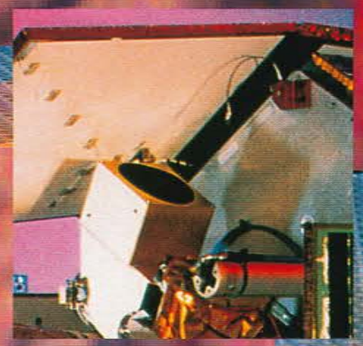

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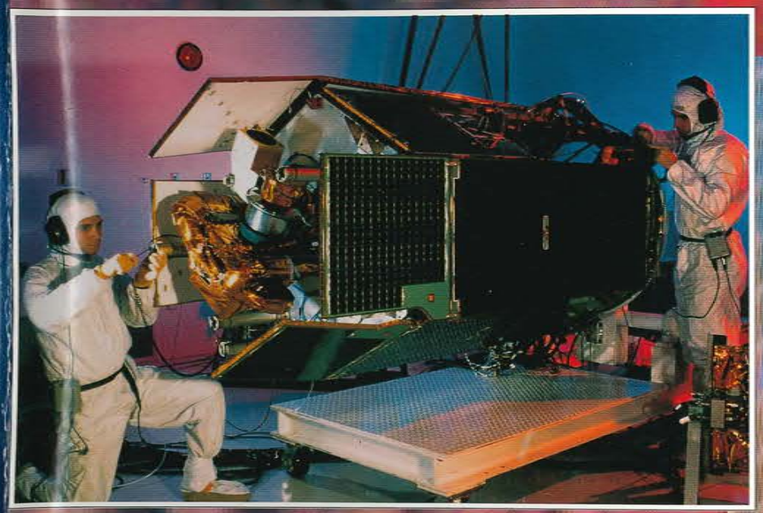
WASTAC

Annual Report



1995

Western Australian Satellite Technology and Applications Consortium

Front Cover:

Caption:

The SeaWiFS instrument is shown mounted (left) in the SeaStar satellite which presently is lying on its side. The sensor currently is undergoing tests at Orbital Sciences Corporation, near Washington DC. The SeaWiFS scan mirror cavity is the silver-coloured cylindrical unit located just above the gold foil wrapped components at the base of the satellite. The large black panels on the side of SeaStar are the solar collector panels which swing out 90° once in orbit.

The SeaWiFS instrument, due for launch in 1997, will be available for the monitoring of sea and land condition.

Acknowledgements:

A special note of appreciation to Remote Sensing Services staff, and Public Sector Reporting staff, for final document formatting and arrangement of printing.

Richard Stovold
EDITOR

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATIONS CONSORTIUM

ANNUAL REPORT 1995

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CONTENTS

WASTAC CHAIRMAN'S REPORT - 1995

With a high level of collaboration between CSIRO, Curtin University of Technology, Bureau of Meteorology and Department of Land Administration (DOLA), WASTAC continues to increase its contribution to the application of NOAA remote sensing data to Western Australia, Northern Territory and South Australia, national weather forecasting and the national archive of NOAA-AVHRR data. WASTAC is now well established and in a position to collect SeaWiFS satellite data.

Ron Craig, Remote Sensing Services (RSS), (DOLA) and Don Ward, Bureau of Meteorology, have made an outstanding contribution in maintaining the operation of the receiving station collecting 400 overpasses per month and archiving 300 per month. In addition they have done much of the planning for the installation of a microwave link to give the Leeuwin Centre near real-time access and upgrade the ingest computers from PC's to HP workstations in late 1996. Richard Stovold, RSS, DOLA, continues to make a significant contribution as Secretary of WASTAC by providing efficient communications between the members of the Consortium.

Assoc. Prof. Merv Lynch, Curtin University and his post-graduates have completed substantial development for the capture and processing of SeaWiFS ocean colour satellite data by WASTAC when it is eventually launched in 1997. The SeaStar satellite will be launched and the first SeaWiFS data will be received over Western Australia in early 1997.

The NOAA data received by WASTAC is being heavily used and its applications are expanding. All TOVS data and some of the NOAA-AVHRR data are processed by the Bureau of Meteorology for input into their national weather forecasts and for sea surface temperature measurements. A copy of all NOAA-AVHRR data is made by WASTAC for archiving by CSIRO, Earth Observation Centre. CSIRO Division of Oceanography and Curtin University use significant amounts of the NOAA-AVHRR data for sea surface temperature and atmospheric research. RSS, DOLA routinely process 1.5Gbytes per month to produce Sea Surface Temperature products for the Fishing Industry and fire hot spots for the Bush Fires Board. An additional 3.6Gbytes per month is processed for vegetation monitoring and fire scar mapping for the Bush Fires Board, Conservation and Land Management (CALM) and Department of Agriculture.

RSS, DOLA's vegetation monitoring products have been extended to cover the Northern Territory and South Australia.

To all the members of WASTAC, I wish to express my thanks for their continuing support and look forward to further exciting developments in 1996.

H. Houghton
Chairman, WASTAC

WASTAC BOARD FOR 1995

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 (COSSA)
Mr Jeff Kingwell	CSIRO, Office of Space Science and Applications (COSSA)
Mr Bruce Neal	Bureau of Meteorology
Mr Len Broadbridge	Bureau of Meteorology

WASTAC STANDING COMMITTEE AND PROXY TO THE BOARD

Dr Richard Smith	(Chairman) Department of Land Administration
Mr Richard Stovold	(Secretary) Department of Land Administration
Dr Doug Myers	Curtin University of Technology
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

WASTAC facilities consist of antenna and antenna controller at Curtin University of Technology, ingest and display computers with hard disk storage located at the Bureau of Meteorology premises at 1100 Hay Street, West 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 grey scale pictures are produced at 180 dpi by a HP Paintjet inkjet printer and these are passed to DOLA(Remote Sensing Services) 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 AVHRR 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 in-house display and post processing. The TOVS data, a subset of AVHRR is automatically sent to Melbourne so that atmospheric temperature retrievals can be included in the global numerical weather prediction models. SST (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.

The facility began to ingest NOAA 14 data on 17th January 1995.

Equipment failures during the year resulted in the loss of 3 days of data.
Due to the dedicated efforts of Ron Craig and BOM staff, total 3712 passes were recorded for the year.

DOLA is currently holding the archive on 8mm data tapes.
An ongoing archive copy program has successfully copied early eighties NOAA passes from reel tape to 8mm data cartridges.

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

Future Directions

WASTAC is entering an exciting era with systems upgrades planned for later in 1996.
The present IBM OS/2 based AVHRR ingest facility will be replaced by a HP Unix system that will provide high levels of automation and system integrity.

A new era in communications is also about to arrive with the WASTAC/PARNET high speed microwave network which will allow fast efficient flow of data/products between WASTAC members, various State government agencies and universities.

WASTAC DATA ARCHIVE

The WASTAC archive of NOAA satellite passes, managed and maintained by the Department of Land Administration (DOLA), Remote Sensing Services group, 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 for CSIRO by COSSA.

