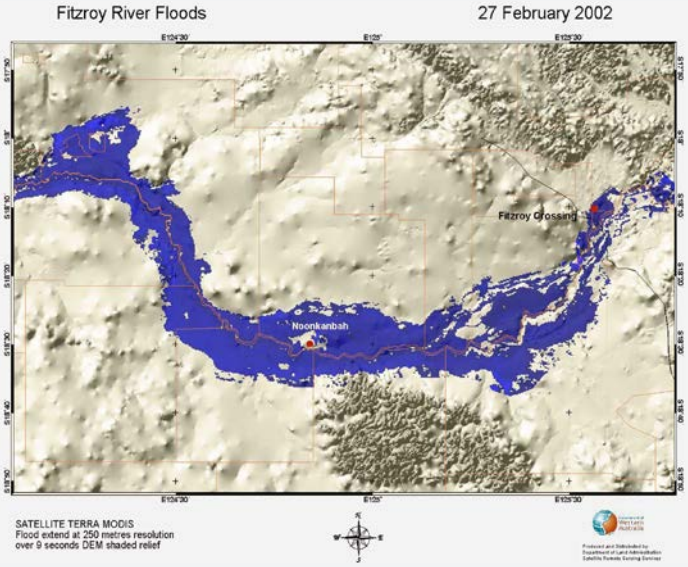


Figure 8: MODIS image showing the Fitzroy floods near Noonkanbah. The image was merged with a digital elevation model to highlight relief.

FROST MONITORING

Mike Steber

Over the past 2 years, SRSS has been providing land surface temperature (LST) images (**Figure 9**) to Agriculture WA on mornings when frosts occurred across the wheatbelt. These images are used to assess the extent of crop damage caused by severe frost conditions. At the end of 2000, SRSS started automatically producing LST images each morning in near real time using channels 3 and 5 of the AVHRR instrument on board NOAA 12 and 14 satellites, the images being placed on the SRSS web site and also in an FTP area for Agriculture WA officers to download. The LST images can be viewed at www.rss.dola.wa.gov.au/newsite/apps/lst. For calibration purposes in the future, 112 weather stations have been chosen by Agriculture WA and temperatures extracted from each LST image for these locations.

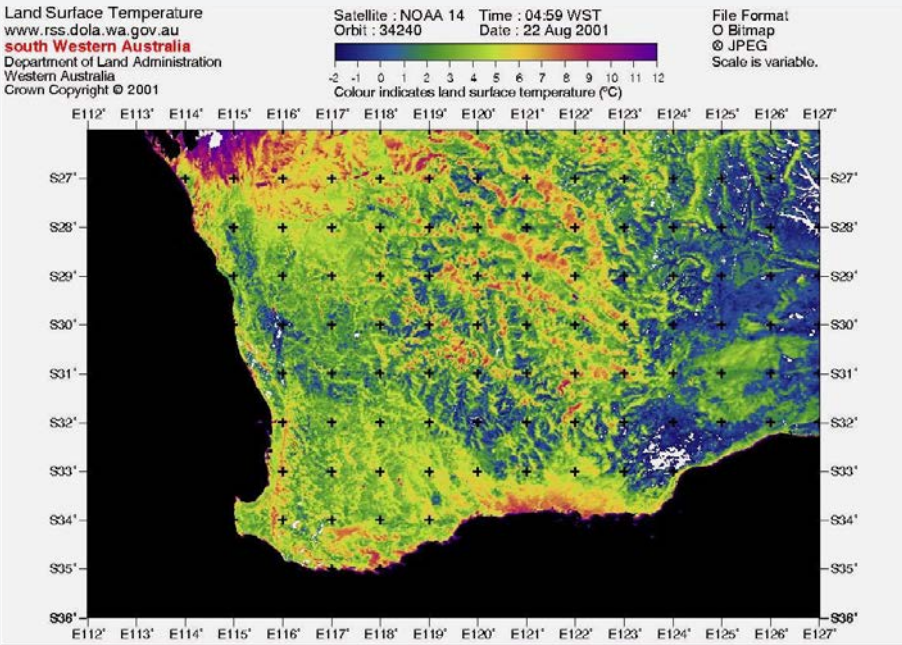


Figure 9. Land Surface Temperature image derived from NOAA 14 orbit 34240 dated 22/08/01 04:59 WST.

SEA SURFACE TEMPERATURE (SST)

M Steber

SRSS and CSIRO Marine Research continued their collaborative project producing sea surface temperature images for the fishing industry (**Figure 10**). During the year, 84 customised SST images were produced for clients and 529 SST images were purchased through "Fishing Hotspots" on DOLA's Land Online website (www.landonline.com.au/hotspots). Of the 84 customised SST images, 10 were produced for a study of whales in the Great Australian Bight. This study, which was commissioned by Woodside Energy, Anadarko and Pan Canadian, determined whether there was a relationship between water temperature and whale distribution. A further 4 images were provided to Woodside Energy to help them determine the direction and speed of the currents off the northwest coast in order to locate a lost buoy.

Work is starting on the production of SST imagery from the MODIS sensor which has an overpass time of 10:30am and will therefore fill the gap between NOAA-15 at 7:00am and NOAA-16 at 2:30pm.

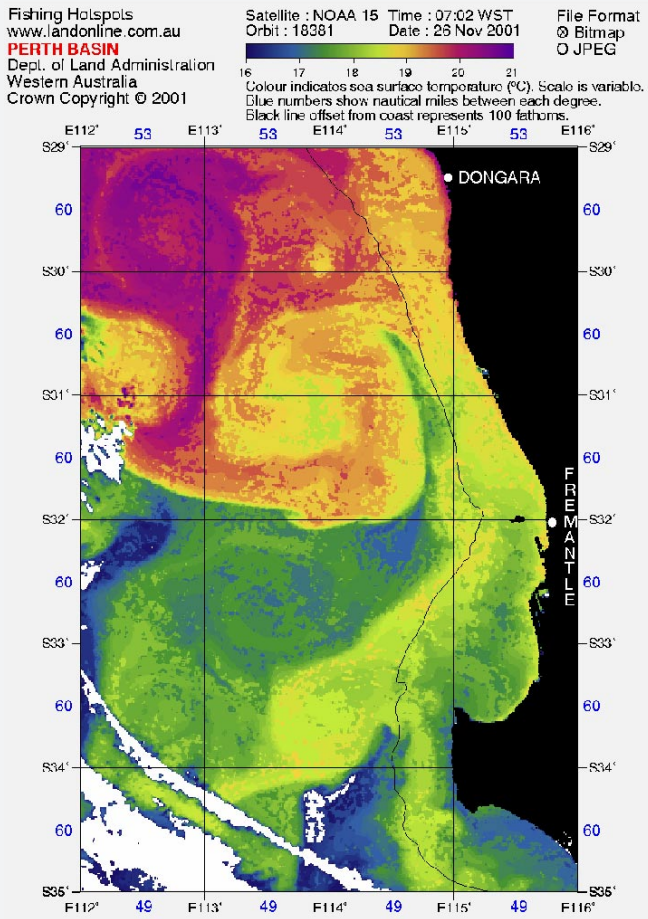


Figure 10: Fishing Hotspots product from NOAA 15 orbit 18381 dated 16/11/01 7:02 WST.

FIREWATCH

B.Heath

The FIREWATCH program mapped fire scars covering approximately 218,000 km sq of Western Australia in 2001 from the NOAA-AVHRR satellite. It must be noted that fires less than 400 ha are not mapped in this project due to the 1 km ground resolution of NOAA-AVHRR satellite images. Fire scars are mapped by manual digitisation on a nine day cycle from both visible and thermal channels. This information is ingested into a GIS that contains nine years of data for the Kimberley region and seven years of data for Western

Australia. The time series of fire information has proven very useful to Fire and Emergency Services Authority of Western Australia (FESA) and land managers in the Kimberley and Pilbara. Fuel loads build rapidly in these regions, thus fire abatement programs are put into place to protect infrastructure, property, human life, flora, and fauna from the threat of wildfire.

The fire history map (**Figure 11**) for the Kimberley region defines nine years of fire activity, showing how many times an area has been subject to fire during the period 1993 to 2001. A narrow band in the far northwest shows an area that has burnt every year since 1993, and is surrounded by areas that have burnt regularly in the nine year period. FESA managers use this map to help in their assessment of fuel loads and to define areas where aerial burning may be required.

The fuel age map (**Figure 12**) shows in what year an area was last burnt. This map was developed at the request of FESA and BHP to help in the assessment of vegetation fuel loads along the BHP rail lines in the Pilbara region. A management plan to protect the infrastructure is being developed and areas shown as not burnt in recent years will be assessed and fire abatement plans will be put into place.

