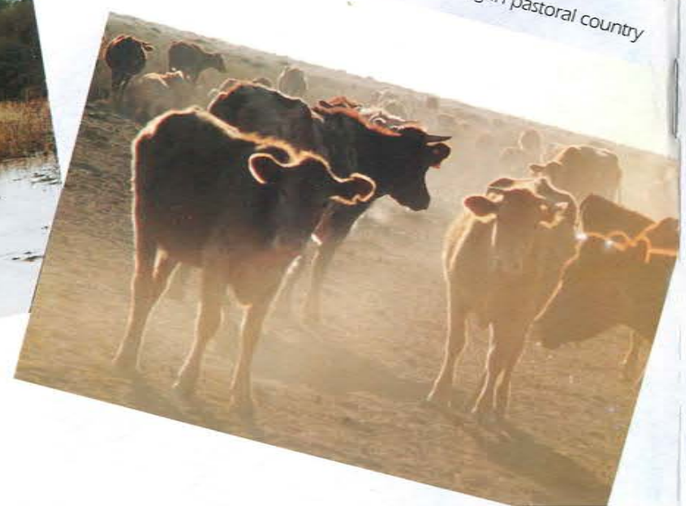
Proliferation of wildflowers in pastoral country following seasonal rainfall - Sandstone / Yalgoo region

Degraded and healthy pastoral land - Sandstone / Yalgoo region

WASTAC satellite receiving dish at Curtin University - Bentley

Flooding resulting from unseasonal rainfall - Mt Magnet

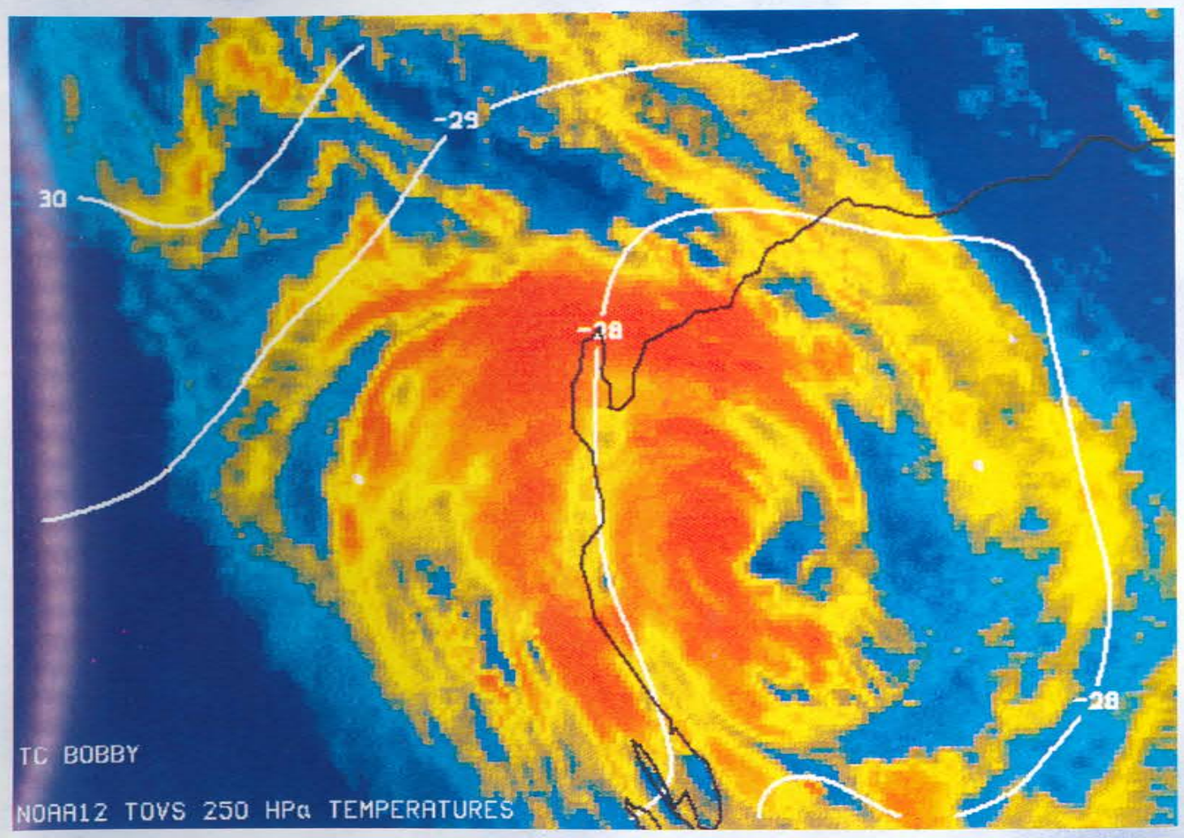
Cattle grazing in pastoral country



WASTAC

Western Australian Satellite Technology and Applications Consortium

Annual Report 1994



WASTAC members

Bureau of Meteorology,
GPO Box 1289K,
Melbourne VIC 3001

Department of Land Administration,
Leeuwin Centre for Earth Sensing Technologies
65 Brockway Road, Floreat, WA 6014

Curtin University of Technology,
Kent Street,
Bentley WA 6102

CSIRO,
Office of Space Science and Applications
GPO Box 3023
CANBERRA ACT 2601

Front Cover:

Colour enhanced imagery of tropical cyclone Bobby, 26 February 1995, after it had crossed the coast of Western Australia. The middle and higher level clouds associated with the cyclone are shown in yellow and orange. The WA coastline is shown in black. Temperatures (^{0}C) at the 250 hPa level, derived from NOAA 12 TOVS data received by WASTAC, are shown as white isotherms and reveal a significant pool of warm air (warmer than 28^{0}C) over the central spiral of the cyclone's cloud field.

Satellite Images: Bureau of Meteorology

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATIONS CONSORTIUM

ANNUAL REPORT 1994

WASTAC
Postal: The Secretary, WASTAC
PO Box 471
WEMBLEY 6014
Western Australia

65 Brockway Road
FLOREAT 6014
Western Australia

Telephone: (09) 340 9330
Fax: (09) 383 7142
International (+619)

C O N T E N T S

WASTAC CHAIRMAN'S REPORT - 1994

WASTAC activities have continued to focus on maintaining a reliable, comprehensive and accessible archive of NOAA-AVHRR satellite data to consortium members for operational, research and application purposes. The deliberations of the Board have focused on some of the strategic issues necessary to maintain relevance in a changing world, these issues are reflected in a new Deed of Agreement shortly to be finalised, and will carry WASTAC into the next 5 years. Reflecting the increasing significance of WASTAC's role in providing national and international coverage of broad resolution satellite data, the new Board welcomes the participation of CSIRO's Office of Space Science and Applications and the Bureau of Meteorology's Satellite Section in Melbourne.

With new advances in satellites and communications, the Board recognises that the next 5 years will pose significant challenges to WASTAC. This coming year it is anticipated that data from the SeaWiFS wide field of view ocean colour satellite will be recorded. This data will measure the chlorophyll content and primary productivity of oceans. New data from the recently launched NOAA-14 satellite will be received in early 1995 replacing data from the ailing NOAA-11. The consortium members are now actively involved in the cross calibration of these two satellites to ensure that the ongoing monitoring of changes in vegetation growth can occur.

To enable the implementation of the automatic processing of NOAA-AVHRR of satellite data in real time, the establishment of a high speed communication link between the Bureau of Meteorology and Remote Sensing Applications Centre has been progressed with approval granted for the construction of the Perth Academic Network (Parnet).

The current report indicates that WASTAC data continued to be increasingly used both operationally and in support of research during the past year. The success of the Consortium has been the result of the willing collaboration and cooperation of WASTAC members. I wish to again acknowledge the effort of key individuals on maintaining an efficient and professional service to all users.

H. HOUGHTON
CHAIRMAN
WASTAC

WASTAC BOARD FOR 1994

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
MR JEFF KINGWELL	CSIRO
MR ALAN PEARCE	CSIRO
MR BRUCE NEAL	Bureau of Meteorology
MR LEN BROADBRIDGE	Bureau of Meteorology
MR DON WARD	Bureau of Meteorology

***L - R**:: Alan Pearce, CSIRO; Brian Embleton, CSIRO; Richard Smith, DOLA; Bruce Neal, Bureau of Meteorology; Doug Myers, Curtin; Len Broadbridge, Bureau of Meteorology; Don Ward, Bureau of Meteorology; Richard Stovold, DOLA; Mervyn Lynch, Curtin.*

***Absent**: Henry Houghton, DOLA; Jeff Kingwell, CSIRO. (Photo by Robert Shaw, DOLA)*

OPERATIONAL STATUS

WASTAC facilities consist of an antenna and antenna controller at the Curtin University of Technology, ingest and display computers with hard disk storage located at the new Bureau of Meteorology premises at 1100 Hay Street, Perth. A microwave and dial up link exists between the two sites to facilitate realtime satellite data relay and acquisition scheduling.

Colour as well as black and while grey scale pictures are produced at 180 dpi by a HP Paintjet printer and these are passed to DOLA (Remote Sensing Applications Centre) for archive, indexing and distribution. The AVHRR raw data archive is produced on 8mm cartridge tape and a duplicate copy is currently produced for a national NOAA data archive program that is coordinated by COSSA.

The HRPT ingest and display system, modelled on the Bureau of Meteorology's facilities at Casey in Antarctica and Darwin, consists of two IBM PS/2 model 80 computers. One PS/2 is dedicated to automated data ingest and the other to providing display, processing and backup facilities. The Bureau's MCIDAS software provides for display and post processing.

