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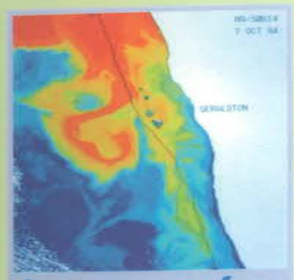

'96 annual report

WASTAC

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATIONS CONSORTIUM

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'96 annual report

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WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATIONS CONSORTIUM

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WASTAC CHAIRMAN'S REPORT - 1996

WASTAC is operating successfully under its new five year deed of agreement. The deed was renewed during 1995 with alterations to enhance the national perspective through the involvement of the CSIRO Office for Space Science and the Bureau of Meteorology Satellite Activities Section. The deed was also modified to embrace the possibility of receiving new coarse resolution satellite data such as SeaWiFS. WASTAC monthly meetings were re-organised into a twice yearly Board of Management and a monthly Standing Committee to enable the attendance of interstate members.

This year WASTAC constructed a Strategic Plan to anticipate the future as our equipment ages, and alternative satellites present new opportunities. The future need for X band reception was discussed, and it was decided that if a successful business case for X-band reception in Western Australia is to be made, then a new consortium is required.

During the year a high speed microwave data link was completed to enable NOAA-AVHRR data to be transferred directly to the Leeuwin Centre for processing. This has enabled Remote Sensing Services (RSS), DOLA, to develop an on-line quick-look facility and to improve the timeliness of bush fire detection for the Bush Fires Board and pastoralists in the inland. This high speed link was complemented by the upgrade of the computer ingest facility at the Bureau of Meteorology (BoM), Perth, with two new HP UNIX workstations and software. This upgrade was carried out at the NOAA receiving stations at Darwin, Perth, Melbourne and Casey, which can all freely exchange data. Don Ward, BoM, and Ron Craig and Richard Stovold, DOLA are commended for making significant contributions to progressing these improvements.

The reliable performance of the WASTAC receiving station and new microwave link enabled RSS, DOLA, to improve its Fire Watch service to the Bush Fires Board of WA. For the development of this service DOLA and the Bush Fires Board received a Government Technology Productivity Gold Award in Canberra on 18 March 1997.

During the year WASTAC received a note from Michel Cazenave, ARGOS Toulouse, France, saying that at 11:19GMT on Christmas Day (1996) one of the NOAA satellites picked up the distress signal from an ARGOS beacon on board Raphael Dinelli's yacht in the Southern Ocean. The signal was received via the Perth (WASTAC) HRPT station, passed on by BoM to the ARGOS Office in Melbourne, and from there to Toulose for processing. ARGOS Toulouse transmitted the processed information to rescue centres in Australia 25 minutes after the signal was generated. This minimised the time Dinelli spent in the icy waters of the Southern Ocean before being rescued.

Due to the pressure of other commitments I have regretably retired as Chairman of WASTAC after having seen the Consortium through its first 12 years of development. I wish my replacement Dr Richard Smith, Manager, RSS, DOLA every success in the future.

Henry Houghton
Chairman

WASTAC BOARD FOR 1996

Mr Henry Houghton	(Chairman)
	Department of Land Administration
Mr Richard Stovold	(Secretary)
	Department of Land Administration
Dr Richard Smith	Department of Land Administration
Assoc. Prof. Merv Lynch	Curtin University of Technology
Dr Doug Myers	Curtin University of Technology
Dr Brian Embleton	CSIRO, Office of Space Science and Applications
Mr Jeff Kingwell	CSIRO, Office of Space Science and Applications
Mr Bruce Neal	Bureau of Meteorology
Mr Len Broadbridge	Bureau of Meteorology

WASTAC STANDING COMMITTEE AND PROXY TO THE BOARD

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Mr Richard Stovold	(Secretary)
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Assoc. Prof. Merv Lynch	Curtin University of Technology
Mr Alan Scott	Bureau of Meteorology
Mr Don Ward	Bureau of Meteorology
Mr Alan Pearce	CSIRO
Mr Jeremy Wallace	CSIRO

OPERATIONAL STATUS

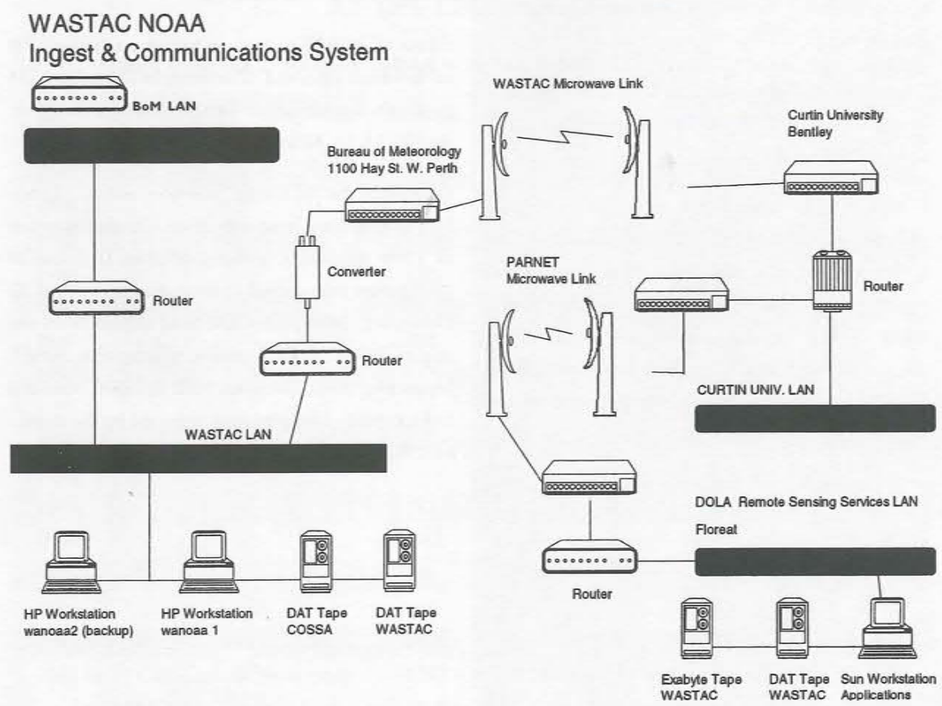
Don Ward,
Regional Computing Manager
Bureau of Meteorology, Perth

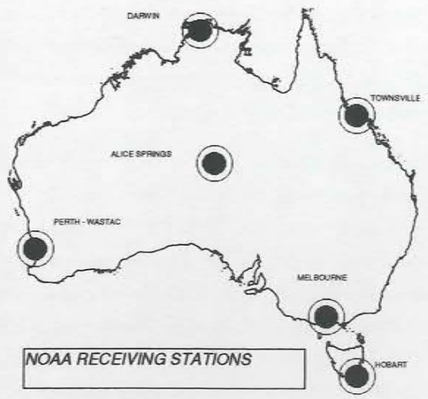
The WASTAC facilities consist of a 2.4 metre antenna and antenna controller at Curtin University of Technology, Bentley, and ingest and display computers with hard disk storage and tape archive facilities located at the Bureau of Meteorology (BoM) premises in West Perth. A low speed uni-directional microwave link connects the antenna to the ingest computers. A second high speed bi-directional microwave system was installed in June 1996 which allows the transmission of raw and processed satellite data between Curtin University, Leeuwin Centre and the WA Regional Office of BoM.

Colour and grey scale quick-look pictures are produced at RSS at the Leeuwin Centre in Floreat in near real-time for archive, indexing and distribution.

The raw data archive is produced on 4Gb DAT tape and a duplicate copy is currently produced for a national NOAA data archive program that is coordinated by COSSA in Canberra.

The new AVHRR ingest and display system, developed by BoM became operational in September 1996. The system operates on two HP UNIX workstations, one provided by WASTAC and the other by BoM. The ingest program runs on both workstations and provides display, processing and backup facilities. The TOVS data, a subset of AVHRR is automatically sent to BoM in Melbourne so that atmospheric temperature retrievals can be included in the global numerical weather prediction models. Sea surface temperature (SST) analyses are produced by BoM and DOLA. With the new communications and workstations DOLA is now able to produce vegetation maps and monitor fire scars in near real-time.





Equipment failures during the year resulted in the loss of three days of data. Due to the dedicated efforts of DOLA and BoM staff, a total of 3910 passes were recorded for the year.

DOLA holds the archive on 8mm TAPES and recently on 4mm DAT tapes.

An ongoing archive copy program has successfully copied 1980s NOAA passes from reel tape to 8mm data cartridges.

Digital data can be provided on 8mm data tape, DAT tape, CD-ROM or 6250/1600bpi magnetic tape in raw or SHARP format.

WASTAC has entered a new era with the implementation of a HP UNIX ingest and archive system that provides high levels of automation and system integrity, and the installation of the WASTAC/PARNET high speed microwave network allows the fast and efficient flow of data and products between WASTAC members, various State government agencies and universities.

A further development will occur with the introduction of WASTAC WWW (World Wide Web) on-line information services.

WASTAC DATA ARCHIVE

The WASTAC archive of NOAA satellite passes, managed and maintained by the DOLA RSS group, is held at the Leeuwin Centre.

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

WASTAC is continuing to supply NOAA passes as part of the Australian contribution of data to the global one kilometre data set which is being administered for CSIRO by COSSA.

The WASTAC duplicate set of NOAA passes which commenced in March 1994, continues to be stored at the Earth Observation Centre at Gungahlin, Canberra, and is specifically for research use by CSIRO and collaborative partners. The global one kilometre data set dates back to April 1992.

Copying of data on to 4mm tapes commenced 25 September 1996. Copying of data onto 8mm tapes ceased on 11 December 1996.

A total of 3910 NOAA passes were recorded for 1996 on 169 8mm tapes and 32 4mm tapes comprising 234 gigabytes of information. Passes comprised data from the NOAA 10, NOAA 12 and NOAA 14 satellites.

Copying of the old Curtin University archive of early NOAA passes has been completed with the exception of a few unreadable or damaged tapes. In excess of 1200 passes were copied to 8mm data tape. As of 12 December, 1460 passes had been copied from the original WASTAC CCT archive, which commenced 9 September 1987. There are 1102 WASTAC files still to be copied. Completion is expected by the middle of 1997.