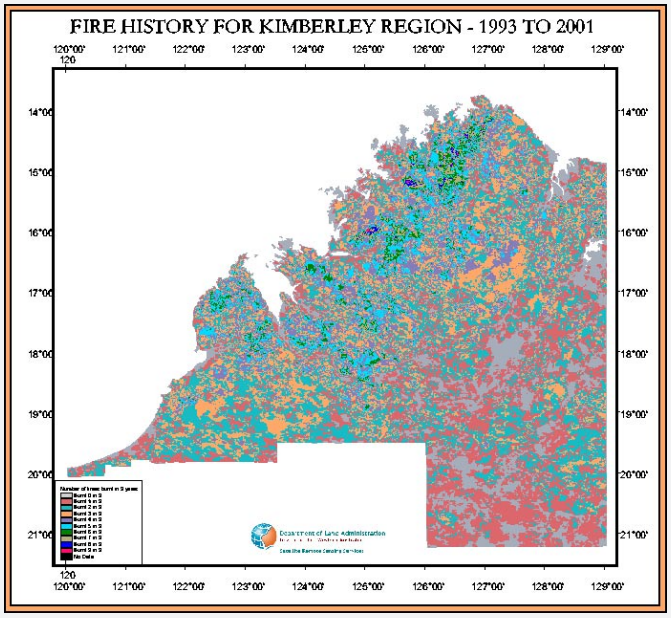


Figure 11: Fire History for Kimberley Region, 1993 to 2001

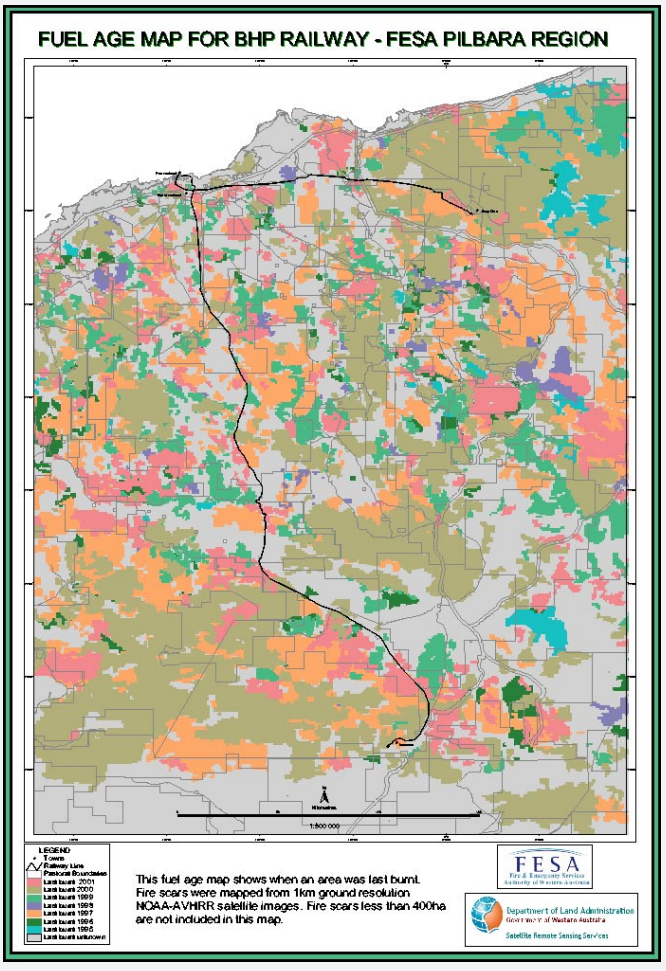


Figure 12: Fuel Age Map for the BHP Rail Line - FESA Pilbara Region

CURTIN UNIVERSITY OF TECHNOLOGY
(REMOTE SENSING AND SATELLITE RESEARCH GROUP)

A CLIMATOLOGY OF OCEAN EDDY SYSTEMS OFF THE MID-WESTERN AUSTRALIAN COAST USING OCEAN COLOUR DATA

Matt Slivkoff and Mervyn Lynch

Ocean eddy systems are significant oceanographic features in continental shelf waters of the northeastern Indian Ocean. These eddies which may extend in the vertical from the surface to the seabed transport significant amounts of energy and angular momentum. They are important for several reasons. Firstly they may be the cause of movement of seabed sediments, the consequences of which may be important in the vicinity of offshore pipelines etc. Secondly, if oil spills or similar events occur offshore, eddies and ocean currents may determine the final destination of that material.

This project is using ocean colour imagery from SeaWiFs (**Figure 1**) to locate and track eddy systems and to compile statistics on their initial location, track, destination, translational velocity, lifetime, seasonality, rotation rates etc. The results are being assembled into a climatology for use by managers and offshore operators.

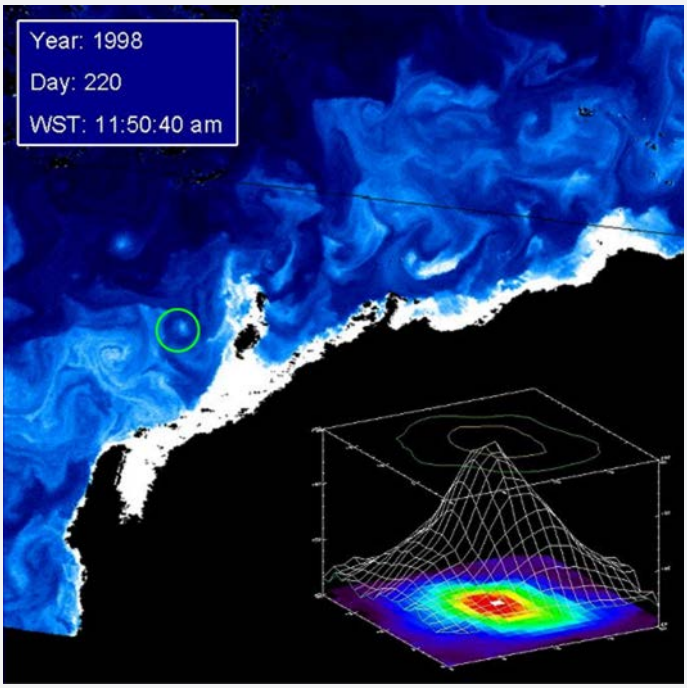


Figure 1: A chlorophyll-a image derived from the ocean colour sensor SeaWiFS for a section of the North West Shelf. Automatic eddy detection software has located an eddy just to the west of Barrow Island. The inset shows the Chl-a concentration for this particular eddy. Time sequential images are analysed and the eddy coordinates, track, drift speed and rotation rate are determined and entered into a data base. (Image courtesy Orbimage/ NASA, processed by Matt Slivkoff).

A STUDY OF THE NINGALOO CURRENT USING OCEAN COLOUR AND TEMPERATURE SATELLITE DATA

Jason Coleman and Mervyn Lynch

Thermal satellite imagery has previously shown the existence of an inshore current moving equatorward along the Ningaloo Reef from about early summer, known as the Ningaloo Current. Ocean colour imagery is now also being used to increase our understanding of the characteristics of this Current. There is preliminary evidence of the Current in the colour imagery in the vicinity of Point Cloates, just to the south of Exmouth (**Figure 2**). In this region the Current appears to terminate its northward trajectory and possibly reverse its flow and

finally dissipate after executing a counterclockwise motion in the vicinity of Point Cloates. The aim of this work is to examine the phenomenon over a 4-year period (1998-2001) and thereby increase our knowledge of the behaviour of this phenomenon following which more definitive statements on its behaviour may be possible. In addition to using SeaWiFS imagery, selected sets of sea surface temperature data have been assembled to establish if there is supporting information from this data set.

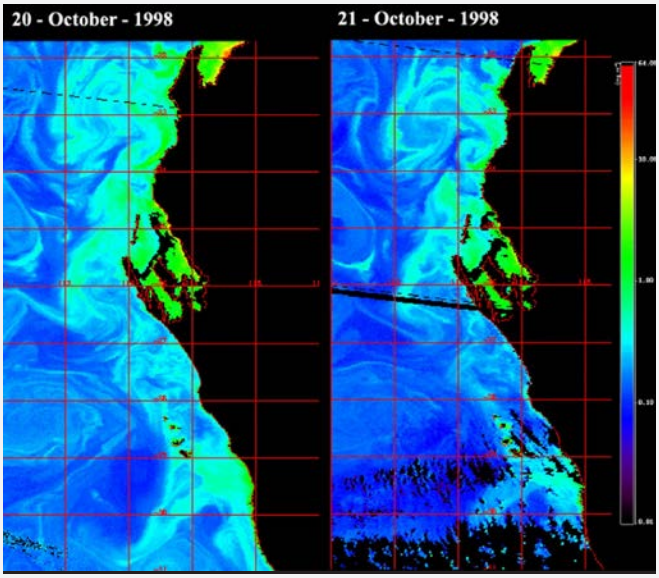


Figure 2: Images of the chlorophyll-a product derived from the ocean colour sensor SeaWiFS for a region from Shark Bay to Exmouth Gulf on the mid west coast for two sequential days in 1998. The complex structure in the coastal waters near Point Cloates at 23°S should be noted. (Image courtesy Orbimage/ NASA, processed by J. Coleman.)

MONITORING THE OCEANIC PRIMARY PRODUCTION OF THE HOUTMAN ABROLHOS

Leon Majewski, Mervyn Lynch and Peter Fearns

Western Australia has commercial and recreational fishing industries with an annual turnover of approximately $1billion. Factors that may affect the quality and quantity of the Western Australian fish stocks – such as the level of nutrients or the quality of ocean waters – need to be monitored. This project undertook to implement algorithms that estimate the ocean's primary productivity, i.e. the fixing of carbon by photosynthetic processes (measured in grams of carbon per square metre).