The TOVS data, a subset of HRPT, is automatically sent to Melbourne so that atmospheric temperature retrievals can be included in the global numerical weather prediction models. SST's (Sea Surface Temperatures) have been produced since June 93 using an IBM PS/2 Model 77 and BOM (Bureau of Meteorology) software. The SST's from each NOAA pass are mosaiced for the Australian/Indian ocean region.

Equipment failures during the year resulted in the loss of 5 days of data.

Due to the dedicated efforts of Ron Craig and BOM staff, over 4230 passes were recorded for the year.

DOLA is currently holding the archive on 8mm tapes.

An ongoing archive copy program has successfully copied many late seventies and early eighties NOAA passes from reel tape to 8mm cartridges.

Orders for digital data are provided on 8mm cartridge or 6250/1600bpi magnetic tape in raw or SHARP (band interleaved or band sequential internationally compatible) format.

DON WARD
REGIONAL COMPUTING MANAGER
BUREAU OF METEOROLOGY : PERTH

WASTAC DATA ARCHIVE

The WASTAC archive of NOAA satellite passes, managed and maintained by the Department of Land Administration (DOLA), through the Remote Sensing Applications Centre, has been situated at the new Leeuwin Centre for Earth Sensing Technologies at Floreat Park, Western Australia since May 1993.

DOLA is actively managing 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 1 kilometre data set which is being administered by COSSA.

In conjunction with this programme, WASTAC negotiated with COSSA to duplicate WASTAC passes for storage at the Australian Land Research Data Centre at Gungahlin, Canberra. This Centre acquires satellite, aircraft and land based data relating to land cover and surface processes. The WASTAC duplicate set of NOAA passes commencing on March 1994 is stored at Gungahlin and is specifically for research use by CSIRO and collaborative partners. The Global 1 kilometre data set dates back to April 1992.

A total of 4230 NOAA passes were recorded for 1994 on 157 8mm tapes comprising 245 gigabytes of information. Passes comprised data from the NOAA 9, NOAA 11 and NOAA 12 satellites.

Copying of the old Curtin University archive of early NOAA passes has been substantially completed with the exception of a few unreadable or damaged tapes. In excess of 1200 passes were copied to 8mm data tape.

A total of 16786 passes are now held in the WASTAC archive at DOLA within the Leeuwin Centre. The bulk of passes comprises data from the NOAA 9, NOAA 11, and NOAA 12 satellites. The data collection commenced in 1981 and is summarised in the following tables.

1994 NOAA DATA HELD BY WASTAC

	NOAA 9	NOAA 11	NOAA 12	TOTAL
JAN	109	137	152	398
FEB	85	124	132	341
MAR	104	128	134	366
APR	118	139	126	383
MAY	98	123	138	359
JUN	111	118	128	357
JUL	123	131	142	396
AUG	115	127	138	380
SEPT	124	113	133	370
OCT	125	87	136	348
NOV	120	-	133	253
DEC	130	-	149	279
TOTAL	**1362**	**1227**	**1641**	**4230**

8mm Tapes: 4230 passes on 157 tapes.
Total Data Archived: 245 gigabytes.

Curtin Archive Copied to 8mm Tapes - 1994

For previously copied dates see WASTAC 1993 Annual Report.

1982	NOAA 7
JAN	1
JUL	1

1983	NOAA 6	NOAA 7
JAN		1
MAR	2	1
JUN		1
JUL		3
OCT		2
TOTAL	**2**	**8**

1984	NOAA 7
JUN	1
AUG	2
OCT	1
DEC	1
TOTAL	**5**

1985	NOAA 7	NOAA 9
FEB		1
JUL		1
AUG		1
SEPT		1
OCT		2
NOV		4
DEC	1	17
TOTAL	**1**	**27**

1986	NOAA 9
JAN	5
FEB	1
MAR	19
APR	14
MAY	15
JUN	11
JUL	20
AUG	16
SEPT	19
OCT	15
NOV	8
DEC	8
TOTAL	**151**

1987	NOAA 9	NOAA 10	TOTAL
JAN	7	1	
FEB	11	3	
MAY	5	1	
JUN	13		
JUL	10		
AUG	10	9	
SEPT	9	4	
TOTAL	**65**	**18**	**83**

Total Number of NOAA Passes Held in WASTAC Archive at Leeuwin Centre

	NOAA 6	NOAA 7	NOAA 8	NOAA 9	NOAA 10	NOAA 11	NOAA 12	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
TOTAL	**31**	**593**	**21**	**2285**	**617**	**7732**	**5507**	**16786**

Held as

57 Curtin archive 8mm tapes
1282 WASTAC archive 6250 bpi tapes
494 WASTAC archive 8mm tapes.

Highlights for 1994:

Research Programmes and Data Applications

CSIRO DIVISION OF OCEANOGRAPHY

Alan Pearce

Satellite Remote Sensing of the Leeuwin Current

Introduction

A new 3-year grant has been obtained from the Fisheries Research and Development Corporation (FRDC) to continue the remote sensing work in the Leeuwin Current region, examining relationships between the marine environment and recruitment to a number of Western Australian commercial fisheries. Among other aspects, this requires the extraction of numerical sea-surface temperature (SST) data from NOAA/AVHRR imagery. Increased effort is therefore being devoted to the reliability (accuracy) of satellite-derived SSTs in comparison with *in situ* temperature data as well as to methods of screening cloud contaminated pixels from the imagery.

Sea-Surface temperature validation

(Paul Tildesley, Angela Way)

The reliability of surface temperature derived from the NOAA satellites is being assessed against *in situ* measurements from surface vessels and buoys. Despite the general paucity of oceanographic data off Western Australia, a wide variety of temperature datasets has in fact been obtained, including temperature profiles from the CSIRO monitoring station west of Rottnest Island, surface samples along a transect off Fremantle, surface temperatures from a strip-chart thermograph installed on the STS *Leeuwin*, XBT (Expendable-BathyThermograph) data from the CSIRO Division of Oceanography, occasional surface temperature data from research vessels (RV *Franklin*, FRV *Southern Surveyor*, RV *Flinders* and the Japanese vessel *Shoyo Maru*), and self-recording temperature loggers operated by the Fisheries Department in Shark Bay, the Abrolhos Islands and off Green Head.

Initial comparisons of the AVHRR SSTs with measurements from the coastal transect have indicated that about half of the satellite-derived temperatures fall within 0.5°C of the surface measurements, and about 75% within 1°C (Figures 1 and 2). Bearing in mind differences in position (area versus spot sampling), time (up to 2 days apart), sampling depth ("skin" against top 50 cm of water) and measuring technique (radiometer versus bucket thermometer), these preliminary results are encouraging. There are, however, some disturbing anomalies, generally with the satellite values being much higher than the boat measurements; these "outliers" will have to be examined in more detail.

This analysis, which involves extracting numerical data from the imagery to match the *in situ* information, will be extended to include comparisons with the other data sets listed above.

Development of cloud-screening techniques

(Mike Bezaud, Ken Subar, Carol Bowron)

With the increasing use of numerical temperature data derived from satellite imagery for use in climatological and time-series studies, it is important that effective techniques be developed to screen clouds from the data. The objective is to remove as many as possible of the cloud-contaminated pixels without losing too many cloud-free pixels.

The simplest (and probably most widely used) methods are those which use "threshold" values defining acceptable limits for parameters derived from the spectral data. We have adopted the Saunders and Kriebel method, but some modifications have been made to the routines to suit local conditions. An intensive study is being made of the various threshold values to use for the Western Australian coastal region, and initial results suggest that both seasonally- and latitudinally-varying values may be required for some parameters.

Acknowledgements

NOAA satellite imagery is obtained from the Western Australian Satellite Technology and Applications Consortium (WASTAC). This research is supported by the Fisheries Research and Development Corporation (FRDC), and the CSIRO Office of Space Science and Applications (COSSA) has provided funding for the SST validation work. Collaborators include the WA Fisheries Department, Curtin University, WA Department of Land Administration, Centre for Water Research (University of Western Australia) and the WA Environmental Protection Authority.

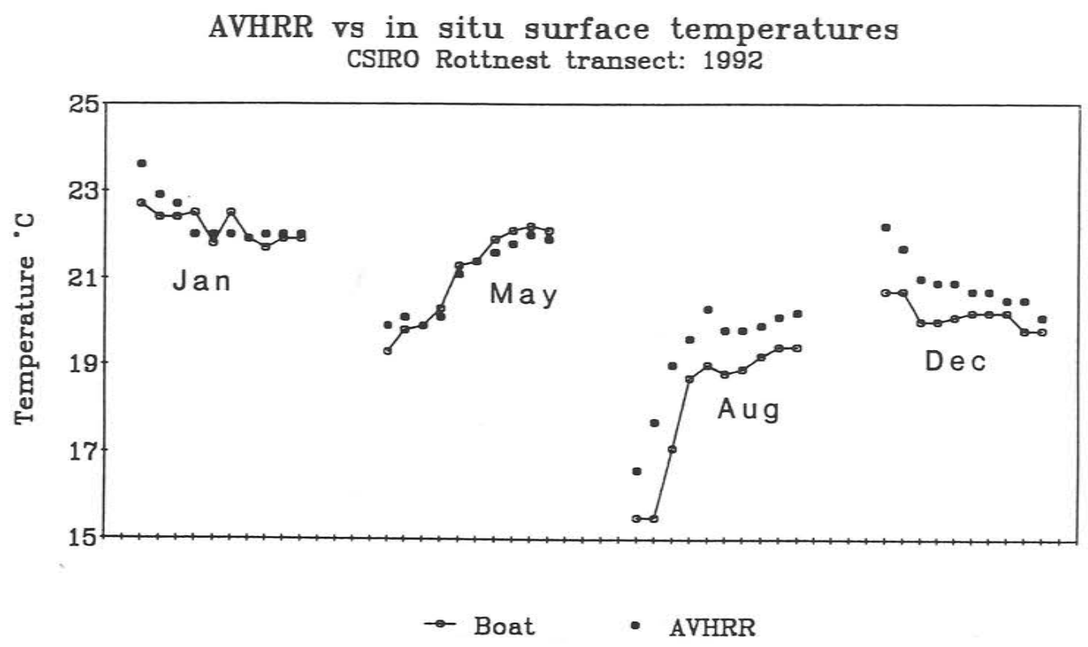


***Figure 1**: Comparison of satellite-derived SSTs (solid lines with open circles) with boat measurements (filled circles) for the transect between Fremantle and CSIRO Rottnest station for four months in 1992. Each transect runs from left (inshore) to right (offshore). The seasonally-reversing SST gradient is well reproduced in the AVHRR data.*