1996 NOAA DATA ARCHIVE HELD BY WASTAC

	NOAA 10	NOAA 12	NOAA 14	TOTAL
JAN		154	157	311
FEB		140	140	280
MAR		149	144	293
APR		143	139	282
MAY		151	151	302
JUN		143	146	289
JUL		152	151	303
AUG	76	154	147	377
SEPT	44	141	141	326
OCT	72	147	142	361
NOV	71	147	155	373
DEC	91	159	163	413

4mm Tapes: 1205 passes on 32 tapes

8mm Tapes: 3472 passes on 169 tapes

Total data archived : 234 gigabytes

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

	NOAA 6	NOAA 7	NOAA 8	NOAA 9	NOAA 10	NOAA 11	NOAA 12	NOAA 14	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
TOTAL:	**31**	**593**	**21**	**3055**	**971**	**7732**	**8613**	**3391**	**24,407**

Held as: 57 Curtin archive 8mm tapes 1282 WASTAC archive 6250 bpi tapes

835 WASTAC archive 8mm tapes 32 WASTAC archive 4mm tapes

HIGHLIGHTS FOR 1996: RESEARCH PROGRAMS AND DATA APPLICATIONS

CSIRO - EARTH OBSERVATION CENTRE

AVHRR and Environmental Satellite Data Processing Issues

David L B Jupp
CSIRO EOC Science Leader
CANBERRA ACT

Environmental Satellite Data Applications

Environmental Satellite Data have provided the promise of monitoring from regional to global scales for more than 15 years. The data time series has been growing since the late 1970s, first as the NOAA TIROS and later as the AVHRR data series. In recent times, the NOAA 'Pathfinder' data sets have provided a pointer to maturing standards of processing and products.

The data provide regional to global scale information for environmental monitoring, they have high time resolution and can be acquired and processed for a low cost per square kilometre. The products have stabilised and have many applications.

Examples of environmental management and monitoring which are now heavily dependent on AVHRR data include:

- fire monitoring and management;
- sea surface temperature;
- pasture growth monitoring;
- exceptional circumstances and drought;
- regional monitoring in global climate variability;
- regional land surface/ENSO interactions and;
- regional issues in land degradation.

The Environmental Satellite data scale is right for this wide range of applications. Valuable and immediately useable products are available commercially, and the cost frame is acceptable for a well defined set of applications.

Despite this "undeniable opportunity", there is still user resistance to the widespread operational use of AVHRR based products in Australia. I believe the problems stem from the lack of consistent and accepted user experience with data delivery, quality and interpretability. This is despite years of extensive international and Australian Research and Development (R&D).

Key Issues in Environmental Satellite Data Applications

The key issues can be separated into questions of:
What is necessary for effective operational use?
What is possible for the best quality operational use?

Over the years during which high quality R&D has been carried out internationally and in Australia, "what is possible" has been discussed more than "what is necessary". Yet it is "what is necessary" that is the basis for the market and operational use of these data. Briefly, we can state:

- it is necessary to have consistent and standard base products; and
- it is possible to have the best practice of advanced scientific algorithms available.

Despite considerable work, consistent and standardised data sets have not been produced. Users and suppliers have been forced to use empirical standardisation to overcome obvious variations in the data which are not due to changes in the earth surface properties. Such empirical and data dependent approaches are not satisfactory for truly operational applications.

In addition, despite research throughout the world, it seems difficult to establish an acceptable standard set of advanced scientific algorithms or an accepted "best practice". However, for end users and for a market to be established and sustained, it is essential that effective standards for both base products and algorithms are agreed to and standardised.

Current Barriers to operational monitoring

What are the most significant barriers to successful operational use of these products in environmental monitoring, assessment and measurement? What must we do to achieve "what is necessary"?

The barriers are in three primary areas:

1. Data Access and Communications

The large amounts of data collected over 15 years are dispersed into many different holdings, with varying levels of processing and with variable levels of accessibility.

2. Data and Product Calibration and Performance

A minimal requirement for monitoring is a level of consistent and well defined calibration. Ideally, if there are no changes to the signal reaching the sensor, the base products should not change. Approaches to data calibration are variable with data suppliers often forced to accept empirical standardisation, and there are few attempts to assess the accuracy of base products. In addition, to compare information over time at a given location requires accurate geolocation or navigation of the data. To separate earth surface changes from those of the atmosphere minimally requires pixel cloudiness to be flagged. These basic requirements are not being met with consistent and (in many cases) acceptable accuracy for users' needs.

3. Data and Product Consistency and Standardisation

Many groups, including station operators and commercial operators provide value added products such as Sea Surface Temperature (SST) and Normalised Difference Vegetation Index (NDVI). However, the algorithms used vary, are often not documented precisely; are sometimes not able to be re-processed if changes to (say) calibrations become available; and, are rarely validated operationally.

CSIRO EOC tasks addressing these issues

Since CSIRO has collected, researched and used AVHRR data for much of the past 15 years, it is important to ask "What is CSIRO (EOC) doing about this situation?"

The CSIRO Earth Observation Centre (EOC) (COSSA, 1996) has been set up in response to some of these issues as these occur in the wider field of Earth observation. Its catalyst was the Simpson Report (Simpson *et al.*, 1995) which dealt specifically with data issues of the kind outlined above. The report pointed to a level of generic fragmentation in the CSIRO effort as a factor in preventing some of these issues being addressed. With an EOC in place to overcome this fragmentation, what is being done?

Among EOC task activity for 1996/97 (see Jupp, 1997 for more detail) are the following:

1. ILS, IMS, IDN and LAS at Canberra for the Global one km data system

As part of the USGS global one km data project, AVHRR data from the stations covering our region (Perth, Darwin, Townsville, (some Melbourne), Hobart, Casey and some from Manila) have been collected in a data archive at the EOC in Canberra. The data series is complete for the Australian land mass and covers from 1992 to the present. The management of such data is being demonstrated by its linkages to the world via:

- a CEOS (Committee for Earth Observation Satellites) Information Locater Service (ILS). This software, to be supplied by the German Space Agency, DARA, will be providing EO information to developing countries. Canberra EOC will provide a node;
- a node for the CEOS IDN (International Directory Network) which maintains a complete copy of the NASA Goddard Global Change Master Directory (GCMD) on site and which is being developed to provide a rapid and efficient overview of international Earth Observation data sets;

- an EOSDIS Earth Science Information Management System (IMS) which supports World Wide Web common interfaces allowing users to browse data from multiple centres; and

- the processing of data series using USGS LAS base software (which is used for the Global one km Data Project) and CSIRO algorithms.

The purpose of these demonstrations is to develop a capacity for the EOC to guarantee data access to researchers when no other option exists, and to undertake comparative data management studies that will enable the best common approach to data management to be established for CSIRO and other Australian data managers.

2. AVHRR Calibration Web Site

Base calibration for AVHRR data is an important issue. The EOC is tackling the problem by setting up a Web site (CalWatch, http://www.eoc.csiro.au) that records the current best estimates over time of calibrations for different sensors. If possible, it will record the actual or likely calibrations used by some of the more common data suppliers so that the data users can judge the effects for their applications. This work is being done collaboratively with the Canadian CCRS. The task leader is Ross Mitchell of DAR who is working with David Parkin of Canberra EOC to maintain the Web site facility.

3. Station vs Time Series Strategies for Calibration

A station operator or near real-time data producer must choose calibrations without current or future knowledge of sensor operation and performance. Past data can benefit from information from the invariant sites of the type described below. Choices of the best strategy for near real-time calibration are being studied to minimise the problems this can create. This involves current calibration estimates and the history of calibration change for a specific satellite and instrument. It is especially important for near real-time uses.

4. Cal/Val sites for product and methods testing

A range of sites has been or is being instrumented for calibration monitoring, atmospheric property measurement and validation of products (referred to generally as "Cal/Val"). These are the CIGSN network (Hay and Amburla) managed by Fred Prata of DAR and a new desert site in northern SA (Tinga Tingana) being instrumented with permanent sun photometers and other instruments by Ross Mitchell and Denis O'Brien of DAR and Dean Graetz of Canberra EOC. These sites provide a base for quality testing as well as calibration monitoring and validation missions. The EOC is investigating how to maximise the consistency and standardisation of field and validation mission data by forming a shared instrument resource, establishing the location and status of instruments at Divisional sites and examining the current status of measurement protocols in well established missions. This is being done through a specific instrumentation task by David Parkin of Canberra EOC and Bob Cechet of DAR.

5. CAPS for Navigation, Calibration and Cloud Tagging

The algorithms developed at CSIRO's Division of Atmospheric Research and Marine Labs are of a high quality and can provide a common basis for Australian base and advanced products. The best choices for navigation, geolocation and remapping, for calibration and for high quality cloud tagging are being realised as an open and extendable software suite called CAPS (Common AVHRR Processing System, Prata (1996)). CAPS is a joint effort between CSIRO's Mathematical and Information Sciences, Marine Research and Atmospheric Research and will provide a level of algorithm description as well as coded demonstration that will enable it to be used as is or provide a blue-print for best practice code development.

Current options for advanced high quality products

The above discussion was about what is *necessary* for the Environmental Satellite Data Series to realise its promise among users. It is only when these primary issues are addressed that the full view of what is *possible* can be had. What is possible in monitoring is to separate real changes in the Earth's surface condition from those only in the data, and to derive geophysical parameters from the measurements the data provide for those changes. Technically, this involves:

- Atmospheric correction based on atmospheric climatologies and image data;

- Accounting for surface/radiation environment interaction (such as BRDF and BEDF); and

- Choice of algorithms for SST, LST, NDVI, GVI, geophysical parameters.

What is the CSIRO EOC doing in this area? Current EOC tasks addressing these opportunities are (Jupp, 1997):

1. CAPS

CAPS as outlined above is being defined as a base system in which to document and implement these advanced processing methods. It is a software environment but it is *not* an image processing system. It is being developed as a tool kit that allows users to work in most image processing environments.

2. AtCor studies using Cal/Val sites

The Calibration and Validation site network, as well as providing a means to quality check base products, is the source of information for atmospheric correction (AtCor) studies. These are being related to water vapour and aerosol climatologies (best default choices) and provide test data for comparing methods. Atmospheric correction is a major factor in retrieving data series that are primarily responding to surface effects rather than instrument, sensor view or atmospheric effects. However, it is still a scientific research area and uninformed use of atmospheric correction can make data series *less* consistent.