The site selected for study was the Houtman Abrolhos Islands off the mid-west coast of Western Australia, an important region for the lobster industry and also as a habitat for numerous other species, quite apart from its recreational and tourism potential. This work used the chlorophyll product from the Sea-viewing Wide-Field-of-view Sensor (SeaWiFS) data stream and implemented the Behrenfeld and Falkowski primary productivity (PP) algorithm to yield monthly mean images of PP. The data showed both the contrast between on-shelf and off-shelf productivity and, importantly, a PP void during summer months in the waters between the Abrolhos Islands and the coast.

RADIATIVE TRANSFER MODELLING AND MEASUREMENT OF CASE 2 WATERS

Woytek Klonowski, Peter Fearns and Mervyn Lynch

Much interest in the oceans is focused on coastal and shelf waters rather than the deep waters off the continental shelf. From a remote sensing perspective, the deeper ocean waters are the simplest to sense from space since they are less influenced by suspended solids and dissolved materials of organic origin. In additional to containing pigments and absorbing matter other than chlorophyll, shallow waters have the additional complexity that the seabed reflectance affects the water leaving radiance that travels back to the satellite sensor. Offshore waters are generally classified as “case 1” waters while nearshore more complex waters are “case 2”.

A more rigorous approach is required to determine the concentration of constituents in case 2 waters than was applicable to case 1 waters. To correct for the sea bottom reflectance and estimate pigment and dissolved organic matter concentrations, the radiative transfer equation must be solved (strictly inverted). Typically, simplification of the radiative transfer equation is required followed by inversion using one of the standard schemes, such as Levenburg-Marquardt. To test the performance of the solution scheme, simulated test data must be constructed using a forward model. Subsequently *in situ* data must be acquired by deploying multi- and hyperspectral instruments both on and below the ocean surface. To date we have collected shallow water data sets using a modified dual Zeiss hyperspectral radiometer and applied a forward model to estimate the bathymetry, chlorophyll concentration and sea bottom reflectance. Implementation of a formal retrieval procedure is in progress. Algorithms developed should be applicable to a series of new sensors such as MODIS, GLI, MERIS and Hyperion as well as airborne instruments such as CASI.

MODIS DIRECT BROADCAST SOFTWARE IMPLEMENTATION

Leon Majewski, Mervyn Lynch, Paul Menzel* and Liam Gumley*

* Cooperative Institute for Meteorological Satellite Studies (CIMSS), Space Science and Engineering Center, University of Wisconsin, Madison.

MODIS is a new generation sensor launched by NASA which intends to advance remote sensing of the Earth system by capturing data on a key set of observables covering the land surface, vegetation cover, the oceans and the atmosphere. The key issue for direct broadcast (DB) users who wish to work with data collected by the WASTAC X-band satellite downlink is to implement a software package and derive an associated suite of geophysical products that are both validated and available in near real-time.

Under a long-standing arrangement with the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin, Curtin is engaged in the cooperative development and implementation of a suite

of DB products. Initially the emphasis will be on ocean products but will extend to other products, to be undertaken cooperatively with other WASTAC members. It is intended that variants on the standard MODIS products will be generated using alternative algorithms and, additionally, that new products will be developed that are of local interest. The intention is that all products will be validated to ensure that the algorithms used are applicable in Australian conditions. One product of particularly high interest is that derived from the MODIS chlorophyll-a fluorescence band at 683 nm. It is anticipated that this product will perform well in estimating Chl a in shallow water environments.

RADIATIVE TRANSFER MODELLING IN THE MARINE ENVIRONMENT.

Peter Fearns, Brendon McGann and Mervyn Lynch

A Monte Carlo ocean optical model was developed and used to investigate the relationships between in-water apparent and inherent optical properties and the water-leaving radiance field. A relationship between the optical properties and the upwelling light field for given solar and viewing geometries has been derived from this investigation.

Predictions of ocean reflectance and the structure of the upwelling radiance field based on this work have been compared to predictions based on HYDROLIGHT. A chlorophyll concentration retrieval scheme based on these predictions has been proposed and is being tested using data from the Hillarys cruise and the SeaWiFS satellite.

More recently, one of us (B McGann) undertook a sabbatical during 2001 at CIMSS (University of Wisconsin in Madison) to work with HYDROLIGHT to model the outflow from major river systems. The particular focus was the estimation of sediment loads and the ability of remote sensing to monitor these loads as a function of time. The transport of sediments in the coastal zone, the deposition rates and the final destination of the deposits in the coastal regime is important for coastal engineering and also for coastal management. Work is continuing with applications to Western Australian river systems which are characterised by heavy sediment loadings when in flood.

SEAWIFS DATA RECEPTION, DECRYPTION AND ARCHIVE

Mervyn Lynch, Ron Craig*, Peter Fearns and Helen Chedzey

* Satellite Remote Sensing Services, Department of Land Administration.

The Agreement between WASTAC, NASA/GSFC and OrbImage to downlink and decrypt SeaWiFS data continued through 2001. As required by the Agreement, the data are held at an ftp site for subsequent capture by the NASA SeaWiFS Science Team. WASTAC retains and archives the raw data to CD. This archive now spans from just after launch in late 1997 to the end of 2001; a period in excess of 4 years.

The data are downlinked via the WASTAC L-band receiver. Delayed data decryption is now achieved using a software package

and an associated decryption key provided by OrbImage rather than the decryption hardware used previously. The data sets are used locally for research purposes under a licensing agreement established with NASA and OrbImage. During the period 1997-2001 the recommended algorithms for the extraction of ocean products (e.g. chlorophyll-a and diffuse attenuation coefficient) from the data have changed and the archive has accordingly been reprocessed.

SEAWIFS APPLICATION TO MONITORING MARINE PARKS

Mervyn Lynch, Peter Fearns and Alan Pearce*
*CSIRO Marine Research, Marmion.

By the end of 2001, this 3-year research project (which was supported under the NHT Coasts and Clean Seas programme) had run for two and a half years. Its primary goal is to apply remote sensing to monitor marine park water quality, which requires that the proposed water quality indicators that can be remotely sensed are accurate. The latter, in turn, require that a field program of *in situ* sampling be undertaken to validate the satellite products.

During the life of the project, a series of cross-shelf transects have been undertaken at regular intervals from Hillarys to some 40 km out to sea. A number of bio-optical (downwelling spectral radiance as a function of depth, underway chlorophyll fluorescence, in-lab spectrophotometry), thermal (water temperature depth profiles, sea surface radiometric temperature, near-surface water temperature), physical (water salinity depth profiles) and biological (phytoplankton and zooplankton species counts) measurements are recorded at eight measurement stations. Satellite data from SeaWiFS are used to produce chlorophyll-a and light attenuation coefficient data at 490 nm. Sea surface temperature data are extracted from the NOAA/AVHRR satellite and used to classify water type, identify dynamical processes and assess seasonal and interannual variability.

The project monitored the variability at a number of coastal sites over the two and a half year period. Baseline data on the means and variances of satellite observations in the Marine Parks has been acquired and is currently under analysis. Additionally, the coastal dynamics that influence coastal water quality are also being studied.

SeaWiFS was not designed for application in waters that are shallower that 30 m deep since the sea bottom reflected radiation affects the performance of the algorithms. During this work a first order correction has been developed and applied to the shallow water data.

ENVIRONMENTAL MONITORING OF TIMOR SEA WATER QUALITY

Peter Hick*, Mervyn Lynch, Peter Fearns, Helen Chedzey and Jenny Wilson*
*CSIRO Exploration and Mining, Leeuwin Centre for Earth Sensing Technologies.

The Curtin University Remote Sensing and Satellite Research Group and CSIRO

Exploration and Mining collaborated on a project that aimed at characterising the Timor Sea marine environment using data from AVHRR, SeaWiFS and Landsat TM satellites. In brief, the thrust of this work was to investigate the effectiveness of remotely sensed data to support an understanding of the spatial and temporal variations in sea surface temperature (SST), chlorophyll-a concentration and light attenuation (K_490) in the Timor Sea.

Valuable information resulted from this work, however the identification of annual trends in the observations was hindered by the persistent presence of cloud at tropical latitudes (9°S to 15°S) during some critical periods. Extending the study interval would have provided more environmental information from the area and allowed the annual cycle to become more distinct, thereby improving confidence in trend analyses. *In situ* sampling and laboratory analyses for chlorophyll-a showed excellent correlation with satellite derived chlorophyll estimates.

ATMOSPHERIC CORRECTION OF OCEAN COLOUR IMAGERY.

Jim Davies and Mervyn Lynch

SeaWiFS was designed to gather information about the global distribution of oceanic chlorophyll concentration by measuring, from space, the effect that pigments have on the radiometric signal scattered back from the ocean. For this to be possible at an accuracy useful for quantitative studies in ocean bio-productivity, the scattering and transmission properties of the atmosphere must be accurately accounted. The signal received at the satellite sensor due to scattering in the atmosphere may be up to ten times the ocean component, so a 1% error in correcting the atmospheric signal will accordingly generate a 10% uncertainty in the oceanic radiance.