The WASTAC duplicate set of NOAA passes commencing on March 1994, continues to be stored at the Earth Observation Centre 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 3712 NOAA passes were recorded for 1995 on 173 8mm tapes comprising 213 gigabytes of information. Passes comprised data from the NOAA 9, 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.

A total of 20498 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, NOAA 12 and NOAA 14 satellites. The data collection commenced in 1981 and is summarised in the following tables.

1995 NOAA DATA ARCHIVED BY WASTAC

	NOAA 9	NOAA 12	NOAA 14	TOTAL
JAN	119	137	58	314
FEB	90	110	113	313
MAR	110	127	137	375
APR	119	132	142	393
MAY	109	135	143	387
JUN	89	51	126	266
JUL	126	9	160	295
AUG	8	38	151	197
SEPT	-	152	144	296
OCT	-	135	141	276
NOV	-	152	152	304
DEC	-	148	148	296
TOTAL	**770**	**1326**	**1615**	**3712**

8mm Tapes: 3712 passes on 173 tapes.
Total Data Archived: 213 gigabytes.

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	NOAA 14	TOTAL
1981	5	22							22
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	3712
TOTAL	**31**	**593**	**21**	**3055**	**617**	**7732**	**6833**	**1615**	**20498**

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

HIGHLIGHTS FOR 1995
Research Programmes and Data Applications

CSIRO EARTH OBSERVATION CENTRE

Jeff Kingwell

During 1995-96, CSIRO took further steps to enhance its ability to develop more accurate high level products from satellite data sets. In particular, the Earth Observation Centre (EOC) was established, with headquarters shared with the CSIRO Office of Space Science & Applications in Canberra. CSIRO established an AVHRR Science Working group to examine, with the Bureau of Meteorology, the possibility of incorporating more advanced algorithms into operational AVHRR processing systems. The Working Group, comprising Dr Fred Prata (CSIRO Atmospheric Research) (Chair), Dr Ian Barton (CSIRO Atmospheric Research/Marine Laboratories), Mr Jeremy Wallace (CSIRO Mathematics & Statistics); Dr David Griersmith and Dr Brian Taylor (Bureau of Meteorology), Dr Alex Held (CSIRO Water Resources) and Dr John Parslow (CSIRO Fisheries) has produced a preliminary report, and further work in this area is being considered.

Also in FY1995, CSIRO, again with the Bureau of Meteorology, developed a new Australian standard archive format for HRPT files. This work, led by Dr Peter Turner of the CSIRO Division of Atmospheric Research, was partly funded by the EOC, and was carried out in consultation with the format sub-group of the CEOS Working Group on Information Systems & Services (WGISS)

CSIRO, through COSSA/EOC, continued to support international efforts in producing AVHRR-based research products, through active participation in the Global 1 km AVHRR Land Data Project (with NASA, NOAA, ESA and USGS) (Eidenshink & Faundeen, 1994); and the 1 km Land Use mapping project under the auspices of the Asian Association on Remote Sensing. CSIRO depends upon the co-operation of the other members of WASTAC, in order to support internationally and nationally important research and development work of this kind. For those interested, information about the Global Land Data project, including 10-day global vegetation composites to early 1993 (at time of writing), can be found on the USGS www site, on :

http://edcwww.cr.usgs.gov/landdaac/1KM/1kmhomepage.html

An important continuing contribution to international earth observation systems, made by CSIRO, is the Continental Integrated Ground-truth Site Network (CIGSN), funded by COSSA/EOC and the Division of Atmospheric Research (Prata et al. 1995). The automated collection of calibration and validation data from sites distributed across Australia is an important development in quality control for missions such as ASTER and ATSR.

CSIRO, through COSSA/EOC and the Marine Laboratories, continued to support the AVHRR multi channel Sea Surface Temperature validation work led by Alan Pearce and Angela Way in Perth, and Paul Tildesley in Hobart (Pearce, 1995).

BUREAU OF METEOROLOGY

John Beard

The NOAA satellite data received at the WASTAC ground station facility in Perth is an important part of the Bureau of Meteorology's national HRPT coverage. Using the WASTAC data, plus data received at the Bureau's own ground stations in Melbourne, Darwin and Casey (Antarctica), the Bureau of Meteorology produces satellite-derived SSTs (Sea Surface Temperatures), TOVS (Tiros Operational Vertical Sounder) - based temperature, humidity 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 the Bureau'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 the Bureau's real time analysis and forecast system and its climate data base.

As part of its upgrade of reception stations, the Bureau, in conjunction with WASTAC, will be upgrading the WASTAC ground facility during 1996/97. The upgrade will include the provision of a Bureau developed UNIX-based NOAA ingester and DAT (Digital Analogue Tape) facility.

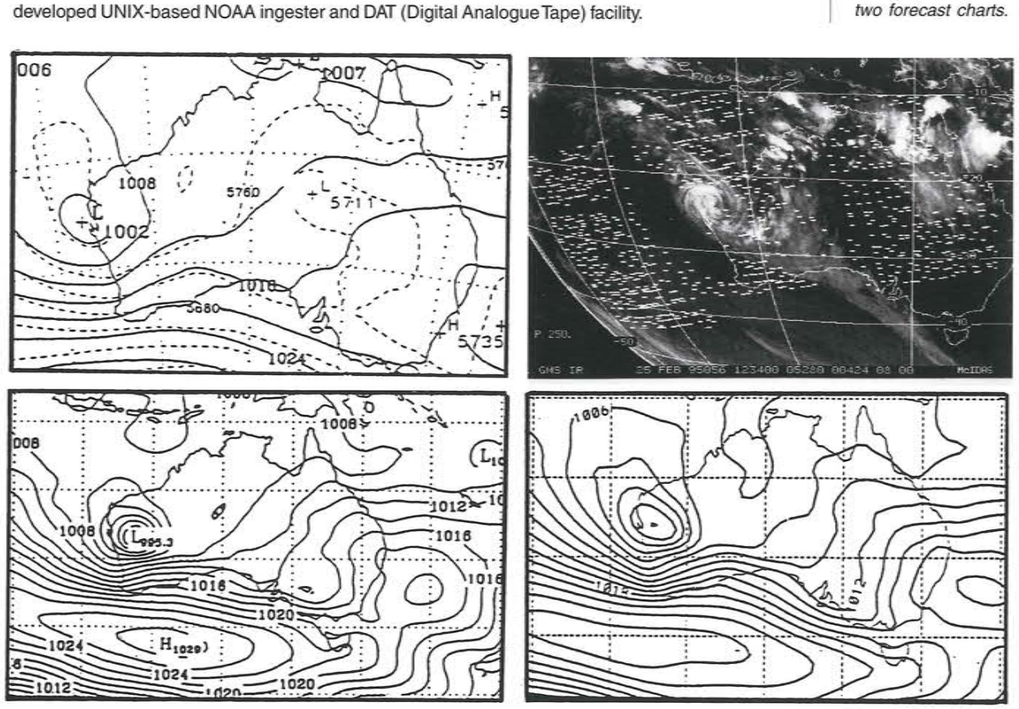


Fig. 1 Illustration of the impact of TOVS data on tropical cyclone forecasting. Clockwise from upper left: the 24-hour MSLP forecast without TOVS data; GMS image with TOVS passes superimposed; 24 hour MSLP forecast with TOVS data included (note TC now forecast inland); the verifying analysis for the two forecast charts.