3. Scene Brightness

The surface effects such as BRDF (Bi-directional Reflectance Distribution Function) and BEDF (Bi-directional Emission Distribution Function) can all be looked at as varying scene brightness that does not indicate changes in the surface type and condition, but rather the varying sun and view geometry of the data. AVHRR and airborne data both share the problem of widely varying scene brightness. AVHRR in particular must account for these effects. Canadian researchers have indicated that about 30% of the variation in AVHRR based NDVI can be due to sun and view angle effects. No wonder deserts can 'green' in the winter! The EOC has a specific task which is tackling BRDF and varying atmospheric effects at a range of scales and which aims to define a BRDF 'typology' for Australian landscapes that can be used to correct Environmental Satellite Data for these effects. The potential to effectively combine calibration, atmospheric correction and scene brightness corrections to create a standard base data set is one of the major goals of the EOC.

4. Best Practice Demonstrations

The end-to-end combination of data management, base processing, advanced information extraction and data series production is being demonstrated in time series of AVHRR, GMS and Landsat data. In the case of AVHRR data, a collation of the current CSIRO best practice is being supported in the Data Consistency and Standardisation Thread. This aims to demonstrate what is *possible* based on best practice in what is *necessary* and best current choices of CSIRO advanced algorithms.

Bringing it Together

The EOC and its "Earth-Observing-Crew" in CSIRO can take actions but these will not develop and expand the market for operational use of Environmental Satellite Data unless coordinated with user and supplier needs. We need to consider the options for a nationally consistent effort on product consistency and standardisation in (minimally) AVHRR data. This will be a framework that can be applied to other satellite data but in the immediate future it has a special need for action.

The main groups that need to discuss this issue are CSIRO (through the EOC), the BoM, QDPI, WASTAC, AIMS, ACRES and representatives of the small but significant user community. There have already been important meetings and discussions concerning these issues (McVicar, 1996; Jupp, 1996).

Principles we must keep in the forefront are that by coming to agreed approaches and standards at the base product and supplier level we are investing in product quality to build the whole market. It is against everybody's interest for the current situation of product inconsistency and lack of standardisation to continue. It is in everyone's interest for the base product issues to be resolved. The real markets and benefits are in the value added products. At present, the impact of these is being compromised by the varying quality and standards among the data archives and supplies across Australia, and by the differences between these and the data available via the Internet from the USA.

The CSIRO EOC is investing in data consistency and standardisation because of their underpinning effects on all products. However, the EOC is science focused and its primary aims are to develop the improvements in the "What is possible" area. If a concerted effort can be made, it would be possible for some of the current EOC tasks to move from a research time frame to an operational time frame. These tasks include the calibration studies, CAPS and the data series. This move will need support of various kinds including collaboration of staff from the different organisations and some specific funds to focus tasks and bring their outcomes into the required time-line of the Australian product suppliers and users.

Some steps towards discussions have been made but they are not enough. It is time for the parties, with the pressure and support of the user community, to nail the issues and see environmental satellite data realise its "Undeniable Opportunity".

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CSIRO - DIVISION OF MARINE RESEARCH
Remote Sensing and the Leeuwin Current

Alan Pearce and Angela Way
CSIRO Division of Marine Research,
Marmion, Western Australia

Processing of locally-received AVHRR thermal data from mid-1983 to the present has now been completed. The result is an invaluable archive of 15 years of SST images of Western Australian waters in a consistent NOAA data format. The imagery is being used to study spatial and temporal variability in the Leeuwin Current and continental shelf waters, and the effect of this variability on recruitment to some Western Australian commercial fisheries.

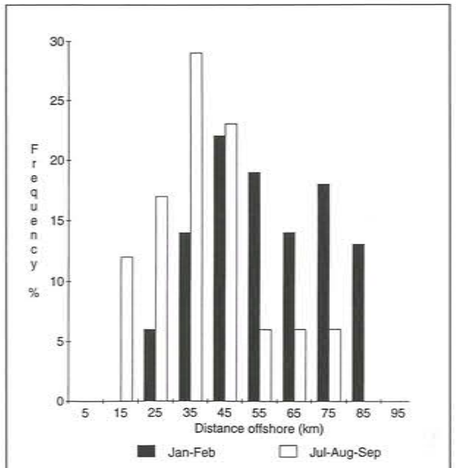


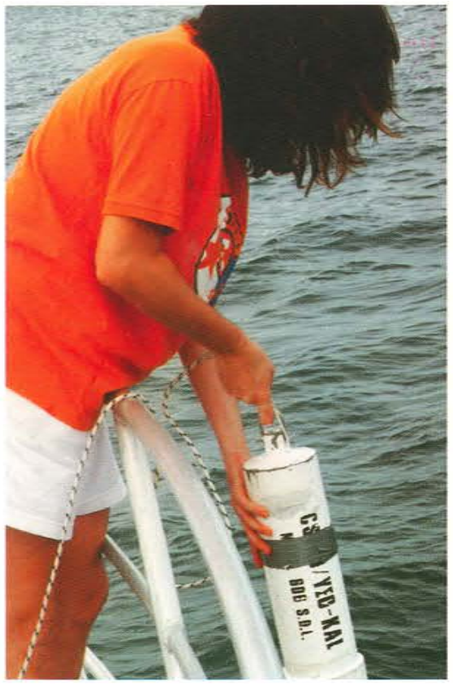
***Figure 1**: Histogram showing the distance offshore of the peak temperature (derived from AVHRR imagery) in the Leeuwin Current off the southern Capes, during the summer months of January-February (solid bars) and in winter (white bars).*

Since 1995, AVHRR data has been obtained in processed format (navigated and calibrated) from WASTAC via Remote Sensing Services (RSS), Department of Land Administration (DOLA), greatly simplifying our in-house procedures. In a joint project with RSS, sea-surface imagery is now being provided to the Western Australian fishing industry and has also been in demand by yachtsmen taking part in oceanic races.

(1) Regional structure and variability of the Leeuwin Current

Seasonal characteristics of the Capes Current (a cool counter-current flowing northwards between Capes Leeuwin and Naturaliste during summer) have been examined (Pearce and Pattiaratchi, submitted). AVHRR images indicate that the Leeuwin Current tends to flow closer inshore during the winter months than in summer (Figure 1), when the cool Capes Current then penetrates northwards along the coast. It may play an important role in the annual migration of salmon from the South coast up the West coast.

Mesoscale (order 100 km) meanders and eddies in the Leeuwin Current have an influence on the return of rock lobster larvae to the coastal reefs at the end of their oceanic migration (Caputi, *et al.*, 1996).



CSIRO oceanographic assistant Angela Way lowering an electronic probe into the water to measure temperature and salinity profiles of the ocean off Perth

An analysis of current patterns near the Houtman Abrolhos Islands from AVHRR images (Pearce, in press) has shown that the Leeuwin Current generally flows strongly southwards along the outer shelf directly past the Islands (Figure 2a). On occasion, however, meanders carry the warm waters over 100 km out into the Indian Ocean (Figure 2b), and it is postulated that the shoreward flow associated with these meanders may well assist in returning "pulses" of lobster larvae back towards the coast during late winter and early spring, thus contributing to better recruitment levels. Numerical ocean circulation models now have sufficient spatial resolution to describe these meanders, with properties comparable with those revealed in the satellite images (Reason and Pearce 1996).

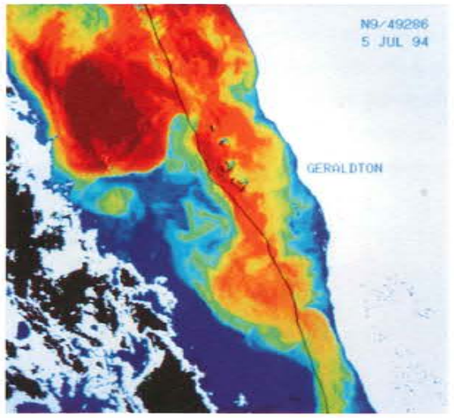


Figure 2a

Figure 2: *(a) AVHRR thermal image of the Leeuwin Current flowing southwards past the Houtman Abrolhos Islands in July 1994. Warmest water is shown in red/orange, cooling through yellow to the coolest water in blue. White and mottled-blue areas are clouds. (b) A corresponding image in October 1994 showing a large meander of the Leeuwin Current transporting the warm tropical waters offshore and then back towards the Houtman Abrolhos Islands. The black line marks the edge of the continental shelf.*

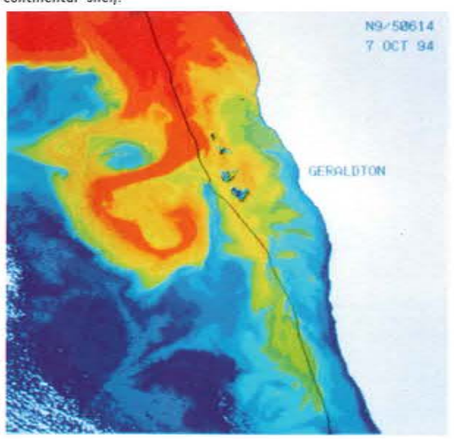


Figure 2b

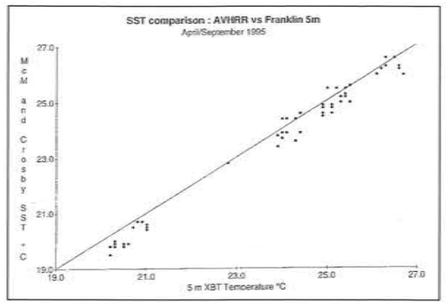


Figure 3: *Comparison of satellite-derived surface temperatures from the AVHRR on NOAA-14 (using the McMillin and Crosby algorithm) and 5m depth temperatures taken by XBT (Expendable BathyThermograph) from the R.V.Franklin in 1995 (XBT data courtesy Dr Susan Wijffels, CSIRO Division of Marine Research, Hobart).*

AVHRR imagery has also supported visual observations of an inshore counter-current along the Ningaloo Reef during the summer months (Taylor and Pearce, in prep.). Strong northward wind stress is believed to be the driving force for this countercurrent, which appears to retain enriched waters from the annual mass spawning of corals within the Ningaloo Reef system and may be one of the reasons for the presence of whale-sharks along the Reef in autumn.

(2) SST validation in Western Australian waters

For both fisheries and climate purposes, it is important that the accuracy of the satellite-derived SSTs is assessed against conventional surface measurements (research vessels, monitoring stations and transects, and moored instruments). Whereas earlier studies off Perth suggested that the simple split-window McMillin and Crosby SST algorithm is appropriate for southwestern Australian waters, more recent *in situ* measurements have shown that scan-angle effects can be important.