In this work the maritime aerosol atmosphere has been modelled using a multi-modal aerosol specification. Single and multiple scattering have been incorporated in the formulation. Test data sets have been used to assess the accuracy of the recovered aerosol information and hence the performance of the atmospheric correction.

CHLOROPHYLL SEASONAL AND INTERANNUAL VARIABILITY IN WA COASTAL WATERS

Marc Marinelli, Mervyn Lynch and Alan Pearce*
*CSIRO Marine Research, Marmion.

The first ocean colour sensor to view the world's ocean and estimate seasonal and interannual variability of chlorophyll-a in the near-surface waters from space was the NASA Coastal Zone Colour Scanner (CZCS). CZCS was truly a remarkable instrument not just because it was the first to achieve such a goal but also because it operated for an exceptionally long period and collected both ocean colour and ocean temperature data. Over such a long life it is clear that maintaining sensor calibration was a problem. Further, with the wisdom of hindsight, different spectral bands and more bands could have been employed.

The key questions guiding the current research include the following. What can we learn from CZCS data over the period 1978-1986 about the biological response of Western Australian and eastern Indian Ocean waters? What were the seasonal cycles observed? What was the cause of the observed seasonality? Despite calibration issues does the data contain an extractable interannual signal? The latter is particularly important since the CZCS observations included the major El Nino event of the early 1980s.

THE PRODUCTIVITY OF INDONESIAN WATERS USING SEAWIFS DATA

Umi Zakiyah* and Mervyn Lynch
*AusAID Scholar from University of Brawijaya, Malang, Indonesia.

The waters around Indonesia vary widely in their productivity. Sources of this variance include factors such as coastal and deep water upwelling, vigorous outflows from river systems that are both rich in nutrients and heavily laden with sediments. Sources of pollution entering coastal waters are numerous in the heavily industrialised regions, and these elevated pollution levels are frequently indicated by the presence of plankton blooms including red tides and hazardous algal blooms.

This project uses data from the SeaWiFS sensor to primarily assess the variability of Chlorophyll-a in these waters both over the annual and interannual cycles. Cloud cover is always an issue in the tropics and satellite data coverage is consequently more limited than for the mid-latitudes. While the project relies heavily on remotely sensed data, the research includes a significant field program of *in situ* sampling from research vessels in Indonesian waters. To date, two research cruises have been undertaken in the region as part of the validation of the satellite-derived products. Analysis and interpretation of the *in situ* data and corresponding satellite imagery are continuing.

DETERMINATION OF LAND SURFACE BI-DIRECTIONAL REFLECTANCE DISTRIBUTION FUNCTION FROM SATELLITE DATA

Frank Yu, Mervyn Lynch, Brian White* and John Le Marshall+
*Department of Mathematics and Statistics, Curtin University of Technology
+ Bureau of Meteorology Research Centre, Melbourne

When a satellite sensor views solar radiation reflected from the Earth's surface, the signal contains information about the reflective properties of the surface for the particular illumination and viewing geometry and the atmospheric aerosol optical depth. This surface information, if it can be extracted, is termed the land surface bi-directional reflectance distribution function (BRDF). The solution scheme applied must extract both the surface BRDF and the atmospheric aerosol optical depth. In real situations the former may be measured *in situ* with a radiometer and the latter using a solar photometer, thereby giving closure to the validation of the algorithm. Typically, however,

there are always N+1 unknowns for N equations (or radiometric observations).

This research is presently testing the performance of algorithms that we have developed using synthetic data produced from MODTRAN radiative transfer code using Rojean's model for the surface BRDF and a series of realistic aerosol optical depths. Data sets from both the Geostationary Meteorological Satellite (GMS 5) and SeaWiFS have been assembled for performing more realistics tests of the algorithms inclusive of instrument noise that was not incorporated in the synthetic data.

Some Interesting Web Links for Ocean Colour

SeaWiFS Homepage
http://seawifs.gsfc.nasa.gov

NASA Ocean Colour Information
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/OB_main.html

NASA Ocean Primary Production Homepage
http://opp.gsfc.nasa.gov

Earth Observatory Homepage
http://www.earthobservatory.nasa.gov

Fisheries WA Homepage
http://www.wa.gov.au/westfish/

International Ocean Color Coordinating Group (IOCCG)
http://www.ioccg.org/

REFERENCES

Chedzey H, Fearns P R C and Lynch M J. (2001).
Observing the Timor Sea from Space. Australian Meteorological and Oceanographic Society (AMOS) Conference, Hobart, Tasmania, February 5 -7.

Chedzey H, Fearns P R C, Lynch M J, Wilson J and Hick P. (2001).
Environmental Monitoring of the Timor Sea. Australian Meteorological and Oceanographic Society (AMOS) Conference, Hobart, Tasmania, February 5 -7.

Fearns, P R C. (2001).
Modelling Water Leaving Radiance in 3 Dimensions. Australian Meteorological and Oceanographic Society (AMOS) Conference, Hobart, Tasmania, February 5 -7.

Fearns P R C, Chedzey H, Lynch M J, Hick P and Wilson J. (2001).
Approaches to Assessment of the Offshore Environment in Relation to Hydrocarbon Production Using Remotely Sensed Data. International Geoscience and Remote Sensing Symposium (IGARSS 2001), Sydney, July 9-13.

Fearns P R C, Dekker A G and Lynch M J. (2001).
Modelling of Water Leaving Radiance. International Geoscience and Remote Sensing Symposium (IGARSS 2001), Sydney, July 9-13.

Lynch M J and Fearns P R C. (2001).
Water Quality in Coastal Waters. 22nd Asian Conference on Remote Sensing, Singapore, November 5-9.

Lynch M J, Erb W and Fearns P R C. (2001).
WARRSAT: A Regional Remote Sensing Capacity Building Centre. 22nd Asian Conference on Remote Sensing, Singapore, November 5-9.

Lynch M J and Fearns P R C, (2001).
A Baseline Study of Perth Coastal Waters. International Geoscience and Remote Sensing Symposium (IGARSS 2001), Sydney, July 9-13.

Lynch M J. (2001).
Observing the Geosphere and Biosphere from Space: Parameters, Processes and Prospects. Taylor Keynote Lecture. Australian Meteorological and Oceanographic Society (AMOS) Conference, Hobart, Tasmania, February 5 -7.

Majewski L, Fearns PRC and Lynch M J. (2001).
Remote Sensing of the Ocean Primary Production of the Abrolhos Island Region. International Geoscience and Remote Sensing Symposium (IGARSS 2001), Sydney, July 9-13.

Marinelli M A, Lynch M J and Pearce A F. (2001).
Phytoplankton Concentration in the Eastern Indian Ocean: Seasonal and Interannual Variability. International Geoscience and Remote Sensing Symposium (IGARSS 2001), Sydney, July 9-13.

McAtee, B K, Lynch M J and Pearce A F. (2001).
The Hillarys Transect Sea Surface Temperature Measurement and Validation Program. International Geoscience and Remote Sensing Symposium (IGARSS 2001), Sydney, July 9-13.

Pearce A, Skirving W J, Barton I J, Lynch M J and Michael K J. (2001).
Validation of Satellite Derived Sea Surface Temperatures in Australian Tropical, Temperate and Polar Waters. International Geoscience and Remote Sensing Symposium (IGARSS 2001), Sydney, July 9-13.

BUREAU OF METEOROLOGY

Compiled by Agnes Apostolou & David Griersmith

SEA SURFACE TEMPERATURES (DERIVED FROM NOAA DATA)

The Bureau of Meteorology calculates satellite derived sea surface temperatures (SSTs) for the Australian region by combining data from the WASTAC Perth station with similar NOAA AVHRR data from its Casey, Melbourne and Darwin stations. The AVHRR data are navigated, calibrated, cloud-cleared in real time and the processed orbit is available within an hour after the completion of the ingest. The resulting SSTs for a particular orbit are then sent to Melbourne for inclusion into the Bureau's national data set. The data are then quality controlled against SST data collected from ships and drifting buoys prior to being mosaicked into a national map.

These data are mainly used in support of internal and defence operations (e.g. assimilation into Bureau numerical weather prediction models) but are also available to external users as metadata and browse images of daily mosaics (since November 1998) via the world wide web at *http://www.bom.gov.au/nmoc/archives/SST/*. A subscription service is also available for real time SST data and regional products via the Bureau's "Weather by Fax" service. The SST grid data are archived as part of Australia's National Climate Record. SSTs are calculated using the Local Area Coverage data received at Melbourne, Perth and Darwin for each orbit of NOAA-16, -15 and -14. Corrections are applied in the SST algorithms for intervening atmospheric absorption, suspected cloud contamination, satellite zenith angle greater than 53° and to daytime algorithms for reflected solar radiation.

A running 15-day composite SST mosaic in Mercator projection is used to provide complete coverage of the Australian region (**Figure 1**) at a resolution of 2 x 2 km at the equator increasing to 1.4 x 1.4 km at 45°S. The Bureau has upgraded the processing of AVHRR data for SSTs to full resolution and future work will address better temporal resolution via use of geostationary satellites (2-hourly as compared to 6-hourly imagery) to reduce the impact of diurnal cloud contamination which can affect current SST mosaics.