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 the Bureau's National Meteorological Centre for regional numerical weather prediction. NOAA-14 data are currently processed in real time test mode; 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.

SBUV/2 (Solar Backscatter Ultra Violet) 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 and 1995. An example of the utility of the data was provided recently, when it was shown that removal of TOVS data from the real time data stream resulted in regional forecasts for Tropical Cyclone Bobby locating the cyclone out to sea, rather than progressing it inland, as was the case. This can be seen in Fig. 1, previous page, where the inclusion of the TOVS data operationally has clearly led to a better forecast of the cyclone track.

DEPARTMENT OF LAND ADMINISTRATION, W.A.

REMOTE SENSING SERVICES

Richard Smith, Mike Steber, Richard Stovold

The NOAA-AVHRR satellite sensor is the ideal sensor for providing daily coverage of the Australian continent. With its five spectral bands covering the visible, near infrared, mid infrared and thermal infrared regions of the electromagnetic spectrum, a large number of land surface phenomena are monitored at continental scale.

APPLICATIONS OF NOAA-AVHRR IN RANGELANDS

Major government agencies receiving near real time NOAA-AVHRR information products of rangelands from Remote Sensing Services are Agriculture, WA, Northern Territory Department of Primary Industry and Fisheries and the South Australian Department of Environmental Resources. The main use is intelligence on seasonal changes in green vegetation cover, using the maximum value composite Normalised Difference Vegetation Index (NDVI). This twice monthly NDVI time series has been produced since 1991 using NOAA 11, 9 and 14. The interpretation of the current NDVI image, for an assessment of present seasonal conditions, depends on comparison with a long term NDVI time series. This assessment is important for determining the seasonal carrying capacity of rangelands. The carrying capacity can be altered intra-annually at mustering in the north and shearing/weaning in the south, when the decision on number of stock to carry through the dry season is made.

APPLICATIONS OF NOAA-AVHRR IN AGRICULTURE

Applications in agriculture are under developed, but opportunities exist. During the dry summer period in the south west of Western Australia, the minimum NDVI as an indicator of the residual ground cover of dry annual species could give a warning when land is becoming sufficiently bare to be susceptible to wind erosion. During the winter period, the NDVI in July-August correlates highly with yields of wheat. Thus yields can be forecast based on the early and mid-season growth of crops and pastures. Opportunities exist to use the thermal sensors to map frost susceptible areas over wheat production.

APPLICATIONS IN FISHERIES INDUSTRY (Sea Surface Temperature Images)

The collaborative project started by RSS and CSIRO late in 1994 made some significant advances during 1995. The aim of the project is to deliver current Sea Surface Temperature (SST) products to the W.A. fishing industry. Data from the Advanced Very High Resolution Radiometer sensor on board the National Oceanic and Atmospheric Administration satellite series are received by WASTAC in Perth. SST charts are produced using DISIMP software and a Calcomp colour plotter. These hardcopy plots are available usually within 12 hours of acquisition. Using the Internet, images can be received within 5 hours of acquisition. Besides a personal computer, the only necessary hardware required by the client is a modem and access to the Internet. The images can be sent using the file transfer protocol (ftp) to an Internet Service Provider (ISP). During the year 103 SST images were produced for 7 different clients from Geraldton, Dongara, Fremantle, Esperance and even Darwin.