Earlier *in situ* temperature measurements off Perth have been supplemented by surface data from the *RV Franklin* both North and South of Perth. In many cases, the McMillin and Crosby algorithm performs adequately, with high correlation against the surface data (*e.g.* Figure 3, where the correlation coefficient is 0.99). On other occasions, however, the discrepancy is well over 1°C and reasons for this are being explored. Some near-surface temperature data are being acquired from the NorthWest Shelf, where conventional SST algorithms may perform poorly because of high water vapour loadings in the atmosphere.

(3) Ocean colour

With the anticipated launch of SeaWiFS in 1997, local interest in remotely-sensed ocean colour data has been increasing. An analysis of Coastal Zone Colour Scanner (CZCS) data from the Nimbus 7 experimental satellite in 1981/82 has shown that the meandering Leeuwin Current entrains high-chlorophyll coastal waters, thus effectively exporting them from the continental shelf (Pattiaratchi et al. submitted). In a joint study with Curtin University, the entire CZCS dataset for Western Australia over the period 1978 to 1986 is being examined to determine the spatial and temporal variability of chlorophyll levels along the coast and offshore.

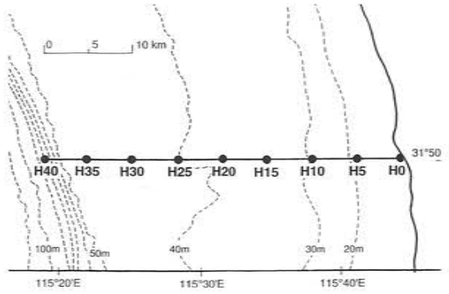


Figure 4a

Figure 4: (a) Positions of the stations H0 to H40 out to 40 km offshore along the Hillarys transect. Bathymetry is shown by the dashed lines. (b) Satellite-derived surface temperatures along the Hillarys transect in December 1996, using the McMillin and Crosby algorithm (solid line) and the newer Non-Linear SST (dotted), compared with in situ bucket temperatures (filled circles). The overpass was at 1428 hrs local time, and the station measurements were between 0900 and 1200 hrs.

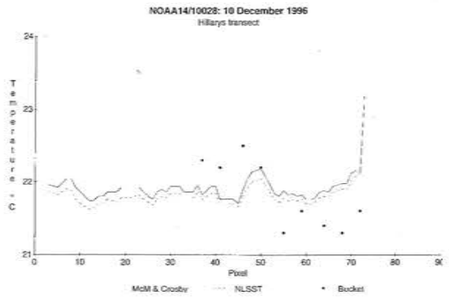


Figure 4b

Curtin University student Andrew Rodger with a Secchi Disc for measuring the turbidity of Perth waters.

SeaWiFS data for the south-east Indian Ocean will be received by WASTAC, and the necessary atmospheric and in-water modelling studies are being undertaken by Curtin University so that reliable chlorophyll products can be derived. Accordingly, a series of monthly monitoring transects has commenced off Hillarys (just North of Perth) to measure some "sea-truth" chlorophyll and light data preparatory to the SeaWiFS launch.

The transects, which comprise both underway sampling and nine profiling stations out to 40 km offshore (Figure 4a), include surface temperature and chlorophyll, temperature and salinity profiles, depth-integrated chlorophyll and nutrients, light measurements, and both phyto- and zoo-plankton trawls. Although the bio-optical data are still being analysed, the surface temperatures are providing valuable information on the cross-shelf thermal structure (Figure 4b). The profile measurements are showing that there is, on occasion, substantial vertical structure, so that the concept of "bulk" temperature (in the so-called "surface mixed-layer" beneath the surface skin) needs to be carefully defined, particularly during the summer months.

Acknowledgements

NOAA imagery has been obtained from WASTAC. The Fisheries Research and Development Corporation (FRDC) and the CSIRO Earth Observing Centre (EOC) are gratefully acknowledged for funding support for this work. Fieldwork and data analysis by Mr Bob Griffiths and Mr Simon Braine (CSIRO Division of Marine Research, Marmion) are gratefully acknowledged.

Collaboration

- Curtin University of Technology
- CSIRO Division of Marine Research, Hobart
- WA Department of Fisheries
- WA Department of Land Administration
- WA Department of Conservation and Land Management
- University of Western Australia
- Weather News International

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BUREAU OF METEOROLOGY

John Beard, John Le Marshall, Melbourne

The NOAA satellite data received at the WASTAC ground station facility in Perth is an important part of the Bureau of Meteorology's (BoM) national HRPT coverage. Using the WASTAC data, plus data received at BoM's own ground stations in Melbourne, Darwin and Casey (Antarctica), the BoM produces satellite-derived SSTs (Sea Surface Temperatures), TOVS (Tiros Operational Vertical Sounder) - based temperature, humidity, total ozone and surface temperature data for use in operational and research numerical models, NDVI (Normalised Difference Vegetation Index) values for land use and cloud imagery for use by BoM's forecasters and researchers. The data collection facility of the NOAA satellites is also used to collect data from remote automatic weather stations (AWS), appropriately equipped ships and drifting buoys. This data is fed into BoM's real-time analysis and forecast system and its climate data base.

In September 1996 BoM, in conjunction with WASTAC, upgraded the WASTAC NOAA ground station to a UNIX based system with a Digital Analogue Tape(DAT) archive. Ingest, via a BoM developed ingest card and processing software, together with archiving and product preparation are now handled by BoM software on the WASTAC HP 715/64 computer. A BoM supplied HP/715 provides on-line backup. The benefits of the upgrade have been better reliability, improved timeliness of data to the customer, a performance and alarm monitoring system and considerably better archiving.

The TOVS data, provided by the WASTAC system, play a vital role in numerical weather prediction in the Australian region. At present, data from NOAA-11 and NOAA-12 satellites (which pass over near the operational forecast base times of 00 UTC and 12 UTC) are processed and provided to BoM's National Meteorological Centre for regional numerical weather prediction. NOAA-14 data are currently processed in real-time test mode and have been used successfully in data assimilation trials (Le Marshall, et al. 1997, two references). These data will soon be available operationally within the National Meteorological Centre. Processing techniques used to provide geophysical parameters for numerical weather prediction are described in Le Marshall et al., 1994. At present TOVS data are also processed in real-time test mode using AVHRR data. This method provides more accurate temperature and humidity fields because of the ability of the AVHRR data to provide a detailed description of surface temperature and cloud characteristics within the fields of view of the TOVS instrument.

Solar Backscatter Ultra Violet (SBUV/2) data from the NOAA satellites have also been used in experimental mode to enhance the ozone retrievals from the TOVS instrument. Initial results from this work are reported in Le Marshall, et al., 1996.

The importance of the TOVS data for operations has been established over many years with most recent skill scores and impacts being reported in Le Marshall, et al., 1991, 1994, 1995 and 1997.

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DEPARTMENT OF LAND ADMINISTRATION REMOTE SENSING SERVICES

Mike Steber, Richard Smith, Richard Stovold, Ronald Craig

The development of direct satellite monitoring in Western Australia began over a decade ago when Dr Frank Honey of CSIRO and Dr Bill Carroll of Curtin University recognised the enormous potential of the NOAA satellite.

A receiving station was established in 1980 at Curtin University. By 1988 the operation of the NOAA satellite receiver was taken over by WASTAC headed by Chairperson, Henry Houghton of DOLA. Since that time, DOLA has been an active participant in the development and running of the facility. Further commitment to the use of the NOAA data in the application areas is evidenced by the rapidly expanding size and range of products being generated by the Remote Sensing Services Branch of DOLA. Major development of the use of NOAA commenced with the Vegetation Watch project covering the entire state of Western Australia. This application has since been expanded to include bush fire, firescar and curing index mapping, flood monitoring and sea surface temperature maps. Coverage for this wide range of products has recently been extended into the Northern Territory and South Australia.

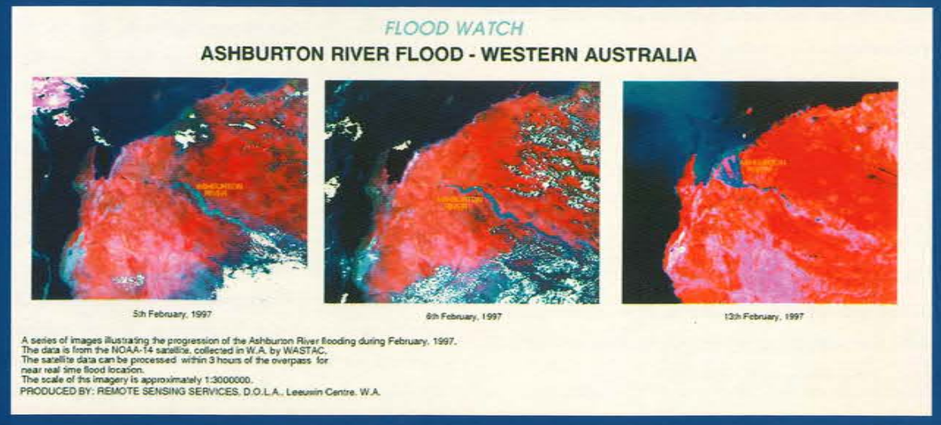
With the recently installed near real-time delivery of satellite data to the Leeuwin Centre, considerable savings and efficiencies have been possible. Electronic delivery of data files to clients has improved with these upgraded communication systems.

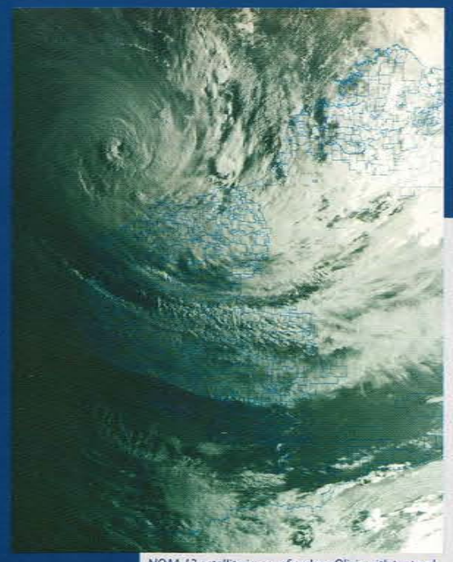
Mike Steber is in the process of developing a near real time digital quick-look archive on the World Wide Web. This digital archive will contain passes within one hour of overpass. The archive will be implemented in 1997 and eventually will hold quick-look images dating back over the last few years.