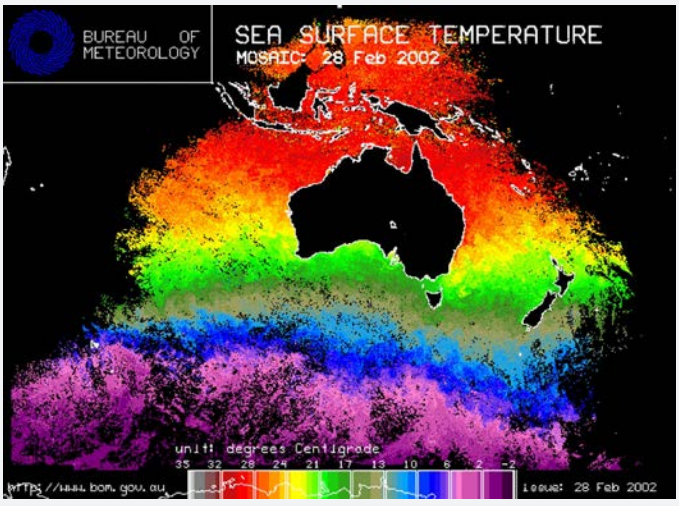


Figure 1: Map showing national coverage of sea surface temperatures for 28 February 2002.

WEATHER MODELLING/FORECASTING

Of primary importance in data assimilation in the southern hemisphere has been the use of the polar-orbiting infra-red and microwave soundings. A main focus within the Bureau has been on the optimum utilisation of the locally derived Tiros Operational Vertical Sounder

(TOVS) and more recently Advanced TOVS (ATOVS) data from NOAA14/15/16. Present strategies are to use the local temperature and moisture retrievals or global retrievals from NOAA/NESDIS in USA converted to the conventional data representations which are then provided to the data assimilation scheme in Numerical Weather Prediction (NWP) models. Recent research in the Bureau has focused on integrating the radiance data directly into the assimilation system in what is called 3D-Var and 4D-Var where the ongoing assimilation system is directly influenced by raw radiance measurements. To this end the Bureau has developed what is termed a generalised multivariate statistical interpolation scheme (GenMVSI/3D-Var) which is a major extension of the current operational system. The data received from the WASTAC system greatly improves the coverage of the data to the west of the continent and hence improves the overall accuracy or skill of the models. **Figure 2** shows the coverage of ATOVS 500 hPa temperatures over southern Australia, while **Figure 3** shows an example of AMSU-A (an ATOVS instrument on board NOAA-15 and -16) data in the form of 250 hPa temperatures.

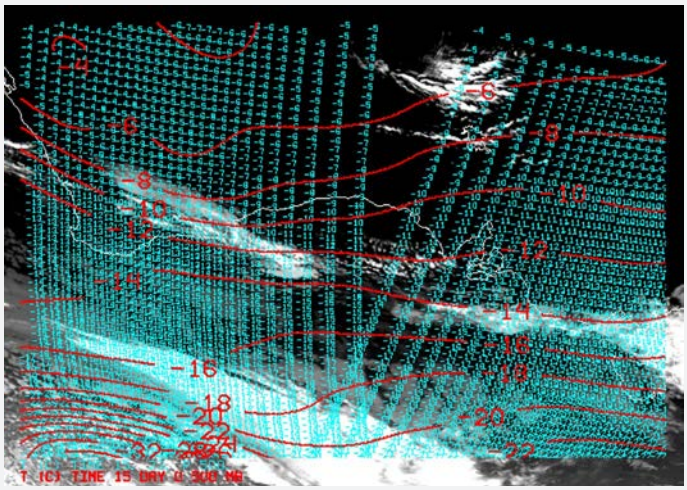


Figure 2: Coverage of ATOVS 500hPa temperatures over the southern portion of Australia (16 April 2001). Background image obtained from GMS-5.

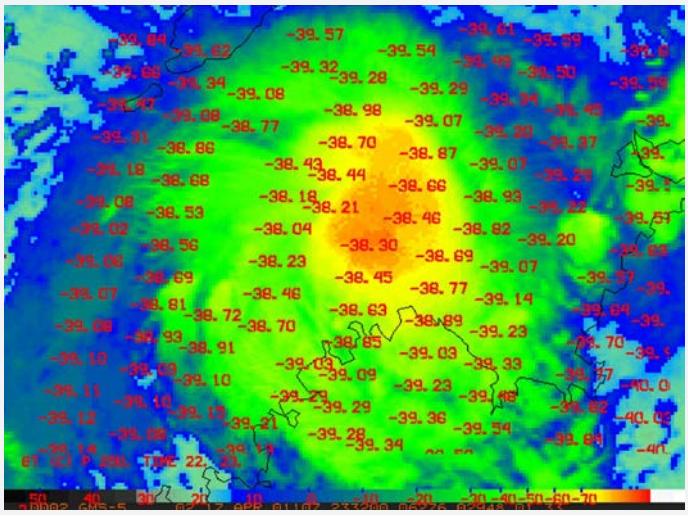


Figure 3: Example of AMSU-A 250 hPa temperatures over Tropical Cyclone Alistair off the north coast of Western Australia (17 April 2001). Background image obtained from GMS-5 and colour enhanced.

FIRE HOT SPOTS AND SMOKE

The Bureau has developed algorithms for fire detection and although focused on the south-eastern States will, in the future, use WASTAC AVHRR data operationally in support of its statutory obligations to supply fire weather forecasting and warning services for Western and South Australia.

NORMALISED DIFFERENCE VEGETATION INDICES (NDVIS)

The Bureau currently produces NDVI products using AVHRR data based on Melbourne and Perth WASTAC data. Data are used to monitor monthly changes in vegetation and other drought/climate related matters; flood monitoring; fire scars; and as input in fire weather forecasting via generation of grassland curing indices. NDVI data are available via the Bureau's Web site at http://www2.ho.bom.gov.au/nmoc/NDVI/ (an example of output is given in **Figure 4**).

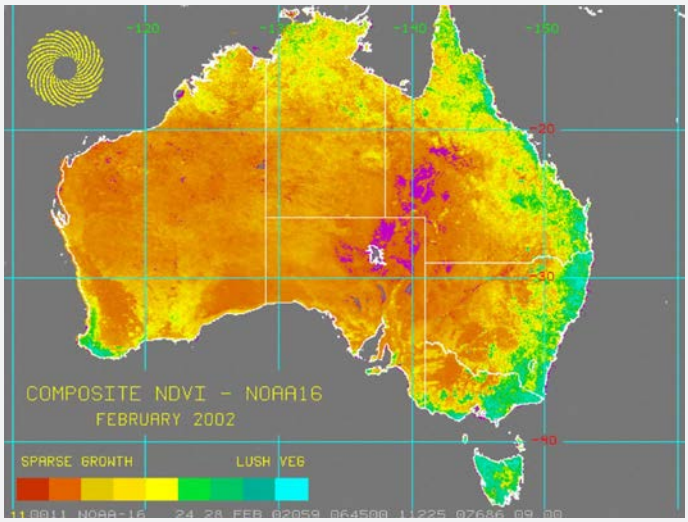


Figure 4: An example of the Bureau's Maximum Value Composite NDVI product.

Recent improvements include increased automation and precise navigation corrections using the Common AVHRR Processing Package (CAPS) developed by CSIRO Atmospheric Research. This package uses orbital elements and satellite attitude parameters computed at CSIRO Marine Research in Hobart.

FLOOD MONITORING

The Bureau uses AVHRR data for flood monitoring in an operational and case study environment using various techniques. These data are useful for the Bureau's hydrological services. The Bureau currently produces special NDVI images to assist in the national monitoring of flooded areas as well as special enhancements using multi channel techniques. An example of flood monitoring using NOAA-16 AVHRR data from northern WA is shown in **Figure 5**.

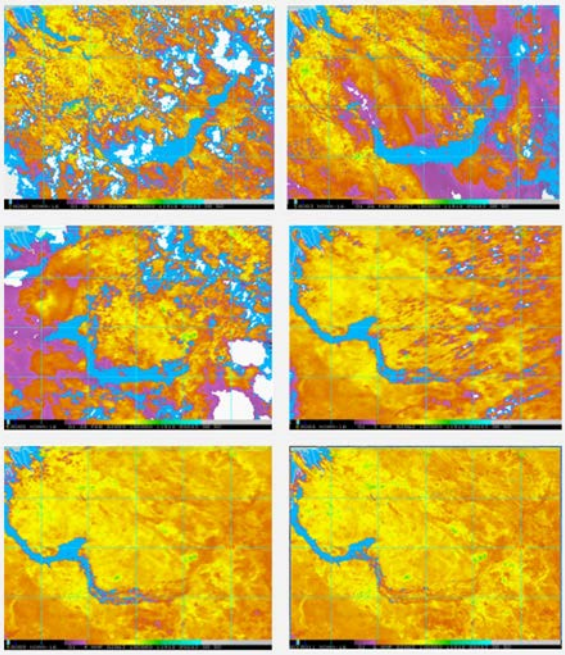


Figure 5: Modified vegetation index (with additional data to pick up water features) NOAA-16 images showing flooding (in blue) along the Fitzroy River (WA) between 25 February and 4 March 2002.