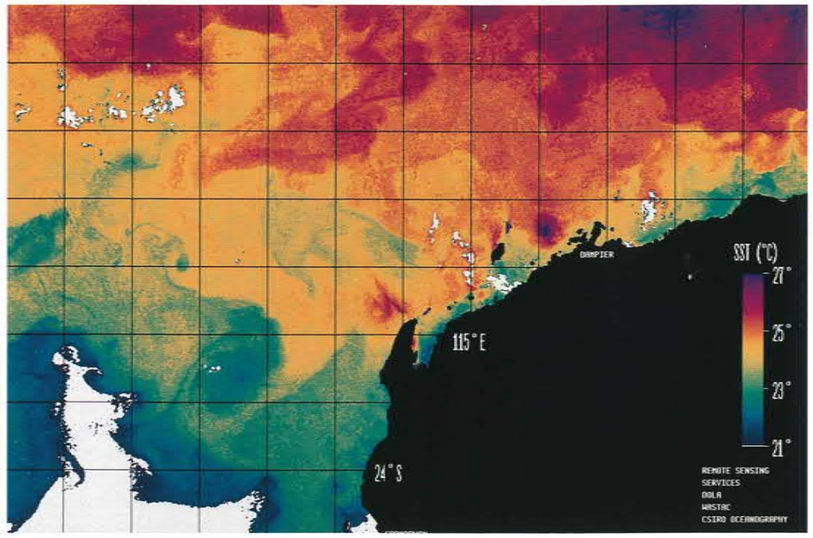


Fig. 1

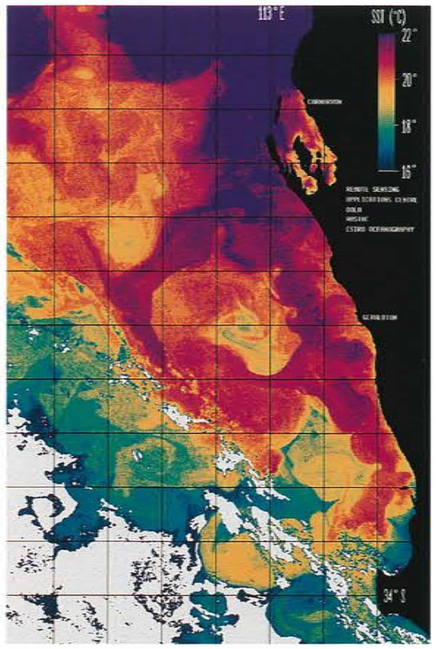
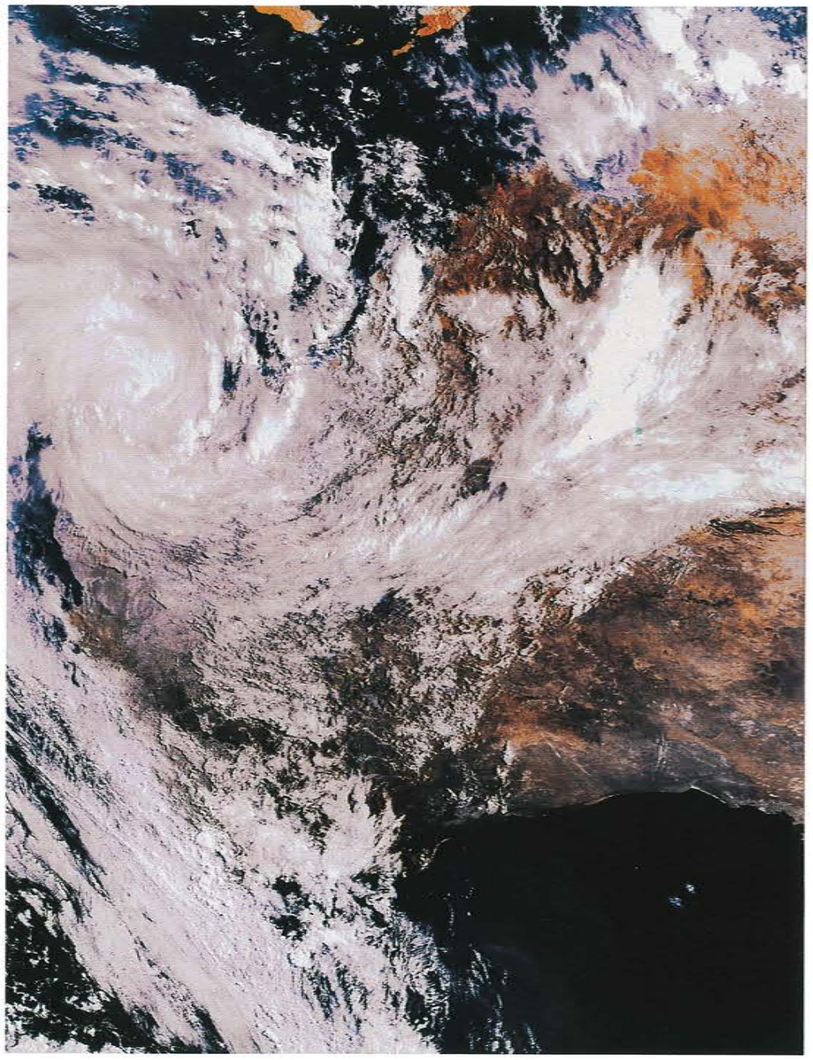


Fig. 2

The images above (Figure 1) and left (Figure 2) taken on the 28th of August, 1995 from NOAA 14 show the warmest water in red (26°/27°C in Figure 1 and 21°/22°C in Figure 2), cooling through orange and yellow to the coolest water in blue (21°/22°C in Figure 1. and 16°/17°C in Figure 2.). The white areas offshore are clouds (or water temperatures less than 21°C in Figure 1 and water temperatures less than 16°C in Figure 2). (Image processing by Mike Steber, Remote Sensing Services, DOLA).

FLOOD MONITORING

Early in 1995 Cyclone Bobby caused widespread flooding in many parts of Western Australia. RSS was asked to provide satellite imagery showing the extent of the flooding between Dampier and Kalgoorlie. This was to help the designers of the Goldfields gas pipeline, which will carry natural gas from the North West shelf to Kalgoorlie, to identify the low lying areas which may be vulnerable to flooding. Channels 1 and 2 of the AVHRR sensor on NOAA 9 were rectified over two map zones (50 and 51) and colour enhanced to show maximum contrast between water and land. The proposed pipeline was placed onto the satellite imagery and 1:250,000 scale paper plots were produced.



Cyclone Bobby taken by the NOAA 9 satellite on February 1995

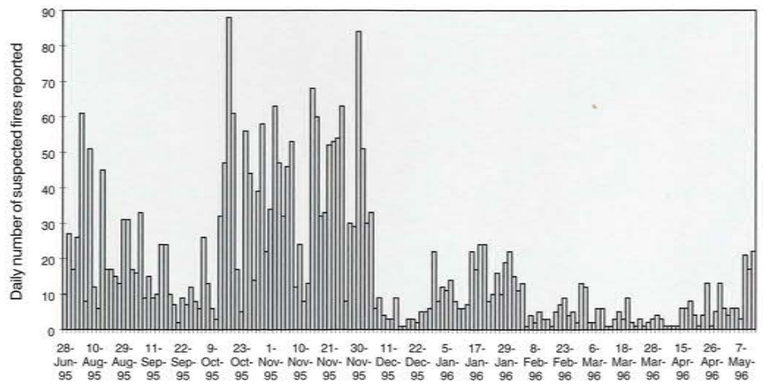
APPLICATIONS OF NOAA-AVHRR IN FIRE MANAGEMENT

WA Government agencies with responsibility for managing fire in rangeland areas are the Bush Fires Board and Department of Conservation and Land Management (CALM). The cloud-free NDVI composite is used by the Bush Fires Board to assess fuel load build up in arid areas. It enables the detection of areas of significant grass growth after rains from the low pressure systems in winter, or the summer cyclones. Areas of fuel load build up warn of areas at high risk from wild fires during the upcoming dry season. We also observe after a seasonal increase in NDVI a period of decline in the NDVI caused by senescence and the curing of the grasslands. The NDVI during this period of decline (Curing Index) and increasing flammability is used systematically in Mediterranean agricultural areas to forecast fire risk from which bans can be based to restrict fire causing activities. This Curing Index was developed by CSIRO in Victoria, with the Victorian Country Fire Authority. We have adopted the same algorithm and applied it in south western Australia with general acceptance by the WA Bush Fires Board. The same concept could be extended to the tropical savanna areas in the north west of Western Australia not to restrict fires but to achieve a better timing of the controlled burning to stop the excessive build up of fuel load. The objective of using NOAA AVHRR is to provide better information for aerial burning practices.

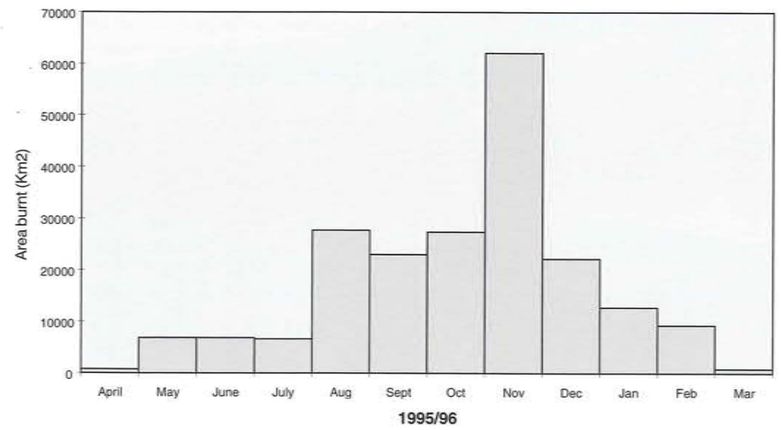
The success of being able to provide this fire detection service to field officers is very dependent on use of the mid thermal infrared band for locating hot spots from the early morning overpass when the influence of solar radiation is minimal. The information on fires is recorded daily onto 1: 250,000 maps and then faxed to the relevant BFB regional officer. Another piece of information that we provide to the Bush Fire Board, Agriculture WA and CALM are monthly maps of firescars during the tropical savanna dry season using the individual overpasses processed for the NDVI composite. We digitise the firescars using the near infrared band at ten day intervals and build up a progressive map of the total area that has been burnt. This mapping has been completed for the three years 1993, 1994 and 1995. The frequency of mapping is required because of the rapid regrowth of the tropical savanna grasses which means that firescars can rapidly disappear on NOAA-AVHRR images, while still being evident on high resolution satellite imagery.