Major applications using NOAA data and undertaken during the year included the examples on the following pages.

Flood Watch - Ashburton River Flood

The results of extensive flooding caused by heavy cyclonic rains in the Pilbara region of Western Australia were monitored daily. A series of NOAA flood enhanced images were produced graphically portraying the extensive flooding and resultant erosion. In conjunction with the NOAA data, higher resolution Landsat Thematic Mapper imagery is being used to assess the spatial extent of eroded pastoral land.

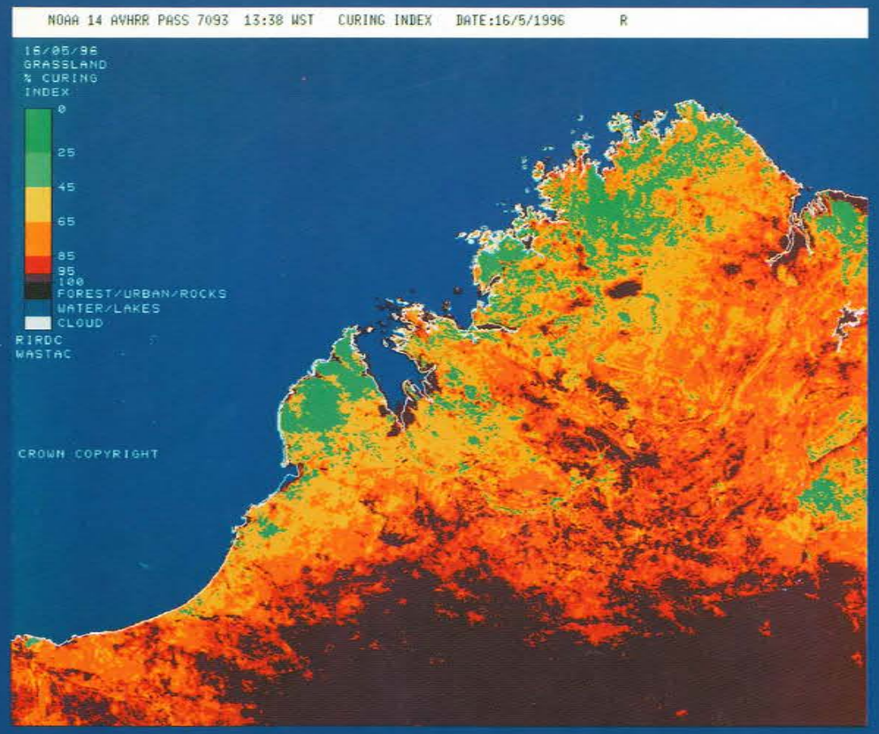




NOAA 12 satellite image of cyclone Olivia with pastoral property boundaries imbedded in the image

Cyclone Olivia Received by WASTAC

On 5 April 1996 tropical cyclone Olivia formed in the Timor Sea. Five days later it crossed the coast of Western Australia. Widespread damage occurred in the town of Pannawonica as wind speeds of over 250km/h were recorded. Rainfall totals along the path of the cyclone did not exceed 117mm as the cyclone was moving so quickly. The image left, taken by the NOAA 12 satellite at 6.15am on 10 April, shows the cyclone 13 hours before it crossed the coast.



Curing Index

The Curing Index is developed from the rate of decline of the Normalised Difference Vegetation Index. In effect the drying and decaying of vegetation litter buildup is a source of fuel for wildfires. An accurate measure of this rate of buildup can be used to assist in fire management strategies such as aerial burning.

The Curing Index has been produced on a regular basis for the Bushfires Board of Western Australia for the last three years. However, it was only ever applied to the south western region of the State. During 1996 it was applied to the northern region of the State for the Kimberley office of the Bushfires Board. The Curing Index shows the rate of vegetation curing and is used to forecast fire risk. This helps to determine at what times and where controlled burning takes place, and can save both time and money. The Curing Index still needs to be field verified to increase its reliability.

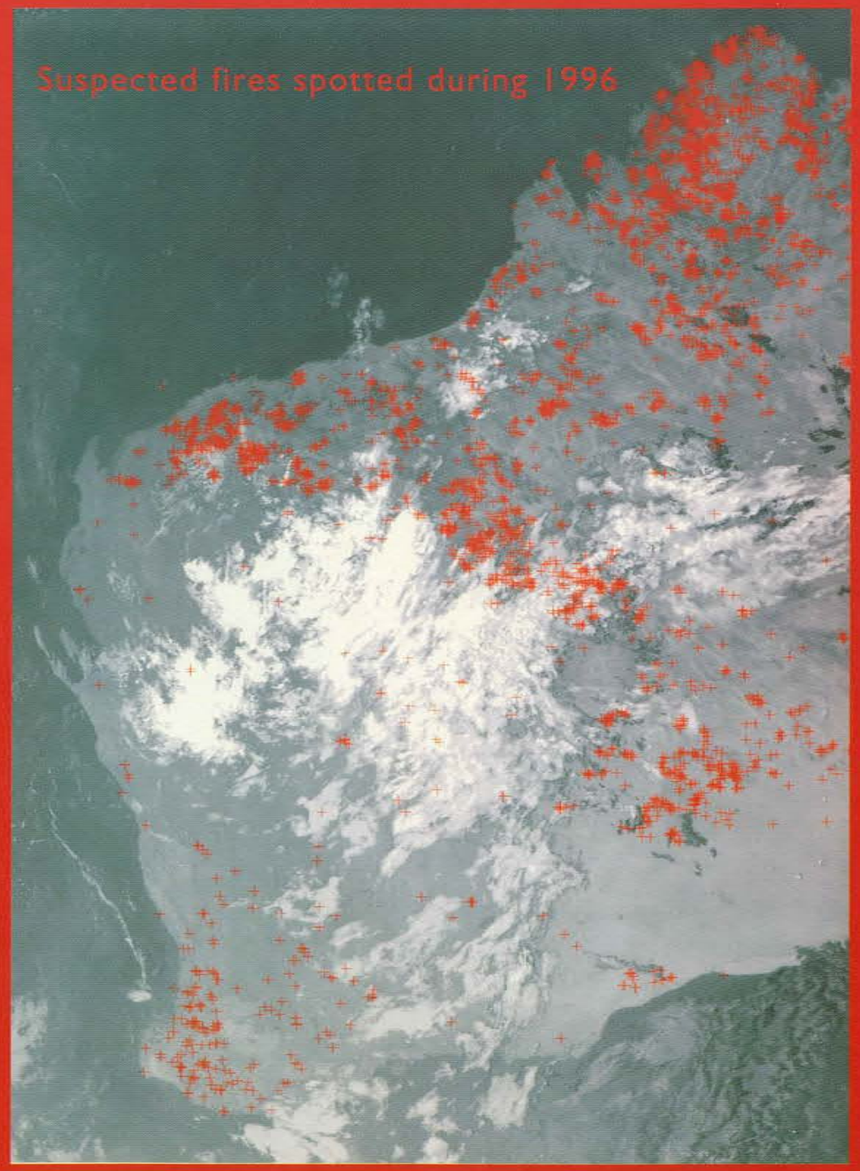
Sea Surface Temperature Maps

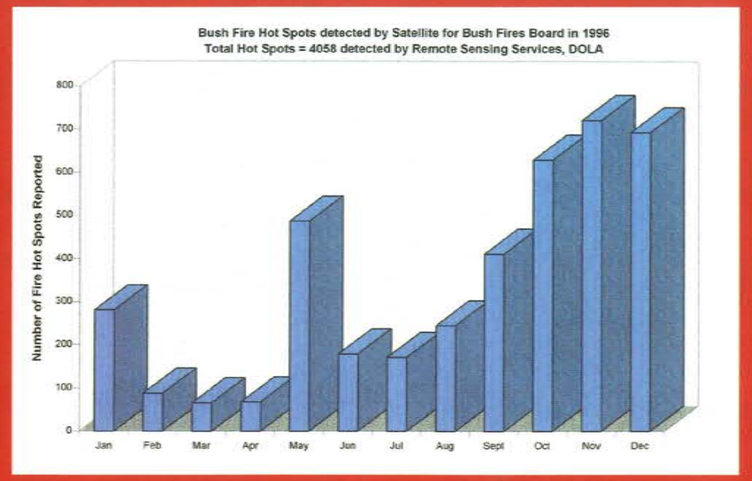
These are continually produced for the fishing industry as a navigational aid to locate potential fish stocks. The lobster and fish industries benefit from access to this technology. Assistance this year was also given to yachtsmen in the Fremantle to Geraldton yacht race. These image maps assist by depicting the Leeuwin current position with its many meandering current streams and eddies. Refer to images in figure 2a and 2b on page 12.

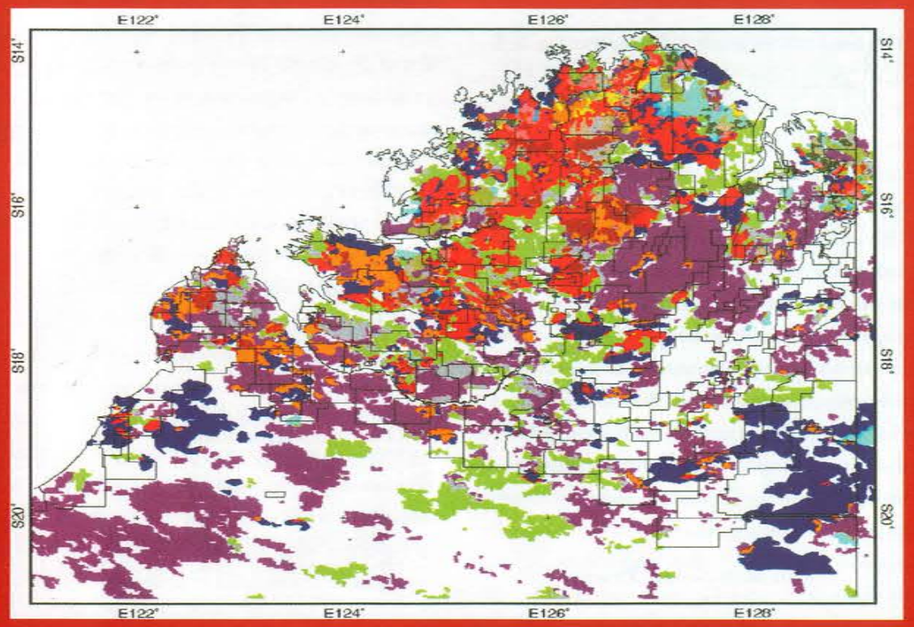
Fire Management

During 1996, Wildfire position information gained from the morning NOAA 12 satellite passes was forwarded to the Bush Fires Board of WA and also, for the first time, to the Bush Fire Council of the Northern Territory.