VOLCANIC ASH

Work is continuing on the use of AVHRR (and GMS-5) satellite data for the discrimination of volcanic ash clouds from water/ice clouds and reduction in the incidence of false alarms. The Bureau's Volcanic Ash Advisory Centre (VAAC) in Darwin provides advice on volcanic ash clouds within its area of responsibility for the aviation industry. The advisory messages are based on advice from aircraft, vulcanological authorities, NOAA and GMS-5 satellite imagery and a volcanic ash trajectory forecast model. Even though the Volcanic Ash Advisory Centre is located in Darwin, the AVHRR data from Perth are used for full coverage of Darwin's area of responsibility. By way of example, in 1996/97 Darwin issued a total of 267 advices covering the area south of 10°N between longitudes 100°E to 160°E. The Bureau is planning to use MODIS data from WASTAC in further R&D efforts to monitor ash clouds.

The BoM has implemented an Atmospheric Transport Model (ATM) and maintains the necessary meteorological data files to respond promptly with trajectory and dispersion guidance in the event of an incident. The model is based on the Hysplit (V.4) model developed by NOAA Air Research Laboratory with some contribution by Bureau of Meteorology Research Centre (BMRC) scientists.

CYCLONE MONITORING

The Bureau's Western Australian Regional Forecasting Centre in Perth provides warnings of tropical cyclones whenever the need arises from their Tropical Cyclone Warning Centre (TCWC). The AVHRR data are used to assist in the monitoring of fine detail of tropical cyclones and supplements the positioning of these large systems by radar, GMS-5 imagery and NWP analysis. It is also a critical back-up to GMS-5 imagery noting that GMS-5 is now beyond its design life and is producing reduced observations to maximise its life until a replacement is launched (MTSAT-1R in 2003). As an example, **Figure 6** shows a tropical cyclone affecting Western Australia.

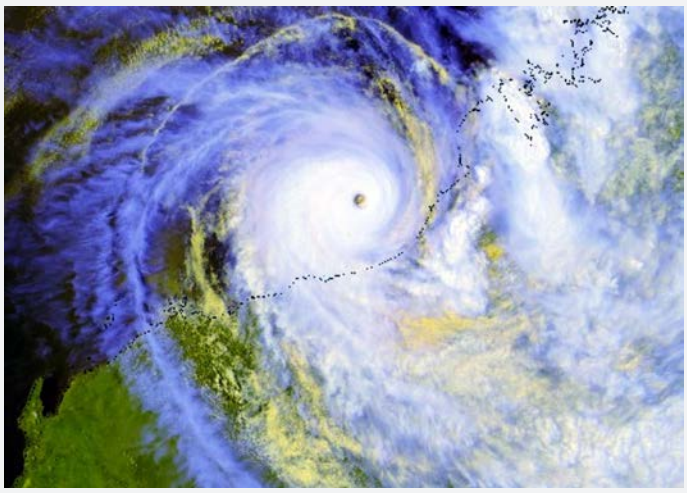


Figure 6: A NOAA-16 image (RGB Channels 1,2,4) of Tropical Cyclone Chris off the north coast of Western Australia (5 February 2002).

FOG AND LOW CLOUD

The Bureau has commenced a fog and low cloud project, aimed at improving our understanding and forecasting capability of fog. Fog and low cloud cause significant disruption and cost to the aviation industry, for example large costs in fuel safety margins, delays and passenger diversions in fog cases. Perth airport can be particularly susceptible to dangerous fog incidents.

The development and validation of a national fog/low-cloud product is based on the use of near real-time NOAA-14, -15 and -16 satellite data from WASTAC. An example of NOAA AVHRR data used for fog and low cloud determination is given in **Figure 7**. During 2002 a fog/low cloud detection scheme using WASTAC data is to be trialled in forecasting operations.

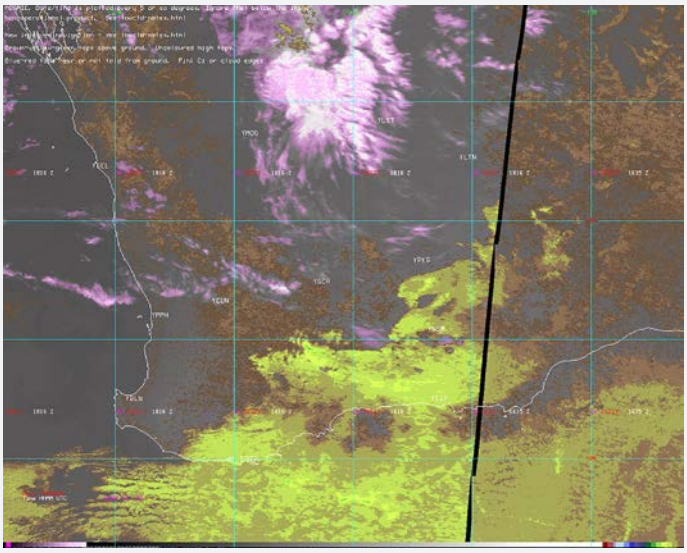


Figure 7: An example of the application of NOAA-15 channels 3 and 4 for the determination of areas of fog and low cloud over Western and central Australia (27 March 2002). Clouds coloured brown (weak detections) through to green (strong detections) are at least 500 m above the ground in most cases. However, fog may occur underneath. Clouds coloured grey-blue (weak detections) through to light blue and red (strong detections) are more likely to be close to or on the ground.

DCPS

As part of an international commitment, the Bureau provides Tiros Information Processor (TIP) data to Argos (Collecte Localisation Satellites) for input into its platform tracking system. The TIP data stream has embedded data from the Argos instrument carried on board NOAA satellites. The instrument allows the collection of data from remote platforms or transmitters on board ships, yachts, ocean buoys, animals, birds, cargo, etc. The Perth data give Argos enhanced capabilities of receiving and using the data real-time (within 15 minutes of the end of the orbit) rather than having to wait 1 to 3 hours for data recorded on board the satellite to be processed in France. In addition, the Bureau extracts and processes DCP data from the WASTAC TIP data to provide observations of meteorological variables such as pressure and temperature over data sparse ocean areas.

AVHRR ACCESS SERVICE

The Bureau provides a real-time ftp subscription service to AVHRR data.

MODIS AND AIRS

Moderate Resolution Imaging Spectrometer (MODIS) data are being obtained from WASTAC for experimental processing studies. MODIS is the key instrument aboard the Terra (EOS AM-1) satellite and views the entire Earth's surface every 2 days, acquiring data in 36 spectral bands. A second MODIS instrument will be launched on the Aqua satellite in April 2002. The Bureau plans to develop products such as fog/low cloud, hotspot detection, SSTs, NDVI and volcanic ash detection, in R&D first, and in operations later.

AIRS (Atmospheric Infrared Sounder) will also fly on Aqua. The Bureau will use AIRS data in NWP models to improve their accuracy.

REFERENCES

Griersmith, D., Rea, A., Willmott, M., Apostolou, A., and Warren, G., 2002.
Overview of Bureau of Meteorology Satellite Activities: Country Report for Australia. Proceedings of the Fourth Meeting on Asia-Pacific Satellite Data Exchange and Utilisation, 13-15 March, Japan Meteorological Agency Headquarters, Tokyo. (to be made available on Internet at http://apsdeu.noaa.gov/ by mid-2002).

Harris, B.A. and Kelly, G. 2001.
A satellite radiance-bias correction scheme for data assimilation. Q.J.R.Meteorological Society, Vol.127, pp.1453-1468.

Le Marshall, J., Seecamp, R., Kuleshov Y., Kelly, G., Leslie, L., Harris, B and Choi, B. 2000.
Regional sounding. The Technical Proceedings of the Eleventh International TOVS study Conference, Budapest, Hungary 20 - 26 September.

Rea, A. 2002.
The use of Direct Broadcast Polar-Orbiting Satellite Data within the Bureau of Meteorology. Proceedings of the Fourth Meeting on Asia-Pacific Satellite Data Exchange and Utilisation, 13-15 March, Japan Meteorological Agency Headquarters, Tokyo. (available on Internet at http://apsdeu.noaa.gov/).