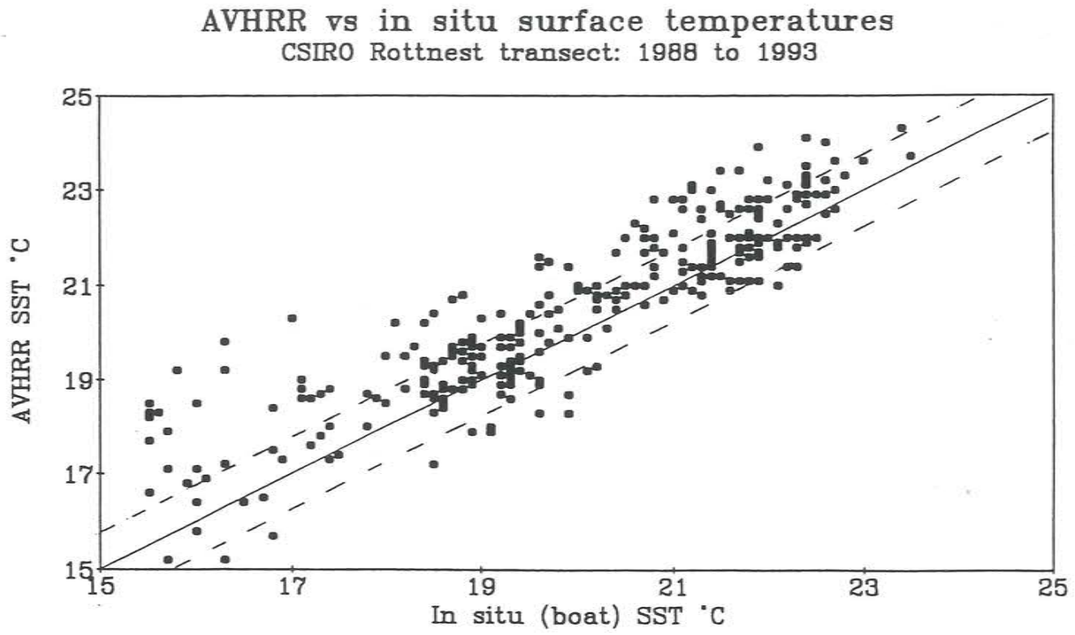


***Figure 2**: Scatterplot of AVHRR SSTs against surface (boat) measurements for all stations along the transect between Fremantle and the CSIRO Rottnest station for the period 1988 to 1993. The solid line represents the ideal fit, and the dashed lines the 0.6°C RMS difference, determined in a previous study.*

CSIRO Office of Space Science and Applications

Jeff Kingwell, Manager, Science, Applications and Public Affairs

For several years - at least since the First Australian AVHRR Ground Station Operators Meeting in Canberra in 1990 - users and providers of AVHRR data in Australia have struggled to reconcile the different policy, hardware, management, resource and historical circumstances of AVHRR ground stations and archives, with the wish of users to have a simple consistent, cheap and rapid route to AVHRR data.

The Global 1 km AVHRR Land Data Project, commenced in International Space Year of 1992, has yielded many lessons and provided a good model for co-operation between ground stations and data archives. Over time, it has become obvious to suppliers and users alike that many problems being addressed by Earth Observation methods require, for their solution, data from several sources. This realisation has focussed increased effort on, first, identifying what Earth Observation data are available, and under what conditions; and secondly, on ensuring that these data are consistent in quality and presentation.

Ideas like the Australian Earth Observation Network, AEON; already commenced plans, like the Eos Data and Information System; and existing electronic networks, like the CEOS International Directory Network, IDN, are all helping to change the orientation of Earth Observation data management in Australia from being "locality-directed" to being "system-directed". In doing so, data managers from the many Commonwealth, State, University and private sector organisations on the scene are looking for :

- better delivery
- more quality assurance
- better return on investment in infrastructure and operations
- the opportunity to redirect resources from routine tasks, or from work which has already been performed elsewhere, towards applications and research which corresponds more closely to their core interests.

Over the past 12 months, CSIRO has taken an active role in these matters. The CSIRO Office of Space Science and Applications has stepped up its emphasis on effective management of corporate data assets, with a more prominent role at WASTAC and at CSIRO Earth Observation data facilities elsewhere. The Australian Land Research Data Centre has continued its work for the Global 1 km Data Project, and has expanded into the archiving of other data sets (ATSR, MSS, Spot). The Tasmanian Earth Resources Satellite Station (TERSS) was formally opened in June. Finally, COSSA embarked upon a wide-ranging review of CSIRO's Earth Observation activities, with a view to improving effectiveness and efficiency. The results of that Review (expected to be published around June 1995) should help place CSIRO, and Australia, in a good position to take advantage of the rapid development occurring throughout the world of Earth Observation and related information retrieval systems.

BUREAU OF METEOROLOGY

Bruce Neal, Melbourne, Victoria

Use of TOVS (TIROS Operational Vertical Sounder) Data

In addition to the AVHRR instrument, which provides 5- band imagery, the NOAA satellites received by the WASTAC ground station facility in Perth also carry a TOVS (TIROS Operational Vertical Sounder) instrument which provides the Bureau of Meteorology with valuable information on the vertical structure of the atmosphere over large areas of sea and land that cannot be monitored by ground based instruments or by the balloon based radiosonde system. Vertical soundings of temperature and moisture throughout the depth of the atmosphere are generated from radiance values measured by the TOVS instrument at a spatial resolution of about 60 km and then assimilated with other types of meteorological data into the Bureau's numerical weather analysis and prediction system for the Australian Region. The techniques, based on a full physical solution of the Radiative Transfer Equation, and its results are described by Le Marshall et al, 1993;1994.

The TOVS data collected by the WASTAC station are used routinely in real time in the Bureau's system and are merged with TOVS data covering other parts of the Australian Region collected by the Bureau's NOAA satellite ground stations in Melbourne, Darwin and Casey (Antarctica). It has been shown in a large number of trials, that these data have a significant positive impact in improving the accuracy of the Bureau's operational analyses and forecasts over the Australian Region.

The TOVS data are now also being used in some new research work by Dr Le Marshall and colleagues to measure anomalies in the upper atmosphere temperatures associated with tropical cyclones who derive most of their explosive energy from the so called "warm core" which forms in the central part of the system. A relationship between temperature anomaly and cyclone intensity has been developed in research mode, and other applications are being explored. An example of the warm core measured by TOVS for tropical cyclone Bobby is shown on the front cover of this WASTAC report.

REFERENCES

J.F. Le Marshall, B.J. Rouse, P.A. Riley and Z-J Wu; 1993; TOVS data reception and assimilation in the Bureau of Meteorology- recent developments; Tech. Proc. 7th Internat. TOVS Study Conference, Igls, Australia, 10-16 Feb 1993;269-279.

J.F. Le Marshall, P.A. Riley, B.J. Rouse, G.A. Mills, Z-J Wu, P.K. Stewart and W.L. Smith; 1994; Real time assimilation and synoptic application of local TOVS raw radiance observations; Aust. Meteor. Mag. 43 (3), 153-166.

DEPARTMENT OF LAND ADMINISTRATION

Richard Stovold, Research Officer, RSAC

Remote Sensing Applications Centre

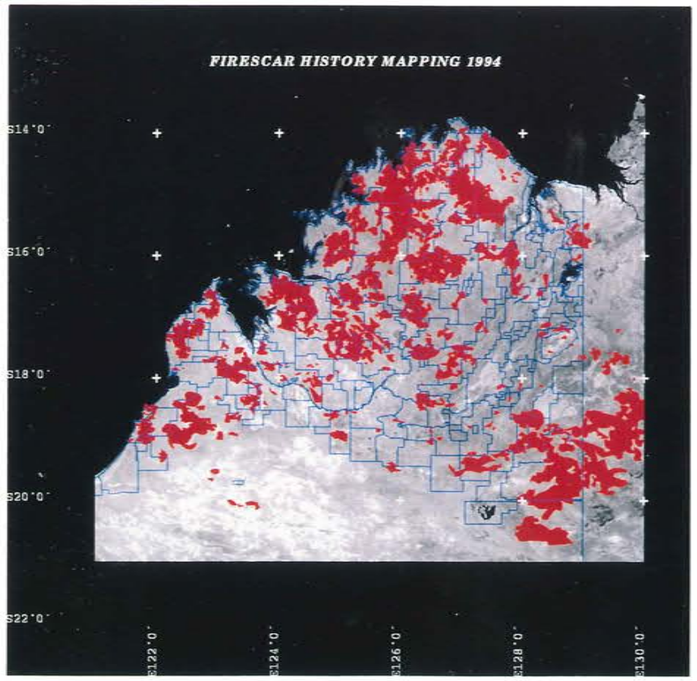
The Remote Sensing Applications Centre (RSAC), a State government centre within the Department of Land Administration, Western Australia, is located within the newly established Leeuwin Centre for Earth Sensing Technologies. It has an extensive and expanding archive of NOAA, Landsat MSS, TM and SPOT digital and photographic products. The Centre's film writing services provides high quality photographic prints. Additionally, RSAC maintains a comprehensive archive of negatives and will support clients with access to an advanced image processing system. The Centre recently took delivery of the ER Mapper image processing software.