Graph 1

Daily number of suspected bushfires in WA detected from NOAA-AVHRR satellite in 1995/96 by Remote Sensing Services, DOLA whose location was reported to the Bush Fires Board within 4 hours of overpass
2796 suspected fires were reported on 166 days



Total Area of Bush Fires Mapped from NOAA-AVHRR in 1995/96. From April to September only fires in Kimberley were mapped, from October all of WA was mapped.
Total Area burnt = 20.6 million ha

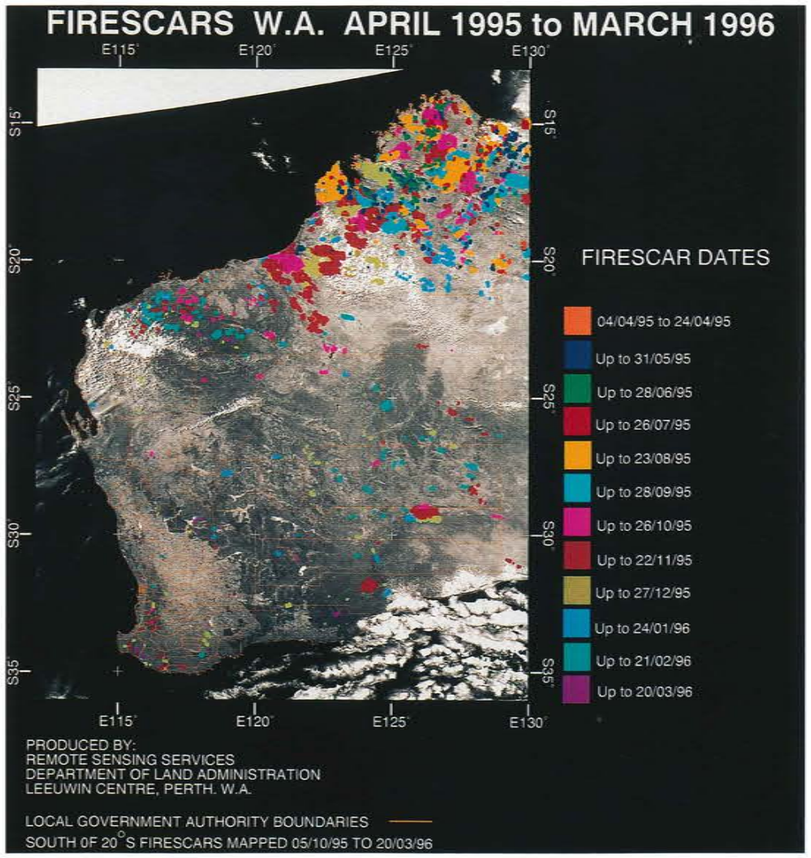


Graph 2

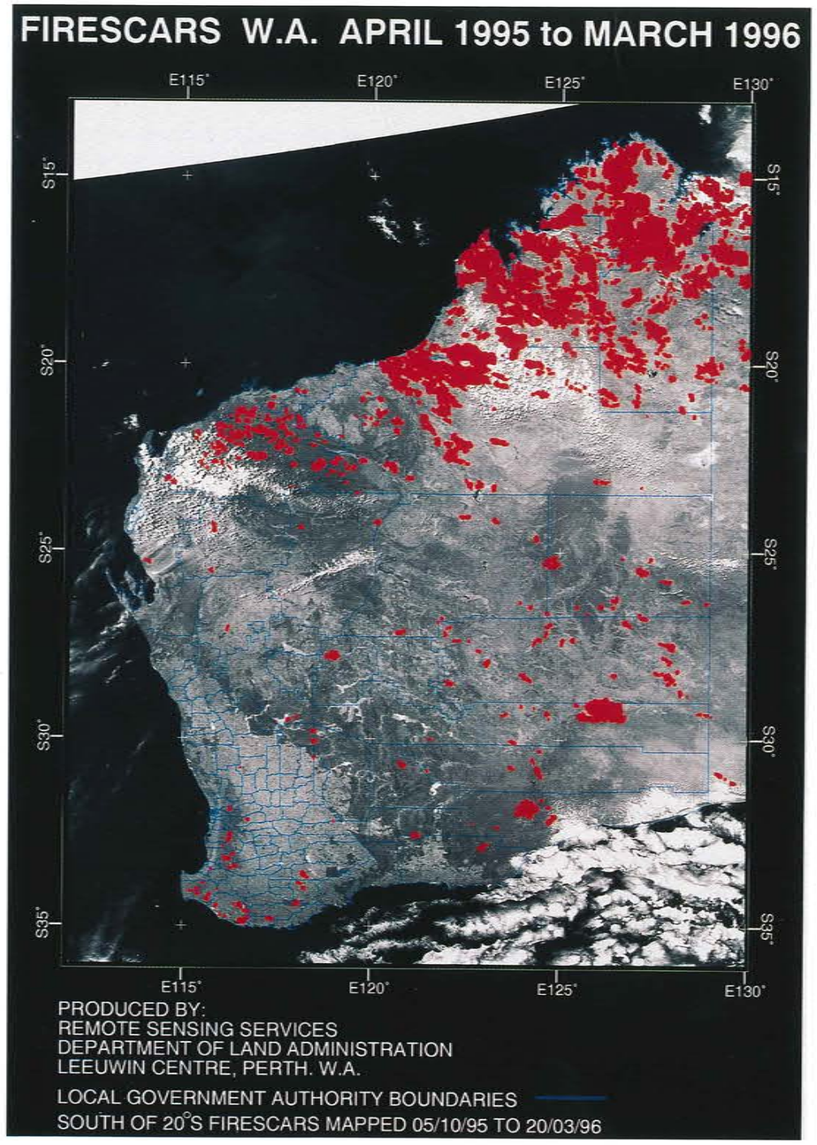
Graph 2

FIRE HISTORY

These cumulative maps of firescars give a history of the total area burnt in relation to pastoral stations, vegetation types, and time of the year. These fire histories in time, will prove very valuable for fire control agencies and fire ecologists. It will enable the control agencies to determine the success of their prescribed burning strategy to see whether it has had the desired effect. Ecologists can interpret ecological changes and understand the impact of fire. From this knowledge, fire regimes can be generated to deliver desired ecological outcomes. While the mapping of the firescars is done using a visual interpretation, there is an opportunity to detect them automatically so as to reduce the time involved.



Firescar 1



Firescar 2

ACKNOWLEDGEMENTS

To all members of the Remote Sensing Services group for their efforts in the management and maintenance of the WASTAC archive. To those staff who assist in the delivery of NOAA data and particularly, Mr Ron Craig for his dedication to the running of the WASTAC facility.