WASTAC GLOSSARY

ACRES
Australian Centre for Remote Sensing

AOT
Aerosol Optical Thickness

AOCWG
Australian Ocean Colour Working Group

AMSU
Advanced Microwave Sounding Unit

AIMS
Australian Institute of Marine Science

AVHRR
Advanced Very High Resolution Radiometer

AIRS
Atmospheric Infrared Sounder

BOM
Bureau Of Meteorology, Australia

CAPS
Common AVHRR Processing Software

CALM
WA Dept. Conservation And Land Management

CGBAPS
Cape Grim Baseline Air Pollution Station

CD-ROM
Compact Disk-Read Only Memory optical storage media

COSSA
CSIRO Office of Space Science and Applications

CSIRO
Commonwealth Scientific and Industrial Research Organisation

DAT
Digital Audio Tape - 4/8 gigabyte

DOLA
WA Department Of Land Adminstration

DVD
Digital Versatile Disk

EEZ
Extended Economic Zone

EOS
Earth Observation System

FAA
Fire Affected Area

FRDC
Fisheries Research and Development Corporation

HP-UX
Hewlett Packard UNIX Operating System

HRPT
High Resolution Picture Transmission

LAPS
Limited Area Prediction System NWP Model

L-Band
Low frequency spectrum, L about 900 MHz to about 1.5 GHz

LST
Land Surface Temperature

MODIS
MODerate resolution Imaging Spectrometer

NOAA
US National Oceanographic and Atmospheric Adminstration

NDVI
Normalised Difference Vegetation Index

NWP
Numerical Weather Prediction

OS
Computer Operating System

SeaWiFS
Sea viewing Wide Field-of-view Sensor - allows ocean colour measurement

SeaDAS
NASA SeaWiFS processing software

SST
Sea Surface Temperature

SPOT
Vegetation satellite sensor

SRSS
WA Satellite Remote Sensing Services

TCWC
BOM WA Tropical Cyclone Warning Centre

TERSS
Tasmanian Earth Resources Satellite Station

TOVS
TIROS Operational Vertical Sounder

WWW
World Wide Web an international information service supported on the Internet.

WASTAC
West Australian Satellite Technology and Application Consortium

X-Band
High frequency spectrum, 7.5 GHz to about 11.5 GHZ - requires large reception antenna

FINANCIALS

Independant Auditor's Report

I have audited the attached financial statements for the year ended 31 December 2001 and in my opinion they fairly represent the transactions of the Consortium for the year then ended, the financial status as at 31 December 2001, and the associated cash flows. The statements are based on proper accounts and records

PJ Perriam FCPA
Director Internal Audit
Curtin University of Technology

9 May 2002

WASTAC X-BAND BUDGET 2002

Estimated expenditure for the year January 2002 – December 2002

		$ PER ANNUM 2002
1.	Data Tapes	10,000
2.	System maintenance	20,000
3.	System repairs	5,000
4.	Telecommunications licence of facility	0
5.	Consultants,product development	30,000
6.	Sundry consumables	5,000
7.	Travelling – Airfares	5,000
8.	Provision for major equipment	15,000
	TOTAL	**$90,000**

Estimated income/revenue for the year January 2002 – December 2002

1.	Annual Contributions ($20,000 each member BoM.DOLA,CSIRO,Geoscience Aust)	80,000
2.	X-Band payments:	
	BoM	100,000
	Auslig	50,000
3.	Interest	2,000
	TOTAL INCOME	**$232,000**

Additional committed expenditure January 2002 – December 2006

1.	X-Band warranty period payment 13 Oct.2002	63,630(exl GST)
2.	Withholding payment to SeaSpace Corp. 13 Oct.2006	31,815(exl GST)
	TOTAL	**$95,445**

WASTAC L Band Budget 2002
Estimated expenditure for the year January 2002 – December 2002

		$ 2002	$ 2001
1.	Telstra Rental	6000	4980
2.	Data Tapes	4000	4800
3.	System maintenance/repairs	6000	6000
4.	Telecommunications lic/maint of facility	1500	1500
5.	Consultants	2000	3000
6.	Sundry consumables	1500	1500
7.	Travelling – Airfares	3000	3000
8.	Provision for major equipment	12000	12000
9.	Annual Report	4000	4000
	TOTAL	**$40,000**	**$40,780**

Estimated income/revenue for the year January 2002 – December 2002

1.	Contributions received ($10,000 each member)	40000	40000
2.	Sundry income (data replication)	1000	1000
3.	Interest	5500	5500
	TOTAL INCOME	**$46,500**	**$46,500**

Extra-ordinary expenditure January 2002 – December 2002

1.	Capital Reserve:	-	-
1.1	Antenna replacement and componentry	110000	110000
1.2	Purchase of microwave comms system	30,000	-
	TOTAL	**$140,000**	**$110,000**

WA Satellite Technology Centre
Balance Sheet as at 31 December 2001

	NOTE	2001 $	2000 $
CURRENT ASSETS			
Cash at Bank		177,067	164,577
Prepayments		-	-
TOTAL CURRENT ASSETS		177,067	164,577
NON - CURRENT ASSETS			
Computer Equipment	2a	13,070	17,426
Other Equipment	2b	581,153	39,309
TOTAL NON - CURRENT ASSETS		594,223	56,735
TOTAL ASSETS		771,290	221,312
CURRENT LIABILITIES			
Creditors & Borrowings		-	-
Accrued Expense		-	-
TOTAL CURRENT LIABILITIES		-	-
NON - CURRENT LIABILITIES			
Creditors & Borrowings		-	-
TOTAL NON - CURRENT LIABILITIES		-	-
TOTAL LIABILITIES		-	-
NET ASSETS		771,290	221,312
SHAREHOLDERS EQUITY			
Retained Profits/(Losses)	3a	771,290	221,312
TOTAL SHAREHOLDERS EQUITY		771,290	221,312

WA Satellite Technology Centre
Income and Expenditure Statement
For the period 1 January 2001 to 31 December 2001 *

	NOTE	2001 $	2000 $
INCOME			
Contributions Received	4	580,000	40,000
Sundry Income		-	-
Interest Received		7,380	7,612
TOTAL INCOME		587,380	47,612
EXPENDITURE			
Annual Report		-	3,729
Outsourced Work		6,482	5,885
Conference Attendance		-	1,115
Telephone		3,275	5,600
Data Tapes and Disks		4,288	6,954
Consumables		180	-
Printing, Stationery & Photocopying		-	4,100
Depreciation		15,795	11,397
Maintenance of Equipment		470	6,500
Equipment purchase		4,818	832
Telecommunications License of Facility		1,225	1,187
Cargo Terminal Fee		869	-
			-
TOTAL EXPENDITURE		37,402	47,299
NET SURPLUS (DEFICIT)		549,978	313
EXTRAORDINARY ITEMS		Nil	Nil
NET SURPLUS (DEFICIT) AND EXTRAORDINARY ITEMS		549,978	313
TRANSFERS TO ASSET REVALUATION RESERVE		Nil	Nil
NET SURPLUS (DEFICIT) TRANSFERRED TO RETAINED PROFITS/(LOSSES)		549,978	313

* These end of year financial statements are prepared in accordance with the WASTAC deed of agreement in place to the end of year 2001 and will be revised as deeds for separate facilities are completed in 2002.

WASTAC

Income & expenditure worksheet for the 12 months ending 31 December 2001

DESCRIPTION	REF.	NOTE	2001 [A]	ACCRUAL 2000 [B]	ADJUSTED TOTAL [C] = A + B	ADJ [D]	TOTAL PER P & L [E] = [C] + [D]
Expenditure							
Salary - General			0.00	-	0.00	-	0.00
On Costs			0.00	-	0.00	-	0.00
Salary Total (A)			0.00	0.00	0.00	0.00	0.00
Fee For Service Charge			0.00		0.00	-	0.00
Outsourced Work		2	6,482.00	0.00	6,482.00	-	6,482.00
Confer ence Attendance			0.00	-	0.00	-	0.00
Data Tapes and Disks			4,288.00	-	4,288.00	-	4,288.00
Annual Report			3,729.00	(3,729.00)	0.00	0.00	0.00
Telephone			3,275.00	-	3,275.00	-	3,275.00
Consumables		3	10,180.00	-	10,180.00	-10,000	180.00
Printing, Stationery & Photocopying			0.00	-	0.00	-	0.00
Mechanical & Equipment Maintenance			470.00	-	470.00	-	470.00
Equipment < $1000			4,818.18	-	4,818.18	-	4,818.18
Computer Equipment Purchases			543,282.82	-	543,282.82	10,000	553,282.82
Furniture			0.00	-	0.00	-	0.00
Telecommunications License of Facility			1,225.00	-	1,225.00	-	1,225.00
Cargo terminal Operators Fee			869.00	-	869.00	-	869.00
Transfers			5,000.00	-	5,000.00	-	5,000.00
Total Other Expenditure (B)			583,619.00	(3,729.00)	579,890.00	0.00	579,890.00
Prior Year Adjustment			(1,817.00)	1,817.00	0.00	0.00	0.00
Depreciation - Comp. Equip.			4,357.00	-	4,357.00	-	4,357.00
Depreciation - Other Equip.			11,438.00	-	11,438.00	-	11,438.00
Total Non Cash Expenditure (C)			13,978.00	1,817.00	15,795.00	0.00	15,795.00
TOTAL EXPENDITURE (D) = (A) + (B) + (C)			597,597.00	(1,912.00)	595,685.00	0.00	595,685.00
Income							
Interest			7,380.00	-	7,380.00	-	7,380.00
Contributions		1	580,000.00	0.00	580,000.00	-	580,000.00
Commonwealth Grant			0.00	-	0.00	-	0.00
TOTAL INCOME (E)			587,380.00	0.00	587,380.00	0.00	587,380.00
TRANSFER OUT (F)			0.00	-	0.00	-	0.00
TRANSFER IN (G)			5,000.00	-	5,000.00	-	5,000.00
EXTRAORDINARY ITEMS			0.00	-	-	-	-
NET TOTAL (H) = (E) - (D) - (F) + (G)			(5,217)	(1,912)	(3,305)	—	(3,305)

Notional Cash Reconciliation

Notional Cash as per GL	$ 164,577.00
Noncash Expenditure	$ 13,978.00
NET TOTAL (H) = (E) - (D) - (F) + (G)	$ (3,305.00)
Prior Year Adjustment	$ 1,817.00
Notional Cash as per Combined GL	$ 177,067.00

Adjustment notes to the worksheet for the 12 months ending 31 December 2001

NOTE 1

The retained funds beginning balance from the past years audited accounts is used.	$	91,315.00
The previous year included a correction for 2001 depreciation charge.	$	-1,817.00
The previous year also included a Annual Report payment made in February 2001		
Ref: D0009928 Batch V6I1421	$	3,729.00
Beginning balance as per G/L	$	93,227.00

NOTE 2

The written down value of assets is adjusted to reflect the position shown in GL.