Major applications undertaken within the Centre during 1994 include :-

Fire Mapping and Monitoring

A programme of bush fire detection within the State continues for the Bush Fires Board and Conservation and Land Management Departments. The Centre has completed the mapping of bush firescars during the period 30 March 1994 to 2 December 1994 in the Kimberley region of WA primarily for the Bush Fires Board. The mapping of firescar history was possible because of the availability of preprocessed NOAA-AVHRR data from the Vegetation Watch programme.

During high fire risk periods, NOAA-AVHRR data is analysed daily to provide fire managers with the location of fires. This data is faxed to regional officers.



FIRESCAR MAPPING:

A sequence of NOAA images dating from the 30th of March, 1994 to the 2nd of December, 1994 have been used to map firescar history. The extensive area of firescars over that period in the Kimberley region of Western Australia, are depicted in red. The pastoral lease boundaries in blue assist in the location of fires and aid management decisions by Bush Fire Board land managers.

(Image processing by Fiona Evans, DOLA) .

Sea Surface Temperature Images

During the year, a collaborative project between RSAC and CSIRO developed products of Sea Surface Temperature (SST) of the WA coast for the fishing industry. Daily NOAA passes were used to produce SST products which were then delivered to fishermen within 10 hours of acquisition. Evaluation of the products has led to the wider distribution of images to the fishing industry.

Sea Surface Temperature Images

The image right (Fig. 1) taken on the 8th of September, 1994 from NOAA 9 clearly shows the warmer water in red depicting the Leeuwin current flowing south. The same pass depicted in Figure 2 shows the extension of this current around the southern coastline. This information is provided from NOAA satellite data for the fishing industry to assist them in their commercial operations. (Image processing by Mike Steber CSIRO/DOLA.)

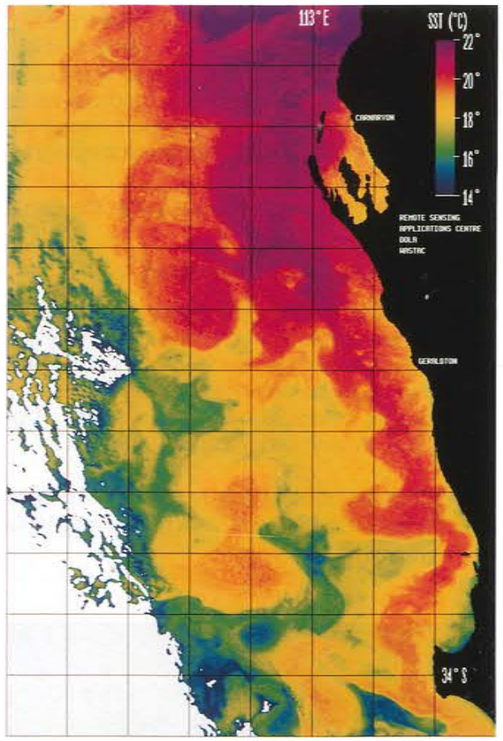


Figure 1

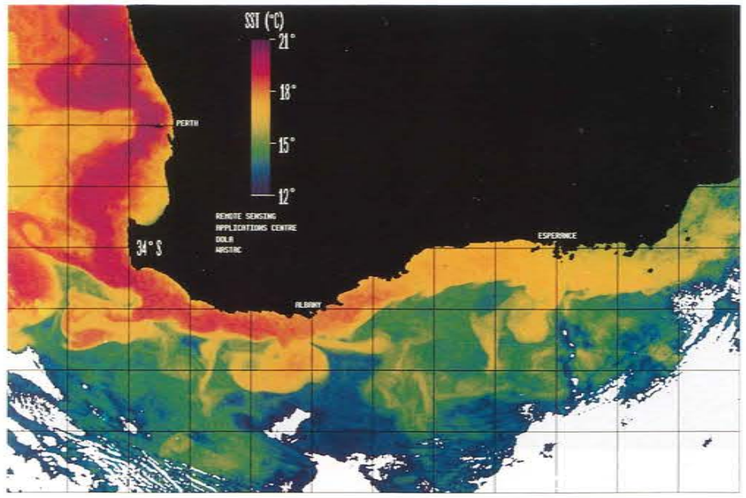
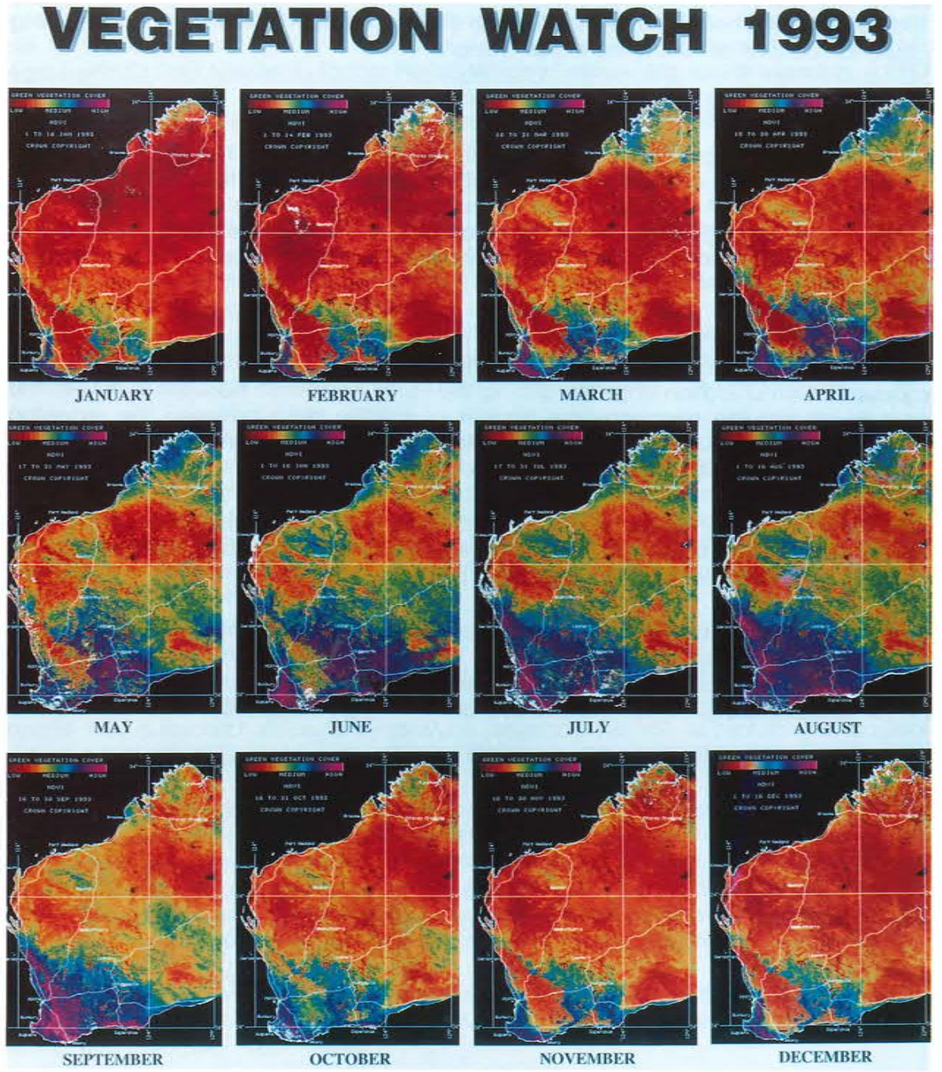


Figure 2

Vegetation Watch Program

The Vegetation Watch project funded by the Rural Industries Research and Development Corporation resulted in RSAC developing an operational system for the processing of NOAA-AVHRR data for the measurement of changes in Green Vegetation Cover (GVC) across the continent. The GVC is based on the Normalised Difference Vegetation Index (NDVI), calculated from the difference in reflectance between Channel 2 and 1 (Near infrared minus Visible reflectance) divided by their sum.

Every two weeks RSAC staff produce the current image of GVC from composites of successive NOAA-AVHRR overpasses that have been received locally by WASTAC. Continuity and quality of the flow of NDVI information is achieved by calibration to remove between and within satellite effects on the data. Thus the continued supply of quality NDVI information was achieved by switching back to the NOAA-9 satellite when NOAA-11 AVHRR sensor failed in 1994.



Sequence of images of Green Vegetation Cover for 1993 of Western Australia produced by the Vegetation Watch project. (Photograph by Red Shaw, DOLA and image processing by John Adams, DOLA.)

The major clients for the composite NDVI images are the Departments of Agriculture in WA and NT who receive the data in digital form and analyse it further for the Pastoral Industry, and the Bush Fires Board who use the data for estimating fuel load. In addition, for Fire Forecasts by the Bureau of Meteorology and the Bush Fires Board for south western Australia, RSAC staff produce an estimate of the CURING INDEX of grasslands and crops from NOAA-AVHRR data between October and December each year. RSAC staff also use the individual NOAA images to map the firescars of the grasslands of north western Australia as a record of the FIRE HISTORY for future fire management.

Because the NOAA processing software contains a number of generic features required for the use of all five channels, wider applications have also developed. These involve the real-time detection of bush fires in remote areas by the automatic detection of hot spots in the landscape using Channel 3 temperatures. Channel 4 and 5 temperatures are also used to estimate Sea Surface Temperature. This information is supplied to Mr Alan Pearce, CSIRO Division of Oceanography for research into the Leeuwin Current and to the Fishing Industry for location of tuna in the Indian Ocean.