Fire history mapping work also continued in 1996. The use of a geographic information system has provided an insight into the repeat burning patterns in the Kimberley region of Western Australia. The analysis displayed in the accompanying figure shows, for the first time, the total area burnt over a four year period, and the areas of multiple burns over the years 1993 to 1996.







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CURTIN UNIVERSITY OF TECHNOLOGY
REMOTE SENSING AND SATELLITE RESEARCH GROUP

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Curtin University of Technology, and
Head, Remote Sensing and Satellite Reasearch Group

Associate Professor Brian White
School of Mathematics and Statistics
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Dr Bedri Subasilar
School of Physical Sciences
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Prof Iosef Fuks
Visiting Professional Fellow
University of Kharkov,
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Memorandum of Understanding (MOU) between Scripps Institution of Oceanography, University of California, San Diego (UCSD) and the Curtin University of Technology.

During 1997 Professor J Maloney, Vice Chancellor, Curtin University and Professor Freeman, Director, Scripps Institution of Oceanography (SIO), University of California at San Diego, signed a Memorandum of Understanding embracing cooperative research, and staff and student exchange. While there has been a history of cooperative activity between the two institutions for many years, it was the visit by Dr Jim Simpson, Director of the Digital Image Analysis Laboratory, SIO to the Remote Sensing and Satellite Research Group at Curtin University that stimulated the initiative. Assoc. Professor Lynch was invited to SIO during 1996 to work with Dr Simpson, Director of the Digital Image Analysis Laboratory, SIO on drafting the MOU which was signed later that year.

Research Group Theme

The Remote Sensing and Satellite Research Group (RSSRG) provides an effective link between Curtin University and the very active remote sensing groups in the WA community. The primary thrust of the Group is remote sensing science. This terminology indicates the focus on the specific aspects of remote sensing that relate to sensor design studies, instrument calibration, radiometric correction, atmospheric and oceanic transmittance studies, algorithm development and geophysical product validation. The spectrum of activities in which the Group is involved is quite extensive, in part to ensure that it embraces the range of student interests in remote sensing science and also to ensure that the links with local industry and public sector agencies are sustained. With respect to the latter it is typical for student research to be both formally and practically linked to community-based remote sensing research. This is typically achieved using both external co-supervision of projects and working either within industry or with industry- provided research data sets.

At the local level the RSSRG represents Curtin University's interests on the Board of WASTAC and on the Coordinating Committee of the Leeuwin Centre for Earth Sensing Technology.

In October 1996, a routine monthly cross-shelf oceanographic research cruise was initiated in collaboration with CSIRO. The transect is from a point West of the Hillary's Marina to a specified location 40 km offshore. The transect includes measurement stations at five kilometres intervals with the stations being identified using vessel GPS. The transect is a component of a joint research project between CSIRO Marine Research and Curtin University's RSSRG and involves participants from State Fisheries, CALM and the Curtin University School of Biological Sciences. Measurements recorded during the transect include in-situ and radiometric sea surface temperature, profiles to sea bottom of salinity and temperature, bio-optical measurements (including fluorimeter, downwelling broadband radiance, spectral ocean reflectance), phytoplankton and zooplankton. The current project will support the transect for two years but funding is being sought to continue it beyond that date. Data from the cruise is used primarily for the important validation of satellite observations of sea surface temperature and ocean colour. Data presently being acquired supports validation of instruments on NOAA, OCTS and GMS satellites. During 1997 it is planned to include validation of SeaWiFS. The transect and the associated data have attracted interest from scientists in Japan, France and the USA.

1. Coastal Zone Research with SeaWiFS Satellite Data

Associate Professor Mervyn Lynch, Mr Jim Davies†, Mr Peter Fearns††,
Mr Alan Pearce* and
Dr John Parslow**

Curtin University is presently putting in place software to ensure that SeaWiFS raw data collected by WASTAC will be converted into coastal zone products. With some 90% of the radiometric signal arising from the atmosphere received by a satellite sensor and just 10% from the ocean, the correction for atmospheric effects is being researched. As part of his PhD studies, Mr Davies has developed a radiative transfer model which is to be used to study sensitivity of SeaWiFS spectral measurements to changes in atmospheric state. This model is currently being compared to other models and preparations made to test its performance against solar photometry measurements. Mr Peter Fearns is modelling the in-water scattering. These two models will be linked to provide a complete sun-ocean-satellite forward model.

* CSIRO Division of Oceanography, Marmion
** CSIRO Division of Fisheries, Hobart
† recipient of an APRA PhD Scholarship
†† recipient of a Digital Equipment Corporation Scholarship

2. Corrections to the Normalised Difference Vegetation Index (NDVI) Derived from NOAA/AVHRR Satellite Data

Associate Professor Mervyn Lynch, Mr Tissa Weerasekera† and Dr Richard Smith*

Atmospheric scattering due to the molecular atmosphere and aerosols, absorption due to atmospheric water vapour, and the angular dependence of surface bi-directional reflectance can cause NDVIs determined from remotely sensed data to be significantly in error.

Present research has drawn upon radiative transfer theory to develop and implement procedures for applying corrections for the molecular atmosphere, aerosols, and atmospheric moisture. Improvements to algorithms for deriving land and vegetation reflectances and ultimately NDVI are continuing.

To date it has been shown that it is possible to retrieve simultaneously the surface reflectance and the atmospheric aerosol optical depth by solving four non-linear equations for a pair of pixels. At present, we are concerned with the validation of the methods using aircraft observations made over WA using a multi-spectral sensor as well as data from international FIFE experiments conducted in the USA.

Project supported by PhD Fellowship from AIDAB. WASTAC is acknowledged for the provision of NOAA/AVHRR satellite data sets.

† Recipient of an AIDAB PhD Fellowship
* Manager, Remote Sensing Services, DOLA

3. Estimation of Atmospheric Aerosols Optical Depth over Oceanic Regions using NOAA/AVHRR Satellite Data

Associate Professor Mervyn Lynch, Ms Jackie Marsden†, Dr Ross Mitchell*, Dr Bruce Forgan**.

Unless accounted for correctly the variability in concentration and physical properties of atmospheric aerosols (on daily and seasonal scales) contributes a source of error to satellite products derived using visible channel sensor data. We are applying radiative transfer methods to develop improved algorithms for estimating aerosol optical depths. These algorithms are best tested over the oceans because this avoids the large and variable contribution from land surface reflectance. For this research we are comparing the aerosol optical depths derived from NOAA satellite data to ground-based solar photometer measurements taken at the Cape Grim Baseline Air Pollution Station, Tasmania. Recently, we have obtained Cape Grim aerosol optical depth data for the years 1991 and 1993 and are in the process of processing satellite sets to enable the comparisons of optical depths to be made.

We acknowledge the provision of NOAA/AVHRR satellite data sets by WASTAC, and Dr Bruce Forgan for the provision of solar photometer data sets for use in validation studies.

* CSIRO Division of Atmospheric Research, Melbourne

** Bureau of Meteorology Research Centre, Melbourne

† PhD student

4. Satellite Microwave Data for Estimating Tropical Cyclone Intensity

Associate Professor Mervyn Lynch, Mr Len van Burgel*, Dr Fred Prata** and Dr John Le Marshall***

This project uses microwave data from the NOAA Microwave Sounding Unit (MSU) to monitor the upper level temperature anomaly (at about 12 km altitude) in WA tropical cyclones. The anomaly is theoretically linked to the central pressure of the storm and therefore may be used directly to infer intensity. A regression relationship has been derived for this purpose. In 1998 an improved microwave sensor (Advanced MSU) was fitted to the NOAA satellites. This sensor provides a superior opportunity for producing data for the estimation of the strengths of tropical cyclones. A final component of this research involves modelling the expected performance of AMSU using synthetic data sets generated with an atmospheric microwave transmittance model. The work is approaching its conclusion with the processing of retrieved temperature profiles by BoM. These data will be compared with the microwave brightness temperatures obtained previously.

Project support: WASTAC is acknowledged for the provision of NOAA satellite data sets

* Bureau of Meteorology, Perth

** CSIRO Division of Atmospheric Research, Melbourne

*** Bureau of Meteorology Research Centre, Melbourne

5. The Genesis and Development of Tropical Cyclones of the NW Australia Region

Associate Professor Mervyn Lynch, Mr Greg Hamilton* and Mr Mark Williams**

The development of tropical cyclones depends on a number of conditions such as elevated sea surface temperature, convergence and so on. The details of the progression from the formation and organisation of a cloud cluster through to the development and deepening of a low pressure system remain unclear. This project has begun the collection of both satellite and numerical model data on cloud clusters which develop and, importantly, those which fail to develop into tropical cyclones in NW Australian waters. The data currently are undergoing analysis to identify systematics and attributes with which to characterise these systems. The use of NOAA AVHRR data for sea surface temperature will complement the extensive data base used in this study.

Project supported by BoM for the provision of both numerical model and GMS satellite data. We record our appreciation of Dr Beth Ebert, at BoM for her assistance.