NOTE 3

An amount of $10,000 freight costs for X-band Satellite receiving station was included in consumables expense and not as fixed assets(other equipment at cost).

A adjustment journal has been requested from the fixed assets area .

WA Satellite Technology Centre
Cash Flow Statement
For the Year Ended 31 December 2001

	$	
BALANCE OF CASH AS AT 1 JANUARY 2001	164,577	CREDIT
RECEIPTS		
Contributions Received		
Dept of Land Administration X Band	300,000	
Bureau of Meteorology X Band	200,000	
CSIRO X Band	50,000	
Dept of Land Administration	10,000	
CSIRO Earth 2001	10,000	
Bureau of Meteorology's 2001 contribution	10,000	
Total Contributions Received	580,000	
SUNDRY INCOME		
Interest Received	7,380	
Total Sundry Income	7,380	
TOTAL RECEIPTS FOR 2001	587,380	
PAYMENTS		
Data Tapes and Disks	4,288	
Printing, Stationery & Photocopying	180	
Telephone	3,275	
Mechanical & Equipment Maintenance	470	
Telecommunications License of Facility	1,225	
Consultants	6,482	
Major Equipment	558,101	
Cargo fee	869	
TOTAL PAYMENTS FOR 2001	574,890	
EXCESS OF RECEIPTS OVER PAYMENTS FOR 2001	12,490	
BALANCE OF CASH AS AT 31 DECEMBER 2001	177,067	CREDIT

WA Satellite Technology Centre
Cashflow Statement
For the Year Ended 31 December 2001 for Accounts
E101-206-0010 (X-BAND)
E101-206-0020 (L-BAND)

	0010 YTD ACTUAL $	0020 YTD ACTUAL $	TOTAL
OPENING CASH BALANCE	164,576	-	164,576
			-
RECEIPTS			-
Contributions	30,000	550,000	580,000
Sundry Income (data replication)	-	-	-
Interest	7,380	-	7,380
Transfers to WASTAC X-Band		5,000	5,000
	37,380	555,000	592,380
PAYMENTS			
Telephone	3,275	-	3,275
Data Tapes	4,288	-	4,288
System Maintenance/Repairs	470	-	470
Telecommunications License of Facility	1,225	-	1,225
Consultants	6,457	25	6,482
Consumables/Printing	180	10,000	180
Travel - Airfares	-	-	-
Major Equipment	4,818	543,283	548,101
Annual Report	-	-	-
Conference Attendance	-	-	-
Cargo Terminal Operators Fee	869	-	869
Transfers to WASTAC X-Band	5,000	-	5,000
	30,311	553,308	569,890
EXCESS OF RECEIPTS OVER PAYMENTS	7,069	1,692	22,490
CLOSING CASH BALANCE	175,374	1,692	187,066
EXTRAORDINARY EXPENDITURE			
Antenna Replacement & Componentry	-	-	-
SeaWiFS - Reception / Development	-	-	-
CLOSING CASH BALANCE	175,374	1,692	187,066

WA Satellite Technology Centre
Notes to and forming part of the Financial Statement
For the period 1 January 2001 to 31 December 2001

These end of year financial statements are prepared in accordance with the WASTAC deed of agreement in place to the end of year 2001 and will be revised as deeds for separate facilities are completed in 2002.

1. STATEMENT OF ACCOUNTING POLICIES

The following accounting policies have been adopted in the preparation of financial statements

1a. General Methodology

The financial statements, prepared in accordance with the provisions of approved Australian Accounting Standards Reporting are on the accrual basis of accounting and the accounts have been prepared under the historical cost convention.

1b. Depreciation

Plant and equipment presented in these financial statement is depreciated in accordance with the following methodology.

Desktop computer equipment	100%
Other Computer equipment	25% reducing balance method
Other Equipment	12.5 % reducing balance method

2. NON CURRENT ASSETS

	2001 $	2000 $
2a. Computing Equipment (at cost)	191,553	191,553
Accumulated Depreciation	(178,483)	(174,127)
TOTAL COMPUTING EQUIPMENT	13,070	17,426
2b. Other Equipment (at cost)	746,203	192,920
Accumulated Depreciation	(165,050)	(153,611)
TOTAL OTHER EQUIPMENT	581,153	39,309
TOTAL NON - CURRENT ASSETS	594,223	56,735

3. RETAINED PROFITS/(LOSSES)

Retained Profits B/fwd	221,312	220,999
Net Surplus (Deficit) for the year	549,978	313
CLOSING BALANCE	771,290	221,312

3a. Retained Profits

Included in retained profits b/fwd is a figure of $ 129,997 previously shown as Asset Revaluation Reserve. This was a result of an adjustment made in 1990 that introduced costs into the financial statements as a extraordinary item. This adjustment has been made to reflect a uniform presentation as with that of the university's financial statements.

4. CONTRIBUTIONS RECEIVED

Dept of Land Admin X Band	300,000	-
Bureau of Meteorology X Band	200,000	-
CSIRO X Band	50,000	-
Department of Land Administration	10,000	-
Bureau of Meteorology	10,000	10,000
CSIRO - Earth Observation Centre	10,000	10,000
Curtin University of Technology	-	10,000
	-	10,000
	580,000	40,000

WA Satellite Technology Centre
Equipment as at 31 December 2001

ASSET NUMBER	DESCRIPTION	ORIGINAL COST	ACCUMULATED DEPRECIATION	CLOSING W/DOWN VALUE	L-BAND (L) X-BAND (X)
COMPUTING EQUIPMENT					
1358800	SYSTEM SATELLITE TRACKING STATION	110,000.00	110,000.00	-	L
2478800	2.3GB 8MM EXABYTE	6,272.00	6,272.00	-	L
2552700	TAPE DRIVE 2 GBYTE X801A	6,840.00	6,840.00	-	L
2553701	ACQNR	3,800.00	3,800.00	-	L
2585200	PAINTJET XL C1602A	2,425.00	2,425.00	-	L
2629700	CARTRIDGE SYSTEM 2.5 G BYTE 8M	4,950.00	4,950.00	-	L
3914000	MICROWAVE COMMUNICATION SYSTEM	57,266.00	44,196.00	13,070.00	
TOTAL COMPUTER EQUIPMENT		191,553.00	178,483.00	13,070.00	
OTHER EQUIPMENT					
1358700	SATELLITE STATION TRACKING	140,000.00	119,771.00	20,229.00	L
1948500	POWER CONDITIONER	2,000.00	1,627.00	373.00	L
2009000	MA 23 CC	20,365.00	16,478.00	3,887.00	L
2553700	RECEIVER NOAA I/F FORMAT	19,500.00	14,908.00	4,592.00	L
3852500	CX-FS1P4 CISCO 4 PORT S/INTER	7,440.00	3,864.00	3,576.00	L
3852501	PA-7KF-E1/75 CISCO DUAL E1 G70	3,400.00	1,766.00	1,634.00	L
3852502	CAB E1 BNC FSIP MIP-CE1 BNC 75	215.00	112.00	103.00	L
4855900	BRADWAY ROCKING FURNANCE	0.00	12.00	(12.00)	L
4857100	X-BAND SATELLITE RECEIVING STATION	553,283.00	6,512.00	546,771.00	X
TOTAL OTHER EQUIPMENT		746,203.00	165,050.00	581,153.00	
DESKTOP EQUIPMENT (expensed)					
3904000	HEWLETT PACKARD 715/64 WORKSTATION	25,208.00	25,208.00	-	L
4085100	9GB DIS DRIVE	2,435.00	2,435.00	-	L
3923700	LYNXPACK 6000E DDS2 4/8GB TAPE	2,098.00	2,098.00	-	L
3923800	LYNXPACK 6000E DDS2 4/8GB TAPE	2,098.00	2,098.00	-	L
4522800	WIDE DISK DRIVE	2,164.00	2,164.00	-	L
4536800	AMSU CARD FOR INST P/C	6,765.77	6,765.77	-	L
TOTAL DESKTOP EQUIPMENT		40,768.77	40,768.77	0.00	
TOTAL EQUIPMENT		978,524.77	384,301.77	594,223.00	