WASTAC Archive Management

RSAC continues to play a leading role in the operation of the NOAA receiving station located at the Curtin University of Technology and Bureau of Meteorology. RSAC staff manage the NOAA/AVHRR data archive of over 17,000 data sets. These have been archived and catalogued for future research and reference. The Centre acts as the prime outlet for the distribution and sale of the data for commercial and research use.

Technical Support

The WASTAC technical sub committee, supported by RSAC staff, has progressed the proposed communication upgrade utilising the Perth Academic Network (PARNET). This upgrade will provide near real-time transfer of satellite data between the receiving facility at the Bureau of Meteorology and the Leeuwin Centre for Earth Sensing Technologies at Floreat.

Computing facilities at RSAC have been upgraded, in particular, the introduction of ER Mapper image processing equipment. Image generation on the ColorFire 240 continues to produce high quality colour photographic products.

The support of all consortium members is appreciated. Special mention should be made of the dedicated staff members at RSAC who work as a team to ensure that our corporate objective of "the provision of resource information through the acquisition, analysis and application of remotely sensed data" is met to our client's satisfaction.

CURTIN UNIVERSITY OF TECHNOLOGY

Mervyn Lynch

Remote Sensing and Satellite Research Group

The Remote Sensing and Satellite Research Group's (RSSRG) activities during 1994 continued to reflect the strong interest that undergraduate and graduate students have in this field. In all 20 students and 4 staff worked with the RSSRG during the year in research and project activities. The composition of the student group was 6 PhD, 4 MSc, 3 Honours, 5 Graduate Diploma and 2 third year Project students.

On the international front, cooperative research links with the Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin and with NOAA/NESDIS, Wisconsin, remained active with Mr Paul van Delst taking up a Post-Doctoral position in Wisconsin, and Mr Mark Gray taking up a Research Assistantship while studying toward an MS degree with Dr Paul Menzel (a former Haydn Williams Fellow). Ms Jackie Marsden, a PhD student, accepted a 6 month exchange fellowship with the University of Nice and Aerospatiale (a major French aerospace company) to work on a METEOSAT-NEXT project. Mr Cecep Rustana completed his PhD and returned to IKIP Jakarta where he will continue to collaborate on research activities relevant to Indonesia.

During October 1994, Associate Professor Lynch was a member of the Faculty of Science delegation to the Institute of Technology Surabaya and the University of Brawijaya (Malang). As part of this mission opportunities for staff training and research collaboration were explored. Dialogue included remote sensing opportunities. A further week was spent in Jakarta and included an extended visit to the remote sensing group at the Agency for Technology Assessment and Application (BPPT). Prospects for collaboration with this agency appear excellent if resources can be identified.

As part of the RSSRG's preparations for SeaWiFS' launch, data reception and product generation, Mr Jim Davies (PhD student and SeaWiFS Project Manager) attended a SeaWiFS Workshop conducted by NASA, Goddard Space Flight Centre. The RSSRG was fortunate to be part of a successful bid by the Australian Science Team to the Japanese (NASDA)/French(CNES) POLDER on ADEOS satellite program. ADEOS is to be launched in 1996 and the Australian proposal will contribute to validation and applications work utilising this innovative instrument.

The RSSRG was a contributor to two round 4 CRC submissions which involved remote sensing. Unfortunately neither was successful. Locally the Group coordinated a University submission to the WA Government's Review of Coastal Management in WA. We remain hopeful that a research opportunity may be developed in WA to monitor the coastal zone and that coastal zone remote sensing will be part of that initiative.

Collaboration with industry remains a high priority and it has worked effectively in 1994. These collaborations reflect well on the employment opportunities for students. Mr Roland Lockhart, Mr Dean Miller, Mr Craig Suttar, Mr Cecep Rustana, Mr Gregg Kirkpatrick and Mr Anwar Khalil were successful in finding employment with industry during 1994. Mr Roland Lockhart was successful in being awarded a Neville Stanley Studentship for the 1994/95 summer period. His project was sponsored by World Geoscience Corporation.

Associate Professor Lynch continues to represent the University in both the WA Satellite Technology and Applications Consortium (WASTAC) and the Leeuwin Centre for Earth Sensing Technologies.

Coastal Zone Research with SeaWiFS Satellite Data

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

Curtin 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 received by a satellite sensor arising from the atmosphere 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. (See Figure 1 below). This model is currently being compared to other models and preparation is being made to test its performance against solar photometry measurements. Mr Peter Fearns is modelling the in-water scattering. (See Figure 2). These two models will be linked to provide a complete sun-ocean-satellite forward scatter model.

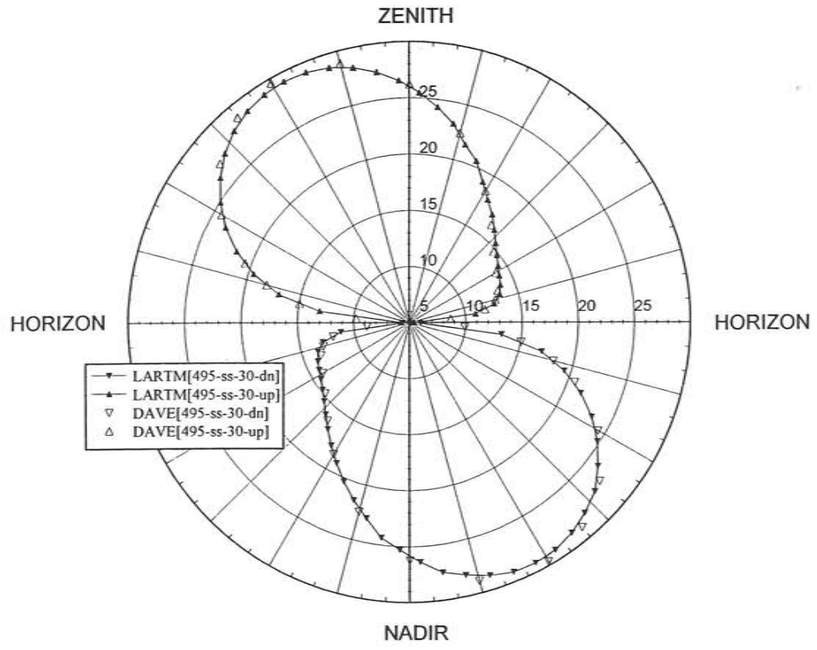


***Figure 1**: Remote sensing of ocean colour relies on the sunlight backscattered from the ocean to convey information about marine constituents. With certain assumptions, it is possible to use remotely sensed data to estimate the concentrations of photosynthetic pigments and suspended sediments in near surface waters. However, satellite observations of ocean colour are modified by scattering and absorption in the overlying atmosphere. At the blue end of the visible spectrum, the atmosphere can account for 80% of the satellite signal. It is clearly important to be able to correct for atmospheric effects. This can be achieved by using models of atmospheric radiative transfer based on estimates of atmospheric constituents. The plot above is a comparison between the layered atmosphere radiative transfer model (LARTM) developed at Curtin and tables of scattered radiation in a terrestrial atmosphere in the presence of ozone produced previously by Dave and Furukawa. The plots are for the plane containing sun, the centre of the earth and the sensor at wavelength 495 nm with sun at angle 30° from zenith. Radiance (in units of* $W.m^{-2}.\mu m^{-1}.sr^{-1}$ *multiplied by the cosine of* sensor zenith angle) is plotted on the radial axis. The plot is for a single scattering *atmosphere over an absorbing ocean. The upper hemisphere gives the scattered radiation leaving the top of the atmosphere - this is what a satellite sensor would see. The lower hemisphere gives the scattered radiation leaving the bottom of the atmosphere - this is what a ground based sensor would see (excluding the direct solar irradiance).*

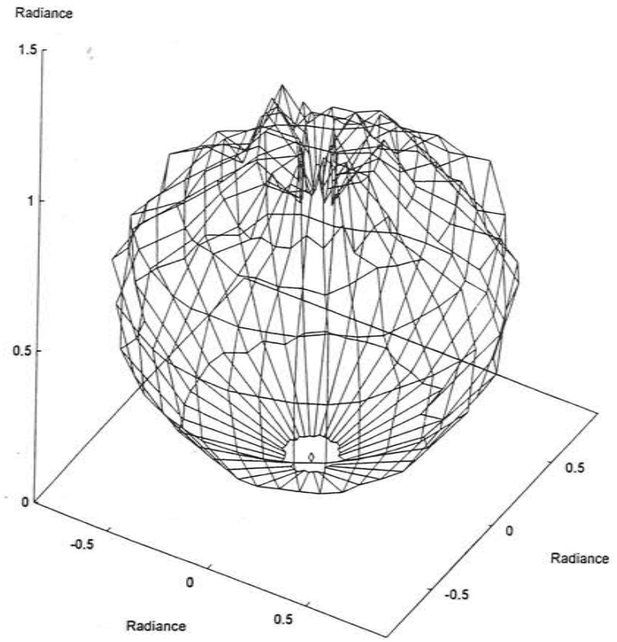


***Figure 2**: The light leaving the ocean surface may be used to determine concentrations of such constituents as chlorophyll, sediment and dissolved organic matter, the sea floor type or bathymetry. To achieve these measurements to any reasonable accuracy, an understanding of how the water-leaving radiance distribution varies with ocean conditions is required. Investigation of the light field above and below the ocean surface may be achieved through computer modelling. This graph shows the 3-dimensional water-leaving radiance distribution produced by a Monte Carlo simulation of ocean optical properties when the sun is at the zenith. The three axes represent the components of the radiance. The surface represents the tip of a radiance vector, in the direction of the outgoing radiation, drawn from the origin (0,0,0), a point on the ocean surface.*

Project support: Grant from the Vice-Chancellor's Discretionary Reserve of $20,000 toward Leeuwin Centre infrastructure is aiding progress on this project. Support of $12,000 for field work was provided by Oceanroutes (Aust) Pty Ltd (now Weathernews Pty Ltd). Digital Equipment Corporation is supporting a research studentship on the project. NASA is providing software support for data processing and coastal zone product generation. Satellite data will be made available courtesy of WASTAC.