CURTIN UNIVERSITY OF TECHNOLOGY

REMOTE SENSING AND SATELLITE RESEARCH GROUP

Mervyn Lynch

Visiting Professor - Remote Sensing

Professor Iosef Fuks, Visiting Professorial Fellow, from the Institute of Radio Astronomy and Astrophysics, University of Kharkov, Ukraine visited Curtin's Remote Sensing and Satellite Research Group from July, 1995 to January, 1996. His studies include a theoretical scattering problem in remote sensing in association with DSTO, Salisbury, SA.

Research Student Activities

The Remote Sensing and Satellite Research Group's (RSSRG) activities during 1995 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 7 PhD, 6 MSc, 4 Honours, 3 Graduate Diploma and 1 third year Project students.

Staff - Academic

Assoc Professor Mervyn Lynch commenced a period of overseas study leave in December 1995. A combination of study leave and Long service leave will mean he is absent through the end of 1996. The bulk of his study leave will be spent at the Cooperative Institute for Meteorological Satellite Studies in the Space Science and Engineering Center, University of Wisconsin. The principal research emphases will involve advanced applications of infrared sounding from high spectral resolution interferometers, familiarisation with the calibration and applications algorithms for the new satellite sensor, MODIS, which is due for launch in mid-1996, liaison with the NASA/Orbital Sciences Corporation Science Team for the soon-to-be-launched SeaWiFS satellite, and interactions with the French Science Team for the POLDER sensor on the Japanese ADEOS satellite platform. Additionally, expanded collaborative research opportunities with the University of Wisconsin, the University of California - San Diego, and the Rochester Institute of Technology Centre for Imaging Science are being explored.

Visitors - National

Professor Don Watts, Chairman of the Australian Space Council.
Members of the Australian Space Council.
Dr Brian Embleton, Director, CSIRO Office of Space Science, Canberra.
Mr Mahendra Pal, Principal Geologist - Research and Development, Hamersley Iron Pty Ltd.
Dr Stuart Anderson, Radar Group, Defence Science and Technology Organisation, Salisbury, South Australia.

Visitors - International

Professor Charles Geoffrion, Acting Vice-President for Research, University of Arizona.
Dr James Simpson, Head, Digital Image Analysis Laboratory, Scripps, Institution of Oceanography, University of California, San Diego, California.

International Collaborative Research Activities.

The Remote Sensing Group, in conjunction with the WA Satellite Technology and Applications Consortium (WASTAC), have continued with preparations for the reception of direct readout data from the SeaWiFS satellite scheduled for launch in late 1996 early 1997.

Curtin and the University of NSW were awarded International Investigator status on the French POLDER remote sensing instrument due for launch in July 1996 on the Japanese ADEOS satellite mission. Initial work in support of POLDER has involved the design and construction of a mount to enable airborne polarisation measurements to be made over the coastal oceans using the Digital Multi - Spectral Video (DMSV) remote sensing instrument developed by SpecTerra Pty Ltd.

Mr Paul van Delst, Mr Liam Gumley and Mr Mark Gray, all graduates from Curtin and former members of the Remote Sensing and Satellite Research Group are currently conducting research on a variety of satellite sensors for both CIMSS and SSEC.

Description of Research Projects

As part of the Remote Sensing and Satellite Research Group's (RSSRG) preparations for SeaWiFS launch, data reception and product generation, Mr Jim Davies (PhD student and SeaWiFS Project Manager) and Mr Peter Fearns (PhD student) have been involved in developmental work associated with the establishment of a SeaWiFS reception, data processing and archival computer facility. The WA Satellite Technology and Applications Consortium has agreed to proceed with the installation of a high speed digital data link which will connect the WASTAC satellite reception facility at Curtin to the Leeuwin Centre (Floreat) and the Bureau of Meteorology (Perth City). This same high speed link will enable the transfer of SeaWiFS data to the SeaWiFS processor at the Leeuwin Centre. Dr Jim Simpson, a Member of NASA's SeaWiFS Science Team visited the Laboratory in September, 1995.

Collaboration with WA industry remains a high priority and it has worked effectively in 1995. These collaborations reflect well on the employment opportunities for students. Mr Dave Foster, Mr Roland Lockhart, Mr Dean Miller, Mr Craig Suttar, Mr Gregg Kirkpatrick, Mr Charles So, Mr Anwar Khalil, Miss Sharlene Andrijich and Mr Andrew Greenhill, all recent members of the Remote Sensing Group, have been successful in finding employment with industry during the last year or so. In almost all cases these students have undertaken research projects with direct industry involvement.

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. 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. These two models will be linked to provide a complete sun-ocean-satellite forward model.

Project support: Grant from the Vice-Chancellor's Discretionary Reserve. Support for field work was provided by Oceanroutes (Aust) Pty Ltd (now WNI 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 Norman 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 Celcius may be achieved using the algorithms. For the field sites studied, a bias corrected LST of rms error of 0.8 Celcius 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 Dr I Foster of Agriculture WA.

* CSIRO Division of Atmospheric Research, Melbourne
** CSIRO Division of Mathematics and Statistics, Perth
*** Agriculture WA
† 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
* Department of Land Administration, Remote Sensing Services

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 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
†† 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 1995 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 remain 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. NOAA/AVHRR data are provided by WASTAC. 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 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, Perth
† 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, Perth
† Honours student
†† Graduate Diploma in Imaging Science student

Remote Sensing of Ocean Biomass Productivity

Associate Professor Mervyn Lynch, Mr Mark Marinelli#, Mr Roland Lockhart* and Mr Alan Pearce. **

The Coastal Zone Colour Scanner (CZCS) provided colour imagery of the oceans for the period 1979 to 1986. While the coverage was not complete because this was a research rather than operational satellite, there were much valuable data collected and archived during the lifetime of the satellite. This project has been examining the data in the Australasian region, but with a particular emphasis on the Western Australian coastal area, in order to establish the importance of the phytoplankton forcing which controls productivity. The role of vertical ocean mixing, nutrient supply, insolation, ocean temperature and the Leeuwin Current are under examination. Mr Mark Marinelli joined the project in 1996.

Project support: Mr Lockhart was a recipient of a Neville Stanley Studentship during the summer of 1995/96. The Studentship co-sponsor was World Geoscience Corporation. The data sets for the project have been provided by NASAGoddard Space Flight Center's DAAC.

\# MSc student
* Undergraduate student
** CSIRO, Division of Oceanography, Marmion

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 sufficiently accurately, then we may infer the heat transfer through the soil, and ultimately estimate physical properties (eg 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 temperature monitors 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. Additionally, we have derived land surface temperatures (LST) from NOAA/AVHRR satellite data and compared these to the in-situ observations. Present 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 it 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 Division of Exploration and Mining

CURTIN UNIVERSITY OF TECHNOLOGY

SCHOOL OF SURVEYING AND LAND INFORMATION
Prof. Graham Lodwick

Introduction

The School of Surveying and Land Information offers remote sensing studies as part of its undergraduate program in Surveying (B Surv) and Cartography (B Sc). In addition, it offers specialised graduate education through the following courses:

- Graduate Diploma in Remote Sensing and Land Information
- Postgraduate Diploma in Surveying and Mapping
- Master of Science (Surveying and Mapping)
- Doctor of Philosophy

Utilisation of NOAA Data

Towards the end of 1995, Dr Michael Roderick was awarded a one year Australian Research Council (ARC) grant to continue his investigations into the seasonal dynamics of arid regions using long term, NOAA-AVHRR derived NDVI data. Funds from both this grant and internal sources have been used to purchase a new high capacity HP workstation. The workstation will support Dr Roderick's research, and will also be used by graduate students conducting research in the Spatial Sciences.