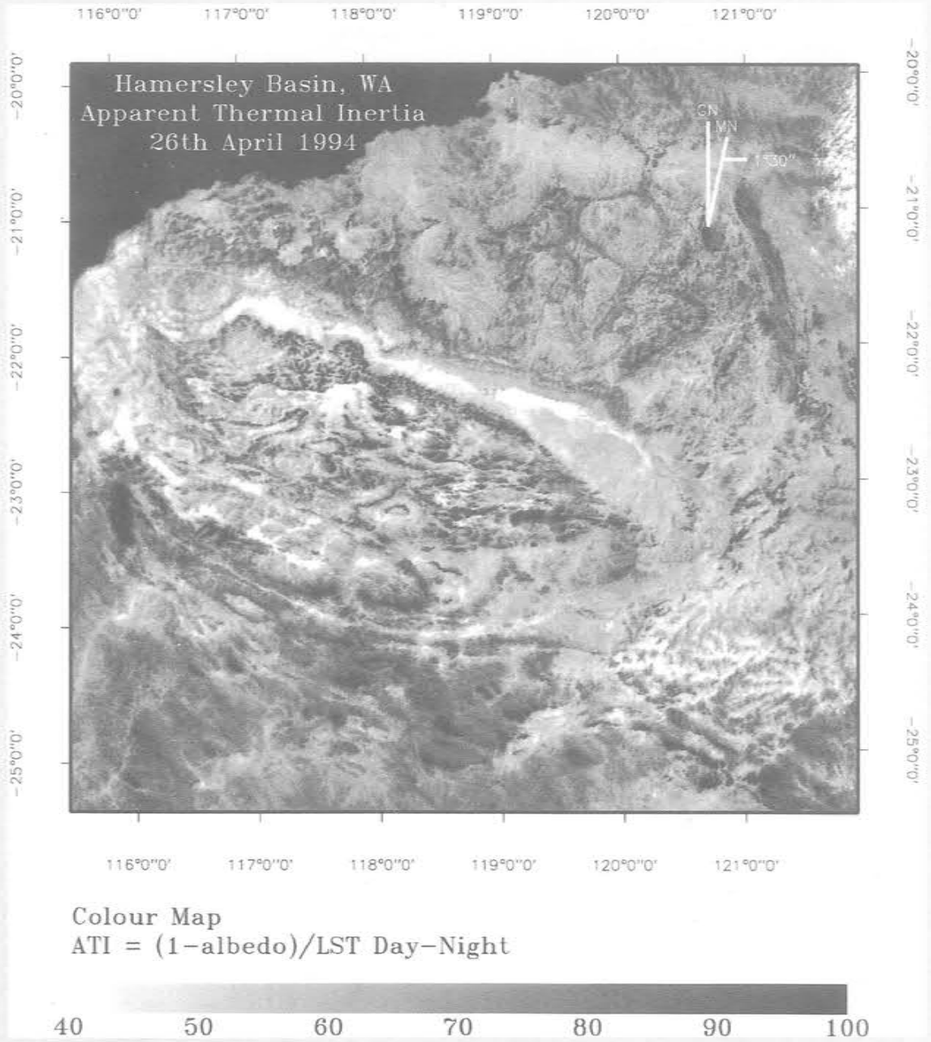
* Bureau of Meteorology, Perth

** Bureau of Meteorology, Melbourne

6. Remotely Sensing Land Surface Thermal Inertia

Associate Professor Mervyn J Lynch, Mr David Ellement# and Dr Ian Tapley*

The temperature excursion of the land surface over the diurnal cycle is determined by the net effect of energy arrival at and energy loss from the surface via conductive, convective and radiative processes. If we are able to define the radiative and convective terms with sufficient accuracy, then we may infer the heat transfer through the soil, and ultimately estimate the physical properties (e.g. thermal conductivity, thermal inertia) of the near-surface geology. This project has progressed initially by implementing a numerical model , due to Kahle, of the diurnal cycle of land temperature. The performance of the model has been evaluated against data from a number of agricultural field sites which have land temperture monitors



An image of apparent thermal inertia (ATI) over the Hamersley Basin, Western Australia. This ATI product was derived from NOAA/AVHRR imagery. The visible band provided the surface albedo and the two long wave infrared bands were used to derive a day/night land surface temperature difference. ATI relates the heat flux through the surface to the thermal properties of the near-surface geology.

installed. This has permitted the diagnosis of several of the component terms because insolation is separately measured. The model is undergoing further investigation pending improvement to the insolation and the downward sky radiance term. In addition, we have derived land surface temperatures (LST) from NOAA/AVHRR satellite data and compared these to the in-situ observations. Plans are to continue the modelling, in-situ and remote observations to achieve consistency on the diurnal scale.

Plans are in place to extend the model execution to much longer time intervals and to test if the model reproduces the seasonal and annual LST cycles, and subsequently to establish if these are in agreement with the in-situ and remotely sensed measurements. If these goals are achieved the implications for the interpretation of the sub-surface geology will be addressed.

The NOAA/AVHRR data are provided courtesy of WASTAC and the field site observations courtesy of Mr Ian Foster, Agriculture WA.

\# Third Year Project student

* CSIRO Exploration and Mining Division

Publications

School members are shown in bold type.

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Davies J E, and Lynch, M J. (1996). Estimating Maritime Aerosol Size Distribution from Synthetic Satellite Radiances and Implications for Ocean Colour Sensing, In Proceedings *International Radiation Symposium,* Fairbanks, Alaska, August 19-24 (Deepak Publ.), in press.

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Fearns, P R and Lynch M J. (1996). Retrieval of Chlorophyll Concentration via Inversion of Ocean Colour Reflectance - a Modelling Approach. Presented *Ocean Optics XIII*, Halifax, Nova Scotia, Canada, October 22-25.

Lynch, M J. (1996). MODIS Vicarious Calibration and Product Validation Plan for Western Australia. Presented at MODIS Science Team Meeting, NASA GSFC, Washington, DC.

Lynch, M J and White, B A. (1996). MODIS ATBD - Infrared Detector Master Curve and Stability of the Calibration Algorithm in the Limit of a Small Second Order Gain Coefficient. Presented at the MODIS Atmospheres Discipline Group Meeting, University of Wisconsin, Madison, August 28-29, 1996.

Revercomb, H E, **Lynch, M J**, Gumley, L E, Strabala, K I and **van Delst, PFW**. (1996). Land Surface Temperature and Emissivity Estimation with High Spectral/High Spatial Resolution Sensors. Presented at *International Land Surface Temperature Workshop*, University of California, Santa Barbara, California, September 17-19.

Ellement, D, Lynch M J, White B A and Tapley I (1996) Remote Sensing of Thermal Inertia Applied to the Hamersley Basin, Western Australia. School of Physical Sciences, Curtin University of Technology pp103. Submitted to Hamersley Iron Pty Ltd.

Marsden, J. (1996) Measurement and Validation of Aerosol Optical Depths Using Data from the Cape Grim Baseline Air Pollution Station. School of Physical Sciences Report No. SPS 667 / 1996 / AP 61, pp9. Report to the Australian Academy of Science for Travel Grant for Research in Climate and Atmospheric Sciences.

Conference Travel

Mr Jim Davies and Mr Peter Fearns attended the Ocean Optics XIII Conference, Halifax, Nova Scotia in October, 1996 and also presented two scientific papers at that meeting. The financial assistance of WASTAC is gratefully acknowledged.

Study Leave

Assoc Professor Mervyn Lynch

Study leave was undertaken at the Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin, Madison, Wisconsin. Leave was taken for the period December 1995 to January 1997. The objectives of the Overseas Study Program (OSP) were primarily to gain currency advances in remote sensing science; in particular with EOS mission satellite instruments and with next generation sensors, namely advanced sounders.

During the OSP participation in several field experiments was achieved, specifically, the SUCCESS experiment in Kansas, the Water Vapour IOP at the DOE Great Plains Site in Oklahoma, and the TARFOX/MODIS airborne simulator mission off the east coast of the USA.

Interaction with the EOS MODIS Science Team on aspects of MODIS calibration was productive. Research was also undertaken on new applications of the high spectral resolution interferometer (AERI) and the marine version of the same instrument (MAERI) including land surface temperature and emissivity, sea surface temperature, and emissivity and ocean heat flux estimation.

Interactions were also undertaken with the SeaWiFS Science Team at NASA/GSFC.

Visits were made to the the Institute of Geophysics, University of Alaska, Fairbanks, AK; Centre for Imaging Science, Rochester Institute of Technology, Rochester, NY; Image Analysis Laboratory, Marine Physical Laboratory, Scripps Institution of Oceanography, University of California at San Diego; the Earth Observations Centre, University of California at Santa Barbara; NASA Goddard Space Flight Center, MD; and NASA Wallops, VA.

A number of conferences and workshops were attended during OSP.

During the International Radiation Symposium (IRS'97), Fairbanks, Alaska in August, 1996, Assoc Prof. Lynch was elected to the office of Secretary to the International Radiation Commission for the four year term 1996 - 2000.

		PER ANNUM	
		$	$
Estimated expenditure financial year January 1997 - December 1997		**1997**	**1996**
1.	Telstra Rental	3,000	2,700
2.	Exabyte Tapes	4,000	4,000
3.	System maintenance/repairs	6,000	4,000
4.	Telecommunications licence of facility	1,200	1,500
5.	Photographic/ink jet quick-look costs	3,100	3,000
6.	Consultants-Archive/product generation assistance	16,500	10,500
7.	Sundries, consumables	2,000	1,000
8.	Travelling - airfares	4,500	4,000
9.	Provision for major equipment	2,000	11,000
10.	Annual Report	4,500	5,000
11.	Special provision for improved communications	-	100,000
12.	WWW site development software (BoM)	3,000	-
	TOTAL	**49,800**	**146,700**
Estimated income/revenue for the year January 1997 - December 1997			
1.	Contributions received ($10,000 each member)	40,000	40,000
2.	Sundry income (data replication)	1,000	4,000
3.	Interest	4,000	2,000
	TOTAL INCOME:	**45,000**	**46,000**
Extra-ordinary Expenditure January 1997 - December 1997			
1.	Capital Reserve:		
	1.1 Antenna replacement and componentry	40,000	
	1.2. SeaWiFS reception	5,000	
2.	SeaWiFS expenditure deferred from 1995. (refer minutes 10/8/95)	10,000	

AUDITOR'S REPORT:

I have audited the attached financial statements and in my opinion these fairly represent the transactions of the Consortium during the 1996 calendar year, together with its financial status as at 31 December 1996. The statements are based on proper accounts and records.