* CSIRO Division of Oceanography, Marmion

** CSIRO Division of Fisheries, Hobart

† recipient of an APRA PhD Scholarship

†† recipient of a Digital Equipment Corporation MSc Scholarship

Land Surface Temperature Estimation from Satellite Data

Associate Professor Mervyn Lynch, Mr Cecep Rustana†, Dr Fred Prata*, Dr Norm Campbell and Dr Ian Foster*****

Algorithms for the retrieval of land surface temperature (LST) depend on correctly accounting for the effects of atmospheric moisture and surface emissivity. This project has modelled regional and seasonal effects on LST estimation from satellite data and derived retrieval algorithm coefficients using atmospheric transmittances calculated from climatological atmospheres using LOWTRAN7 atmospheric transmittance code. Algorithm validation, using data sets from a CSIRO instrumented field site at Walpeup, Victoria and from field stations operated by the WA Department of Agriculture (WADA), has been completed. The results of the study show that accuracies of 1 degree Celsius may be achieved using the algorithms. For the field sites studied, a bias corrected LST of rms error of 0.8 Celsius is obtained which we believe is approaching the limit of accuracy achievable with the AVHRR sensor.

Project supported by a PhD Fellowship from AIDAB. NOAA satellite data sets provided by WASTAC. Field data from the Walpeup Research Station provided by CSIRO DAR. WA field station data provided by the WADA

* CSIRO Division of Atmospheric Research (DAR), Melbourne

** CSIRO Division of Mathematics and Statistics (DMS), Perth

*** WA Department of Agriculture (WADA)

† Recipient of an AIDAB PhD Fellowship

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 bidirectional 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. Presently, 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 the international FIFE experiment 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

* CSIRO Division of Exploration and Mining, Perth

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 and Mr Gregg Kirkpatrick††**

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 optical depths to be made.

We acknowledge for 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

†† Honours student

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 1996 an improved microwave sensor (Advanced MSU) will be fitted to the NOAA satellites. This sensor will provide for 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 the Bureau of Meteorology. 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

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 prerequisite conditions being met 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 remains unclear. This project to date 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.

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

* Bureau of Meteorology, Perth

** Bureau of Meteorology, Melbourne

Estimation of Ocean Current from Satellite Infrared Imagery

Associate Professor Mervyn Lynch, Mr Steven Buchan*, Mr Alan Pearce, Dr John Hunter**, Mr Ross Dodds† and Mr Brendan McAtee††**

Estimation of the quality of vector fields of ocean current produced from sequential satellite thermal images is the thrust of this project. While feature tracking is the most straight forward approach, several additional approaches are under review.

Project supported by the award of a 1993/1994 Neville Stanley Studentship ($5,000) to Mr McAtee. The studentship was undertaken in collaboration with Steedman Science and Engineering. The satellite data sets were provided by WASTAC.

* Steedman Science and Engineering, Perth

** CSIRO Division of Oceanography

† Graduate Diploma in Image Science student

†† Neville Stanley Studentship Award student

Improved Cloud Detection and Classification Scheme using AVHRR Data

Associate Professor Mervyn Lynch, Mr Alan Pearce*, Mr Mark Gray† and Mr Michael Bezaud††

It is apparent that many scientists use cloud detection schemes but are not particularly confident of their performance and a little uncertain of when they fail and how to detect failure. A typical motivation is to keep the cloud test both simple and computationally efficient. In practice, however, cloud detection is frequently a more complex problem than the particular application being addressed in the research itself. The absence of good truth data hampers progress in improving cloud detection algorithms. Further, some tasks, such as the detection of high thin cirrus cloud and sub-pixel cloud, are inherently difficult tasks. We are implementing a set of established algorithms with a view to statistically assessing comparative performances. Validation data is being sourced from a solar photometer operated by the Solar Observatory at Exmouth, WA.

Project supported by the provision of NOAA/AVHRR satellite data from WASTAC.

* CSIRO Division of Oceanography

† Honours student

†† Graduate Diploma in Imaging Science student

Remote Sensing of Ocean Biomass Productivity

Associate Professor Mervyn Lynch and Mr Roland Lockhart†

The Coastal Zone Colour Sensor (CZCS) provided ocean colour imagery of the oceans for the period 1979 to 1986. While the coverage was not complete because this was a research satellite, there were much valuable data collected. SeaWiFS, a new ocean colour sensing satellite due for launch in late 1995, will provide daily coverage of the oceans enabling chlorophyll distribution mapping. This project has been examining the data in the Australasian region in order to establish productivity and its links to ocean mixing processes and the associated nutrient fluxes to the surface. (See Figure 3).

Project support: Mr Lockhart was a recipient of a 1995/6 Neville Stanley Studentship. This research continued during the summer supported by the Studentship and sponsor World Geoscience Corporation.

† Student

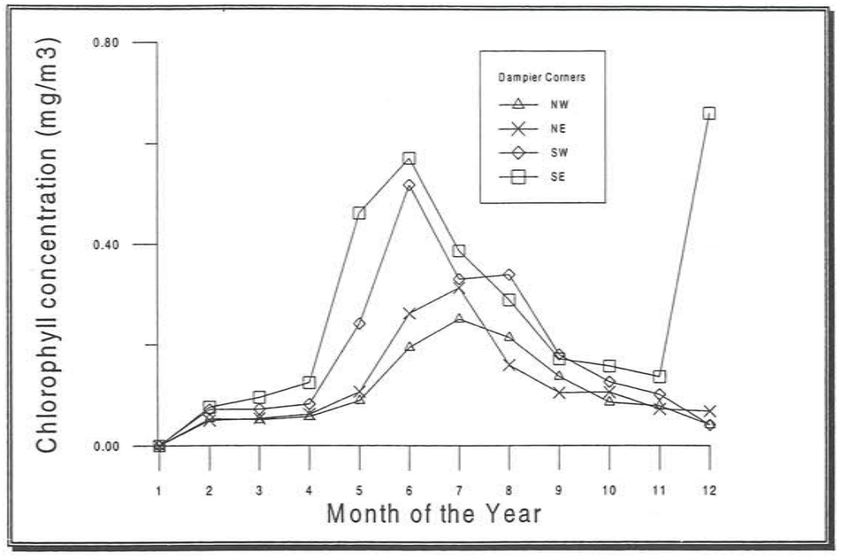


***Figure 3**: Dampier coastal region chlorophyll cycle for 1981. The areas of interest are four adjacent sectors in the Indian Ocean due north of Dampier, Western Australia. The peak in the winter months is consistent with the annual productivity cycle of chlorophyll in this region. Note that the winter bloom tends to begin in the sector closest to the shoreline (SE) and move offshore as time progresses.*

The Inversion of Spectral Radiometry to Estimate Aerosol Size Distribution

Associate Professor Mervyn Lynch and Mr Dean Miller†

The next generation of satellites typically will have signal-to-noise ratios of the order 500:1. Such an improvement in measurement quality coupled with the move toward some form of on-board calibration encourages more effort at data analysis. The constrained inversion of visible radiances to yield aerosol size distribution is such an opportunity. This project initiated the setting up of the inversion procedure and calculated the weighting functions to support the inversion scheme.

† Honours student

CURTIN UNIVERSITY OF TECHNOLOGY

G.D. Lodwick, School of Surveying and Land Information

Introduction

The School of Surveying and Land Information offers remote sensing studies as part of its normal undergraduate courses, comprising the Bachelor of Surveying degree and the Bachelor of Science (Cartography) degree. In addition, it offers specialised studies in remote sensing, GIS and cartography through a Graduate Diploma in Remote Sensing and Land Information. Remote sensing teaching and research is also carried out as part of the graduate programs, which consist of a Postgraduate Diploma in Surveying and Mapping, Master of Science and Doctor of Philosophy.

The main remote sensing research interests of the School are in digital image processing and interpretation, as well as softcopy photogrammetry. Two members of School staff have research interests that are directly related to these topics. They are Dr Michael Roderick and Dr Zhilin Li. Several graduate and undergraduate students are undertaking work in these areas, which are supported by grants from both government and industry. The research involves a range of hardware and software systems. These include an Intergraph Image Station soft photogrammetry workstation, a Sun Sparcstation 10 computer and several PC 486 computers. All of these have a range of input and output facilities allowing the presentation of remote sensing images and maps. In addition, they include a range of commercial image processing software packages.

Publications of staff and students in the schools are included in the publication listing at the back of this report.

Remote Sensing Research Projects Utilising NOAA Data

Temporal Variation in Arid and Semi-arid Zone Ecosystems

(M L Roderick)

Signal processing techniques in common use in systems engineering are being adapted to the study of plant growth in ecological systems in arid and semi-arid areas. It was demonstrated that the impulse-response function was an appropriate model for use with multitemporal NOAA-AVHRR data. The results of the research project are to be presented at the International Rangelands Congress in Utah in July 1995.