Derivation of Arid Zone Plant Growth Models

Dr Michael Roderick

Variability in rainfall, and the subsequent variability in plant growth, are major factors influencing the sustainable use of Australia's rangelands. The impact of this variability is often assessed using simulation models and long term meteorological data (e.g. rainfall, evaporation, temperature). However, a systematic validation of these models across the whole Australian continent has not been conducted.

This research is comparing the time traces of vegetation condition produced by simulation models, to long term (1981-1991) AVHRR derived NDVI data. The research has two components, identification of inadequate models and subsequent validation where the model is adequate.

WASTAC BUDGET 1996

Estimated expenditure financial year January 1996 - December 1996

		PER ANNUM $ 1996	$ 1995
1.	Telecom Rental	2,700	2,700
2.	Exabyte Tapes	4,000	4,000
3.	System maintenance	4,000	4,000
4.	Telecommunications licence of facility	1,500	500
5.	Photographic/ink jet quicklook costs	3,000	3,000
6.	Consultants-Archive/product generation assistance	10,500	10,500
7.	Sundries, consumables	1,000	1,000
8.	Travelling - airfares	4,000	4,000
9.	Provision for major equipment	11,000	12,000
10.	Special provision for improved communications existing facilities (transferred from 1995)	100,000	100,000
11.	Annual Report	5,000	4,000
	TOTAL:	**$146,700**	**145,700**

Estimated income/revenue financial year January 1996 - December 1996

INCOME	$ 1996	$ 1995
Contributions received ($10,000 each member)	40,000	40,000
Sundry income (data replication)	4,000	2,000
Interest	2,000	2,000
TOTAL INCOME:	**$46,000**	**$44,000**

WA SATELLITE TECHNOLOGY AND APPLICATIONS CONSORTIUM FINANCIAL STATEMENTS:

YEAR ENDED 31 DECEMBER 1995

AUDITOR'S REPORT

I have audited the attached financial statements and in my opinion they fairly represent the transactions of the Consortium during the 1995 calendar year, together with its financial status as at 31 December 1995. The statement is based on proper accounts and records.

P J Perriam

P J Perriam
MANAGER, INTERNAL AUDIT
CURTIN UNIVERSITY OF TECHNOLOGY

27 July 1996

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

BALANCE SHEET AS AT 31 DECEMBER 1995

	NOTE	1995	1994
		$	$
CURRENT ASSETS			
Cash at Bank		177,668	164,642
Prepayments		732	-
TOTAL CURRENT ASSETS		**178,400**	**164,642**
NON - CURRENT ASSETS	3		
Computer Equipment		29,138	38,851
Other Equipment		65,832	75,237
TOTAL NON - CURRENT ASSETS		**94,970**	**114,088**
TOTAL ASSETS		**273,370**	**278,730**
CURRENT LIABILITIES			
Creditors & Borrowings		368	1,805
TOTAL CURRENT LIABILITIES		**368**	**1,805**
NON - CURRENT LIABILITIES			
Creditors & Borrowings		-	-
TOTAL NON - CURRENT LIABILITIES		-	-
TOTAL LIABILITIES		**368**	**1,805**
NET ASSETS		**273,002**	**276,925**
SHAREHOLDERS EQUITY			
Asset Revaluation Reserve	4	129,997	129,997
Retained Profits/(Losses)	5	143,005	146,928
TOTAL SHAREHOLDERS EQUITY		**273,002**	**276,925**

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

INCOME AND EXPENDITURE STATEMENT FOR THE PERIOD 1 JANUARY 1995 TO 31 DECEMBER 1995

	NOTE	1995	1994
		$	$
INCOME			
Contributions Received	6	40,000	40,000
Sundry Income	7	1,200	12,212
Interest Received		2,537	-
TOTAL INCOME		**43,737**	**52,212**
EXPENDITURE			
Salaries and Wages		13,275	11,791
Conference		-	1,200
Telephone		2,247	3,043
Travel		-	-
Consumables		6,794	5,893
Printing, Stationery & Photocopying		3,550	3,280
Depreciation		19,118	23,698
Maintenance of Equipment		2,676	2,780
Feasibility Study		-	3,000
TOTAL EXPENDITURE		**47,660**	**54,685**
NET SURPLUS (DEFICIT)		(3,923)	(2,473)
EXTRAORDINARY ITEMS		Nil	Nil
NET SURPLUS (DEFICIT) AND EXTRAORDINARY ITEMS		(3,923)	(2,473)
TRANSFERS TO ASSET REVALUATION RESERVE		Nil	Nil
NET SURPLUS (DEFICIT) TRANSFERRED TO RETAINED PROFITS/(LOSSES)		(3,923)	(2,473)

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

CASH FLOW STATEMENT FOR THE YEAR ENDED 31 DECEMBER 1995

	$
BALANCE OF CASH AS AT 1 JANUARY 1995	**164,642 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	
Department of Defence	1,200
Interest Received	2,537
Total Sundry Income	**3,737**
TOTAL RECEIPTS FOR 1995	**43,737**
PAYMENTS	
Salaries and Wages	13,275
Telephone	3,440
Consumables	10,344
Maintenance of Equipment	3,652
TOTAL PAYMENTS FOR 1995	**30,711**
EXCESS OF RECEIPTS OVER PAYMENTS FOR 1995	**13,026**
BALANCE OF CASH AS AT 31 DECEMBER 1995	**177,668 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 1995 TO 31 DECEMBER 1995

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 Equipment	12.5% reducing balance method.