P J Perriam

Manager Internal Audit

CURTIN UNIVERSITY OF TECHNOLOGY

CURTIN UNIVERSITY OF TECHNOLOGY
WA SATELLITE TECHNOLOGY CENTRE

BALANCE SHEET AS AT 31 DECEMBER 1996

	NOTE	1996	1995
		$	$
CURRENT ASSETS			
Cash at Bank		95,091	177,668
Prepayments		2,911	732
TOTAL CURRENT ASSETS		98,002	178,400
NON - CURRENT ASSETS			
Computer Equipment	2	55,076	29,138
Other Equipment	2	67,968	65,832
TOTAL NON - CURRENT ASSETS		123,044	94,970
TOTAL ASSETS		221,045	273,370
CURRENT LIABILITIES			
Creditors and Borrowings		-	368
Accrued Expense		-	-
TOTAL CURRENT LIABILITIES		-	368
NON - CURRENT LIABILITIES			
Creditors and Borrowings		-	-
TOTAL NON - CURRENT LIABILITIES		-	-
TOTAL LIABILITIES		-	368
NET ASSETS		**221,045**	**273,002**
SHAREHOLDERS' EQUITY			
Asset Revaluation Reserve	3	129,997	129,997
Retained Profits/(Losses)	4	91,048	143,005
TOTAL SHAREHOLDERS' EQUITY		**221,045**	**273,002**

CURTIN UNIVERSITY OF TECHNOLOGY
WA SATELLITE TECHNOLOGY CENTRE

INCOME AND EXPENDITURE STATEMENT FOR THE PERIOD 1 JANUARY 1996 TO 31 DECEMBER 1996

	NOTE	1996 $	1995 $
INCOME			
Contributions Received	5	40,000	40,000
Sundry Income	6	-	1,200
Interest Received		12,846	2,537
TOTAL INCOME		**52,846**	**43,737**
EXPENDITURE			
Salaries and Wages		14,235	13,275
Conference		4,035	-
Telephone		3,129	2,247
Travel		750	-
Consumables		6,432	6,794
Printing, Stationery and Photocopying		3,971	3,550
Depreciation		40,248	19,118
Maintenance of Equipment		1,993	2,676
Equipment < $1,000		606	-
Computer Equipment Purchases		29,404	-
Feasibility Study		-	-
TOTAL EXPENDITURE		**104,803**	**47,660**
NET SURPLUS (DEFICIT)		(51,957)	(3,923)
EXTRAORDINARY ITEMS		Nil	Nil
NET SURPLUS (DEFICIT) AND EXTRAORDINARY ITEMS		**(51,957)**	**(3,923)**
TRANSFERS TO ASSET REVALUATION RESERVE		Nil	Nil
NET SURPLUS (DEFICIT) TRANSFERRED TO RETAINED PROFITS/(LOSSES)		**(51,957)**	**(3,923)**

CURTIN UNIVERSITY OF TECHNOLOGY
WA SATELLITE TECHNOLOGY CENTRE

CASH FLOW STATEMENT FOR THE YEAR ENDED 31 DECEMBER 1996

	$	
BALANCE OF CASH AS AT 1 JANUARY 1996	177,668	**CREDIT**
RECEIPTS		
Contributions Received		
COSSA Canberra	10,000	
Bureau of Meteorology	10,000	
Curtin University of Technology	10,000	
Department of Land Administration	10,000	
Total Contributions Received	**40,000**	
SUNDRY INCOME		
Interest Received	12,846	
Total Sundry Income	**12,846**	
TOTAL RECEIPTS FOR 1996	**52,846**	
PAYMENTS		
Salaries and Wages	14,235	
Accommodation	4,035	
Travel	750	
Printing	3,971	
Telephone	3,497	
Consumables	6,432	
Equipment < $1,000	606	
Equipment Maintenance contracts	4,172	
Computer Equipment Purchases	86,670	
Other Equipment Purchases	11,055	
TOTAL PAYMENTS FOR 1996	**135,423**	
EXCESS OF RECEIPTS OVER PAYMENTS FOR 1996	**(82,577)**	
BALANCE OF CASH AS AT 31 DECEMBER 1996	**95,091**	**CREDIT**

CURTIN UNIVERSITY OF TECHNOLOGY
WA SATELLITE TECHNOLOGY CENTRE

NOTES TO AND FORMING PART OF THE FINANCIAL STATEMENTS FOR THE PERIOD 1 JANUARY 1996 TO 31 DECEMBER 1996

1. STATEMENT OF ACCOUNTING POLICIES

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

(a) 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.

(b) Valuation of Fixed Assets

In the years preceding 1990, the University operated on a cash accounting basis and consequently all fixed asset purchases were expensed in the year of acquisition. During 1990, all fixed assets were introduced into the financial statements at cost or valuation as an extraordinary item. This value was subsequently transferred to an Asset Revaluation Reserve.

In accordance with relevant Treasurer's Instructions, items costing less than $1,000 which were purchased during 1990 have been expensed in 1990. Items of plant purchased prior to 1 January 1990 which cost less than $1,000 have been excluded from the group of assets introduced during 1990.

(c) Depreciation

Plant and equipment present in these financial statements 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.

	1996 $	1995 $
2. NON CURRENT ASSETS		
Computing Equipment (at cost)	243,849	186,583
Accumulated Depreciation	(188,774)	(157,445)
TOTAL COMPUTING EQUIPMENT	**55,076**	**29,138**
Other Equipment (at cost)	194,820	183,765
Accumulated Depreciation	(126,852)	(117,933)
TOTAL OTHER EQUIPMENT	**67,968**	**65,832**
TOTAL NON - CURRENT ASSETS	**123,044**	**94,970**
3. ASSET REVALUATION RESERVE		
Opening Balance	129,997	129,997
Movement During the Year	Nil	Nil
CLOSING BALANCE	**129,997**	**129,997**
4. RETAINED PROFITS/(LOSSES)		
Opening Balance	143,005	146,928
Net Surplus (Deficit) for the year	(51,957)	(3,923)
CLOSING BALANCE	**91,048**	**143,005**
5. CONTRIBUTIONS RECEIVED		
Department of Land Administration	10,000	10,000
Curtin University of Technology	10,000	10,000
Bureau of Meteorology	10,000	10,000
COSSA Canberra	10,000	10,000
	40,000	**40,000**
6. SUNDRY INCOME		
Supply of NOAA - AVHRR passes to the Department of Defence	Nil	1,200
	Nil	**1,200**

COMPUTING EQUIPMENT AS AT 31 DECEMBER 1996

Asset number	Description	Original cost $	Accumulated depreciation $	Written down value $
2494515	MICROSOFT OS/2 PM TOOLKIT	488.00	488.00	0.00
2587007	MATHS CO-PROC INTEL 20MHZ	570.00	570.00	0.00
2494511	ETHERLINK MC CARD	590.00	590.00	0.00
2587001	MOUSE	109.00	109.00	0.00
2552700	TAPE DRIVE 2 GBYTE X801A	6,840.00	6,840.00	0.00
2587010	2MB MEMORY MODULE	475.00	475.00	0.00
2494507	OS/2 EXTENDED EDITION V1.2	700.00	700.00	0.00
2553701	ACQNR	3,800.00	3,800.00	0.00
2587200	ULTRA 1000 20"	2,870.00	2,870.00	0.00
2494506	PS/2 CARD TO OPTION SCSI	142.00	142.00	0.00
2494509	MATHS CO-PROCESSOR INTEL 25MHZ	726.00	726.00	0.00
2494503	PS/2 DUAL ASYNCH ADAPTOR	233.50	233.50	0.00
2494500	PS2 25MHZ 4/320MBHD AND MONITOR VGA	16,686.00	16,686.00	0.00
2478800	2.3GB 8MM EXABYTE	6,272.00	6,272.00	0.00
2587002	DUAL ASYNCH ADAPTOR	233.50	233.50	0.00
2494512	MONITOR DISPLAY CABLE	120.00	120.00	0.00
2587005	2MB MAIN MEMORY EXPANSION	953.00	953.00	0.00
2494510	4-16MB MEMORY BOARD 4MB	1,501.00	1,501.00	0.00
2629700	CARTRIDGE SYSTEM 2.5 G BYTE 8MM EX	4,950.00	4,950.00	0.00
2494516	FORTRAN V2.0	754.00	754.00	0.00
2587011	2MB MEMORY MODULE	475.00	475.00	0.00
2587000	PS/2 20MHZ 2/320MBHD VGA AND SCSI CARD	9,392.00	9,392.00	0.00
2587300	5.25 DISKETTE	501.00	501.00	0.00
2494504	PS/2 DUAL ASYNCH ADAPTOR	233.50	233.50	0.00
2587003	DUAL ASYNCH ADAPTOR	233.50	233.50	0.00
2587014	MONITOR DISPLAY CABLE	120.00	120.00	0.00
2587009	2MB MEMORY MODULE	475.00	475.00	0.00
2585200	PAINTJET XL C1602A	2,425.00	2,425.00	0.00
2587100	ULTRA 1000 20"	2,870.00	2,870.00	0.00
2494505	5.25 EXTERNAL DISKETTE ADAPTOR	204.00	204.00	0.00
2587012	ETHERLINK MC CARD	590.00	590.00	0.00
2494517	LOCAL AREA NETWORK TECH MANUAL	70.00	70.00	0.00
2494501	MEMORY EXPANSION BOARD 4MB	1,911.00	1,911.00	0.00
2587008	2-8MB MEMORY EXPANSION	1,450.00	1,450.00	0.00
2494513	MS MACRO ASSEMBLER V5.1	174.00	174.00	0.00
2494508	320MB HD DRIVE	4,739.00	4,739.00	0.00
2494518	PS/2 MOUSE	109.00	109.00	0.00
2587013	FUTURE DOMAIN	450.00	450.00	0.00
2587004	OS/2 EXTENDED EDITION V1.2	700.00	700.00	0.00
1358800	SYSTEM SATELLITE TRACKING STATION	110,000.00	110,000.00	0.00
2494514	MICROSOFT C COMPILER V6	448.00	448.00	0.00
3914000	MICROWAVE COMMUNICATION SYSTEM	57,266.00	2,190.50	55,075.50
TOTAL COMPUTING EQUIPMENT		**243,849.00**	**188,773.50**	**55,075.50**

OTHER EQUIPMENT AS AT 31 DECEMBER 1996

Asset number	Description	Original cost $	Accumulated depreciation $	Written down value $
200900	MA 23CC	20,365.00	12,783.16	7,581.84
1358700	SATELLITE STATION TRACKING	140,000.00	100,531.90	39,468.10
2553700	RECEIVER NOAA I/F FORMAT	19,500.00	10,543.41	8,956.59
1948500	POWER CONDITIONER	2,000.00	1,271.78	728.22
2552600	SGSI HOST ADAPTOR 598A	1,900.00	1,027.30	872.70
3852500	CX-FS1P4 CISCO 4 PORT S/INTER	7,440.00	467.41	6,972.59
3852501	PA-7KF-E1/75 CISCO DUAL E1 G70	3,400.00	213.60	3,186.40
3852502	CAB E1 BNC FSIP MIP-CE1 BNC 75	215.00	13.50	201.50
TOTAL OTHER EQUIPMENT		**194,820.00**	**126,852.06**	**67,967.94**