WASTAC BUDGET 1995

Estimated expenditure financial year January 1995 - December 1995

		PER ANNUM $ 1995	$ 1994
1.	Telecom Rental	2,700	2,500
2.	Exabyte Tapes	4,000	6,000
3.	System maintenance	4,000	4,000
4.	Telecomunications licence of facility	500	500
5.	Photographic/ink jet quicklook costs	3,000	3,000
6.	Consultants-Archive/product generation assistance	10,500	8,500
7.	Sundries, consumables	1,000	1,000
8.	Travelling - airfares	4,000	4,000
9.	Provision for major equipment	12,000	12,000
10.	Special provision for improved communications existing facilities (transferred from 1994)	100,000	100,000
11.	Annual Report	4,000	3,000
	TOTAL	**145,700**	**144,500**

Estimated income/revenue financial year January 1995 - December 1995

INCOME	**1995**	**1994**
Contributions received ($10,000 each member)	40,000	40,000
Sundry income (sale of data)	12,000	12,000
Interest	4,000	2,000
TOTAL INCOME	**56,000**	**54,000**

WA SATELLITE TECHNOLOGY AND APPLICATIONS CONSORTIUM

FINANCIAL STATEMENTS: YEAR ENDED 31 DECEMBER 1994

AUDITOR'S REPORT

I have audited the attached financial statements and in my opinion they fairly represent the transactions of the Consortium during the 1994 calendar year, together with its financial status as at 31 December 1994. The statement is based on proper accounts and records.

P J Perriam
MANAGER, INTERNAL AUDIT
CURTIN UNIVERSITY OF TECHNOLOGY

8 March 1995

CURTIN UNIVERSITY OF TECHNOLOGY WA SATELLITE TECHNOLOGY CENTRE - SF COST CENTRE 1198

BALANCE SHEET AS AT 31 DECEMBER 1994

	NOTE	1994	1993
		$	$
CURRENT ASSETS			
Cash at Bank		164,642	142,158
TOTAL CURRENT ASSETS		164,642	142,158
NON-CURRENT ASSETS	3		
Computer Equipment		38,851	51,255
Other Equipment		75,237	85,985
TOTAL NON-CURRENT ASSETS		114,088	137,240
TOTAL ASSETS		278,730	279,398
CURRENT LIABILITIES			
Creditors & Borrowings		1,805	-
TOTAL CURRENT LIABILITIES		1,805	-
NON-CURRENT LIABILITIES			
Credits & Borrowings		-	-
TOTAL NON-CURRENT LIABILITIES		-	-
TOTAL LIABILITIES		1,805	-
NET ASSETS		276,925	279,398
SHAREHOLDERS EQUITY			
Asset Revaluation Reserve	4	129,997	129,997
Retained Profits/(Losses)	5	146,928	149,401
TOTAL SHAREHOLDERS EQUITY		276,925	279,398

CURTIN UNIVERSITY OF TECHNOLOGY
WA SATELLITE TECHNOLOGY CENTRE
- SF COST CENTRE 1198

INCOME AND EXPENDITURE STATEMENT FOR THE PERIOD 1 JANUARY 1994 TO 31 DECEMBER 1994

	NOTE	1994	1993
		$	$
INCOME			
Contributions Received	6	40,000	40,000
Sundry Income	7	12,212	18,800
Interest Received		-	1,530
TOTAL INCOME		**52,212**	**60,330**
EXPENDITURE			
Salaries & Wages		11,791	11,110
Conference		1,200	-
Telephone		3,043	2,890
Travel		-	1,490
Consumables		5,893	8,116
Printing, Stationery & Photocopying		3,280	2,715
Depreciation		23,698	29,369
Maintenance of Equipment		2,780	50
Feasibility Study		3,000	2,840
TOTAL EXPENDITURE		**54,685**	**58,580**
NET SURPLUS (DEFICIT)		(2,473)	1,750
EXTRAORDINARY ITEMS		Nil	Nil
NET SURPLUS (DEFICIT) AND EXTRAORDINARY ITEMS		(2,473)	1,750
TRANSFERS TO ASSET REVALUATION RESERVE	4	Nil	Nil
NET SURPLUS (DEFICIT) TRANSFERRED TO RETAINED PROFITS/(LOSSES)		(2,473)	1,750

CURTIN UNIVERSITY OF TECHNOLOGY
WA SATELLITE TECHNOLOGY CENTRE
- SF COST CENTRE 1198

CASH FLOW STATEMENT FOR THE YEAR ENDED 31 DECEMBER 1994

	$
BALANCE OF CASH AS AT 1 JANUARY 1994	**142,158 CREDIT**
RECEIPTS	
Contributions Received	
Department of Land Administration	10,000
C.S.I.R.O.	10,000
Curtin University of Technology	10,000
Bureau of Meteorology	10,000
Total Contributions Received	**40,000**
SUNDRY INCOME	
Supply of Raw Data to various organisations	12,212
Total Sundry Income	**12,212**
TOTAL RECEIPTS FOR 1994	**52,212**
PAYMENTS	
Salaries and Wages	11,791
Conference	1,200
Telephone	1,482
Consumables	9,173
Feasibility Study	3,000
Maintenance of Equipment	2,536
Fixed Assets	546
TOTAL PAYMENTS FOR 1994	**29,728**
EXCESS OF RECEIPTS OVER PAYMENTS FOR 1994	**22,484**
BALANCE OF CASH AS AT 31 DECEMBER 1994	**164,642 CREDIT**

CURTIN UNIVERSITY OF TECHNOLOGY
WA SATELLITE TECHNOLOGY CENTRE
- SF COST CENTRE 1198

NOTES TO AND FORMING PART OF THE FINANCIAL STATEMENTS

FOR THE PERIOD 1 JANUARY 1994 TO 31 DECEMBER 1994

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.

Computer equipment	25% reducing balance method.
Other plant & equipment	12.5% reducing balance method.

3. NON CURRENT ASSETS

	1994 $	1993 $
Computing Equipment (at cost)	186,583	186,037
Accumulated Depreciation	(147,732)	(134,782)
TOTAL COMPUTING EQUIPMENT	38,851	51,255
Other Equipment (at cost)	183,765	183,765
Accumulated Depreciation	(108,528)	(97,780)
TOTAL OTHER EQUIPMENT	75,237	85,985
TOTAL NON-CURRENT ASSETS	114,088	137,240

	1994 $	1993 $
4. ASSET REVALUATION RESERVE		
Opening balance	129,997	129,997
Movement During The Year	Nil	Nil
CLOSING BALANCE	129,997	129,997
5. RETAINED PROFITS/(LOSSES)		
Opening Balance	149,401	147,651
Net surplus (Deficit) for the year	(2,473)	1,750
CLOSING BALANCE	146,928	149,401
6. CONTRIBUTIONS RECEIVED		
Department of Land Administration	10,000	10,000
C.S.I.R.O.	10,000	10,000
Curtin University of Technology	10,000	10,000
Bureau of Meterology	10,000	10,000
	40,000	40,000
7. SUNDRY INCOME		
Supply of Raw Data to various organisations	12,212	18,800
	12,212	18,800

COMPUTING EQUIPMENT AS AT 31 DECEMBER 1994

ASSET NO.	DESCRIPTION	ORIGINAL COST	ACCUM DEPREC	WRITTEN DOWN VALUE
		$	$	$
2494515	MICROSOFT OS/2 PM TOOLKITT	488.00	316.44	171.56
2587007	MATHS CO-PROC INTEL 20MHZ	570.00	369.61	200.39
2494511	ETHERLINK MC CARD	590.00	382.58	207.42
2587001	MOUSE	109.00	70.68	38.32
2552700	TAPE DRIVE 2 GBYT X801A	6,840.00	4,555.55	2,284.45
2587010	2MB MEMORY MODULE	475.00	308.01	166.99
2494507	OS/2 EXTENDED EDITION V1.2	700.00	453.91	246.09
2553701	ACQNR	3,800.00	2,530.86	1,269.14
2587200	ULTRA 1000 20"	2,870.00	1,861.02	1,008.98
2494506	PS/2 CARD TO OPTION SCSI	142.00	92.08	49.92
2494509	MATHS CO-PROCESSOR INTEL 25MHZ	726.00	470.77	255.23
2494503	PS/2 DUAL ASYNCH ADAPTER	233.50	151.41	82.09
2494500	PS/2 25MHZ A/320 MBHD & MONITOR	16,686.00	11,516.44	5,169.56
2478800	2.3GB 8MM EXABYTE	6,272.00	4,328.85	1,943.15
2587002	PS/2 DUAL ASYNCH ADAPTER	233.50	151.41	82.09
2494512	MONITOR DISPLAY CABLE	120.00	77.81	42.19
2587005	2MB MAIN MEMORY EXPANSION	953.00	617.96	335.04
2494510	4-16 MEMORY BOARD 4MB	1,501.00	973.31	527.69
2629700	CARTRIDGE SYSTEM 2.5 G BYTE 8MM	4,950.00	3,122.75	1,827.25
2494516	FORTRAN V2.0	754.00	488.92	265.08
2587011	2 MB MEMORY MODULE	475.00	308.01	166.99
2587000	PS/2 20MHZ 2/320MBHD VGA	9,392.00	5,872.58	3,519.42
25873000	5.25 DISKETTE	501.00	324.87	176.13
2494504	PS/2 DUAL ASYNCH ADAPTER	233.50	151.41	82.09
2587003	PS/2 DUAL ASYNCH ADAPTER	233.50	151.41	82.09
2587014	MONITOR DISPLAY CABLE	120.00	77.81	42.19
2587009	2MB MEMORY MODULE	475.00	308.01	166.99
2585200	PAINTJET XL C1602A	2,425.00	1,572.47	852.53
2587100	ULTRA 1000 20"	2,870.00	1,861.02	1,008.98
2494505	5.25 EXTERNAL DISKETTE ADAPTER	204.00	132.29	71.71
2587012	ETHERLINK MC CARD	590.00	382.58	207.42
2494517	LOCAL AREA NETWORK TECH MANUAL	70.00	45.39	24.61
2494501	MEMORY EXPANSION BOARD 4MB	1,911.00	1,318.95	592.05
2587008	2-8MB MEMORY EXPANSION	1,450.00	940.23	509.77
2494513	MS MACRO ASSEMBLER V 5.1	174.00	112.83	61.17
2494508	320MB HD DRIVE	4,739.00	3,072.94	1,666.06
2494518	PS/2 MOUSE	109.00	70.68	38.32
2587013	FUTURE DOMAIN	450.00	291.80	158.20
2587004	OS/2 EXTENDED EDITION V1.2	700.00	453.91	246.09
1358800	SYSTEM SATELLITE TRACKING STATION	110,000.00	97,152.17	12,847.83
2494514	MICROSOFT COMPILER V6	448.00	290.50	157.50
		186,583.00	**147,732.23**	**38,850.77**

OTHER EQUIPMENT AS AT 31 DECEMBER 1994

ASSET NO.	DESCRIPTION	ORIGINAL COST	ACCUM DEPREC	WRITTEN DOWN VALUE
		$	$	$
2009000	MA 23 CC	20,365.00	10,463.62	9,901.38
1358700	SATELLITE STATION TRACKING	140,000.00	88,458.65	51,541.35
2553700	RECEIVER NOAA I/F FORMAT	19,500.00	7,797.30	11,702.70
1948500	POWER CONDITIONER	2,000.00	1,048.96	951.04
2552600	SGSI HOST ADAPTOR 598A	1,900.00	759.74	1,140.26
		183,765.00	**108,528.27**	**75,236.73**
		370,348.00	**256,260.50**	**114,087.50**

REMOTE SENSING PUBLICATIONS

Adams, J (1994), Wildfire Monitoring in New South Wales, Australia, International Journal of Remote Sensing Vol. 15, No. 18 December 1994, pp. 3641-3642.

Adams, J (1994), Bushfire Devastation on the Australian Continent, International Journal of Remote Sensing (in print)

Albertz, J, Li Z and Zhang, W (19940 Rectification of Airborne Line-scanner Imagery Utilising Flight Parameters, Proceedings of First International Airborne Remote Sensing Conference, Strasbourg, France, September 1994, pp. 447-456.

Cridland, S W, Burnside, D G and Smith, R C G (1994) Use by Managers in Rangeland Environments of Near Real-time Satellite Measurement of Seasonal Vegetation Response, Proceedings of 7th Australasian Remote Sensing Conference, Melbourne, Vic, March 1994, Vol. 2, pp. 1134-1141.

Davies, J. E., Fearns, P., Lynch, M. J. and Pearce, A. F. 1994. SeaWiFS Product Development and Validation Program: Status Report. Proceedings Pacific Ocean Remote Sensing Conference, Melbourne, March 1-4, pp 267-274.

Domenikiotis, C, Lodwick, G D and Wright, G L (1994) Reconstruction of a Remotely Sensed Road Network Using an Expert System Approach, Proceedings of 7th Australasian Remote Sensing Conference, Melbourne, Vic, March 1994, Vol. 1, pp. 448-455.

Evans, F, Wyllie, A and Kierath, P (1994) Barrow Island Engineering and Rehabilitation Assessment, Proceedings of 7th Australasian Remote Sensing Conference, Melbourne, Vic, March 1994, Vol. 2, pp. 1054-1059.

Hick, P T, Wyllie A and Kirkman, H (1994) Marine Substrate Feature Delineation from Thematic Mapper Data: The Geographe Bay Example, Proceedings of 7th Australasian Remote Sensing Conference, Melbourne, Vic, March 1994, Vol. 2, pp 706-173.

Jernakoff, P and Hick, P T (1994) Spectral Measurement of Marine Habitat: Simultaneous Measurements and CASI Data, Proceedings of 7th Australasian Remote Sensing Conference, Melbourne, Vic, March 1994, Vol. 2, pp. 706-173.

Khokhar, M S (1994) Optimisation of the Radiometric and Geometric Properties of a Line Array Photogrammetric Scanner, paper presented to 22nd Annual Research Seminar, School of Geomatic Engineering, University of New South Wales, Sydney NSW, November 1994.

Lyon, R J P, Honey, F R and Hick, P T (1994) Second Generation Airborne Digital Multispectral Video: Evaluation of a DMSV for Environmental and Vegetation Assessment, Proceedings of First International Airborne Remote Sensing Conference, Strasbourg, France, September 1994, p. 12.

Marsden, A. J., Lynch, M. J., Forgan, B. and Mitchell, R. 1994. The Estimation and Validation of Aerosol Optical Depths from NOAA/AVHRR. PrR. Proceedings Pacific Ocean Remote Sensing Conference, Melbourne, March 1-4, pp 119-126.

Ong, C, Wyllie, A and Hick, P T (1994) Mapping Marine Habitats Using Geoscan Mk2 Airborne Multispectral Scanner Data, Proceedings of 7th Australasian Remote Sensing Conference, Melbourne, Vic, March 1994, Vol. 2, pp. 706-173.

Pattiaratchi, C. Lavery, P. Wyllie, A and Hick, P (1994) Estimates of Water Quality in Coastal Waters Using Multi-date Landsat Thematic Mapper Data, International Journal of Remote Sensing, Vol. 15, No. 8, pp. 1571-1584.

Reader, M, Stovold, R, Steber, M, Christie, R (1994) The Remote Sensing of Interacting Morning Glories in Northern Australia with NOAA/AVHRR Data, Proceedings of 7th Australasian Remote Sensing Conference, Melbourne, Vic, March 1994.

Roderick, M L (1994) Satellite Derived Vegetation Indices for Monitoring Seasonal Vegetation Conditions in Western Australia, PhD Thesis, School of Surveying and Land Information, Curtin University of Technology, Perth WA, 351 pp.

Rustana, C. E., Lynch, M. J. and Prata, A. J. 1994. Development and Validation of Algorithms for Land Surface Temperature Measurement from NOAA-11/AVHRR Satellite Data. Proceedings Pacific Ocean Remote Sensing Conference, Melbourne, March 1-4, pp 161-168.

Rustana, C. E., Lynch, M. J., Foster, I. and Prata, A. J. 1994. The Performance of Satellite Estimates of Land Surface Temperature in the WA Agricultural Region. Proceedings Pacific Ocean Remote Sensing Conference, Melbourne, March 1-4, pp 153-160.

Silberstein, R P, Wyllie, A Sivapalan, M and Smith, R C G (1994) Application of Remote Sensing to Modelling Terrestrial Water and Energy Balances, Proceedings of 7th Australasian Remote Sensing Conference, Melbourne, Vic, March 1994, Vol. 2, pp. 753-760.

Smith, R C G (1994) Australian Vegetation Watch, Final Report to Rural Industries Research and Development Corporation, CSIRO Division of Exploration and Mining, Perth, WA, July 1994, 111 pp.

Smith, R C G, Adams, J and Hick, P T (1994) Forecasting Wheat Yields from Satellite Observations, Proceedings of 7th Australasian Remote Sensing Conference, Melbourne, Vic, March 1994, Vol. 2, pp. 641-650.

van Burgel, J. L., Le Marshall, J. and Lynch, M. J. 1994. Determination of Upper Level Warm Temperature Anomalies in Australian Region Trpical Cyclones Using Retrieved Temperatures from the Microwave Sounding Unit, Proceedings Pacific Ocean Remote Sensing Conference, Melbourne, March 1-4, pp 291-225.

van Delst, P. W. F., Lynch, M. J., White, B. A., Revercomb, H., Knuteson, R. O. and Smith, W. L. 1994. The Retrieval of Atmospheric Ozone Concentration Profiles from High Spectral Resolution Infrared Radiances. Proceedings Pacific Ocean Remote Sensing Conference, Melbourne, March 1-4, pp 423-433.

Weerasekera, T., Lynch, M. J. and Smith, R. C. G. 1994. Approaches to Achieving Consistency in Satellite Measurements of Normalised Difference Vegetation Index (NDVI). Proceedings Pacific Ocean Remote Sensing Conference, Melbourne, March 1-4, pp 127-133.

Wright, G L and Chafer, M (1994) An Analysis of Land Capability Assessment Using Remotely Sensed Data, Proceedings of 7th Australasian Remote Sensing Conference, Melbourne, Vic, March 1994, Vol. 2, pp. 601-608.

Wyllie, A and Evans, F (1994) Marine Habitat Mapping Using Landsat Thematic Mapper and SPOT Panchromatic Data, Proceedings of 7th Australasian Remote Sensing Conference, Melbourne, Vic, March 1994, Vol. 2, pp. 693-689.

Wyllie, A, Hick, P T, Duncan, A, Evans, F, Jernakoff, P, Kirkman, H and Ong, C (1994) A Review of Remote Sensing for Marine Applications in Western Australia, Proceedings of Second Thematic Conference on Remote Sensing for Marine and Coastal Environments, New Orleans, Louisiana, January/February, Vol. 1, pp. 687-698.

Wyllie, A and Ong, C (1994) The Use of Landsat Thematic Mapper Band 6 to Determine the Spatial Distribution of Sea Surface Temperature, Proceedings of 7th Australasian Remote Sensing Conference, Melbourne, Vic, March 1994, Vol. 1, pp. 169-174.

Wyllie, A, Pattiaratchi, C and Wright, G L (1994) Hydrodynamic Inferences Using Remotely Sensed Data - The Dawesville Channel Case, Proceedings of 7th Australasian Remote Sensing Conference, Melbourne, Vic, March 1994, Vol. 2, pp. 714-722.

Back cover:

WASTAC plays a vital role in the collection of data for the monitoring of the natural resources of the state of Western Australia. Information received from this facility aids improved management for the following industries:

- Pastoral
- Beekeeping
- Conservation
- Agriculture
- Mining
- Tourism

(Photographs courtesy of Alex Wyllie and Ken Leighton, DOLA)