	1995 $	1994 $
3. NON CURRENT ASSETS		
Computing Equipment (at cost)	186,583	186,583
Accumulated Depreciation	(157,445)	(147,732)
TOTAL COMPUTING EQUIPMENT	**29,138**	**38,851**
Other Equipment (at cost)	183,765	183,765
Accumulated Depreciation	(117,933)	(108,528)
TOTAL OTHER EQUIPMENT	**65,832**	**75,237**
TOTAL NON - CURRENT ASSETS	**94,970**	**114,088**

	1995 $	1994 $
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	146,928	149,401
Net Surplus (Deficit) for the year		(2,473)
CLOSING BALANCE	**146,928**	**146,928**
6. CONTRIBUTIONS RECEIVED		
Department of Land Administration	10,000	10,000
C.S.I.R.O	-	10,000
Curtin University of Technology	10,000	10,000
Bureau of Meteorology	10,000	10,000
COSSA Canberra	10,000	-
	40,000	**40,000**
7. SUNDRY INCOME		
Supply of NOAA - AVHRR passes to the Department of Defence	1,200	12,212
	1,200	**12,212**

COMPUTING EQUIPMENT AS AT 31 DECEMBER 1995

ASSET NO.	DESCRIPTION	ORIGINAL COST	ACCUM DEPREC VALUE	WRITTEN DOWN
		$	$	$
2494515	MICROSOFT OS/2 PM TOOLKIT	488.00	359.33	128.67
2587007	MATHS CO-PROC INTEL 20MHZ	570.00	419.71	150.29
2494511	ETHERLINK MC CARD	590.00	434.44	155.56
2587001	MOUSE	109.00	80.26	28.74
2552700	TAPE DRIVE 2 GBYTE X801A	6,840.00	5,126.66	1,713.34
2587010	2MB MEMORY MODULE	475.00	349.76	125.24
2494507	OS/2 EXTENDED EDITION V1.2	700.00	515.43	184.57
2553701	ACQNR	3,800.00	2,848.15	951.85
2587200	ULTRA 1000 20"	2,870.00	2,113.27	756.73
2494506	PS/2 CARD TO OPTION SCSI	142.00	104.56	37.44
2494509	MATHS CO-PROCESSOR INTEL 25MHZ	726.00	534.58	191.42
2494503	PS/2 DUAL ASYNCH ADAPTOR	233.50	171.93	61.57
2494500	PS2 25MHZ 4/320MBHD & MONITOR VGA	16,686.00	12,808.83	3,877.17
2478800	2.3GB 8MM EXABYTE	6,272.00	4,814.64	1,457.36
2587002	DUAL ASYNCH ADAPTOR	233.50	171.93	61.57
2494512	MONITOR DISPLAY CABLE	120.00	88.36	31.64
2587005	2MB MAIN MEMORY EXPANSION	953.00	701.72	251.28
2494510	4-16MB MEMORY BOARD 4MB	1,501.00	1,105.23	395.77
2629700	CARTRIDGE SYSTEM 2.5 G BYTE 8MM EX	4,950.00	3,579.56	1,370.44
2494516	FORTRAN V2.0	754.00	555.19	198.81
2587011	2MB MEMORY MODULE	475.00	349.76	125.24
2587000	PS/2 20MHZ 2/320MBHD VGA+SCSI CARD	9,392.00	6,752.44	2,639.56
2587300	5.25 DISKETTE	501.00	368.90	132.10
2494504	PS/2 DUAL ASYNCH ADAPTOR	233.50	171.93	61.57
2587003	DUAL ASYNCH ADAPTOR	233.50	171.93	61.57
2587014	MONITOR DISPLAY CABLE	120.00	88.36	31.64
2587009	2MB MEMORY MODULE	475.00	349.76	125.24
2585200	PAINTJET XL C1602A	2,425.00	1,785.60	639.40
2587100	ULTRA 1000 20"	2,870.00	2,113.27	756.73
2494505	5.25 EXTERNAL DISKETTE ADAPTOR	204.00	150.22	53.78
2587012	ETHERLINK MC CARD	590.00	434.44	155.56
2494517	LOCAL AREA NETWORK TECH MANUAL	70.00	51.54	18.46
2494501	MEMORY EXPANSION BOARD 4MB	1,911.00	1,466.96	444.04
2587008	2-8MB MEMORY EXPANSION	1,450.00	1,067.67	382.33
2494513	MS MACRO ASSEMBLER V5.1	174.00	128.12	45.88
2494508	320MB HD DRIVE	4,739.00	3,489.46	1,249.54
2494518	PS/2 MOUSE	109.00	80.26	28.74
2587013	FUTURE DOMAIN	450.00	331.35	118.65
2587004	OS/2 EXTENDED EDITION V1.2	700.00	515.43	184.57
1358800	SYSTEM SATELLITE TRACKING STATION	110,000.00	100,364.13	9,635.87
2494514	MICROSOFT C COMPILER V6	448.00	329.88	118.12
		186,583.00	**157,444.95**	**29,138.05**

OTHER EQUIPMENT AS AT 31 DECEMBER 1995

ASSET NO.	DESCRIPTION	ORIGINAL COST	ACCUM DEPREC	WRITTEN DOWN VALUE
		$	$	$
2009000	MA 23 CC	20,365.00	11,701.29	8,663.71
1358700	SATELLITE STATION TRACKING	140,000.00	94,901.32	45,098.68
2553700	RECEIVER NOAA I/F FORMAT	19,500.00	9,260.14	10,239.86
1948500	POWER CONDITIONER	2,000.00	1,167.84	832.16
2552600	SGSI HOST ADAPTOR 598A	1,900.00	902.27	997.73
		183,765.00	**117,932.86**	**65,832.14**
		370,348.00	**275,377.81**	**94,970.19**

REMOTE SENSING PUBLICATIONS

Allen, A. (1995). Derivation and Visualisation of a Multitemporal Remotely Sensed Data Set, Cartography Honours Dissertation, School of Surveying and Land Information, Curtin University of Technology, Perth, WA, 105 pp.

Bower, N. (1994). Polarised Airborne Observations of the Coastal Zone. Internal Project Report, School of Physical Sciences, Curtin University of Technology. Submitted to SpecTerra Pty Ltd.

Davies, J.E and M.J. Lynch. (1994). Modelling Sky Radiances for SeaWiFS. Abstracts of the Joint Australian Physical Oceanography Conference - Australian Meteorological and Oceanographic Society (APOC/AMOS) Conference, Lorne, Victoria, February 20-22 1995.

Dodds, L.R. (1995). Shallow Water Bathymetry from Landsat TM Data - Montebello Islands W.A. Internal Project Report, School of Physical Sciences, Curtin University of Technology. Submitted to World Geoscience Corporation.

Domenikiotis, C . (1995). Knowledge-based Interpretation of a Forest Road Network Using Remote Sensing Data, PhD Thesis, School of Surveying and Land Information, Curtin University of Technology, Perth, WA, 356 pp.

Domenikiotis, C., G.D. Lodwick, and G.L.Wright, (1995) Intelligent Interpretation of SPOT Data for Extraction of a Forest Road Network, Cartography, Vol.J24, No.J2, pp.J47-57. Also Proceedings of 17th International Cartographic Conference, Barcelona, Spain, September, Vol. 1, pp.1023-1032.

Eidenshink, J.C. and J.L. Faundeen. (1994). The 1 km AVHRR global land data set: first stages in implementation. International Journal of Remote Sensing, 15, 3443-62.

Ellement D. (1995). Remote Sensing of Land Surface Thermal Inertia for Subsurface Exploration. I. Internal Project Report, School of Physical Sciences, Curtin University of Technology. Submitted to Hamersley Iron Pty Ltd.

Ellement D. (1995). Remote Sensing of Land Surface Thermal Inertia for Subsurface Exploration II. Internal Project Report, School of Physical Sciences, Curtin University of Technology. Submitted to Hamersley Iron Pty Ltd.

Fearns, P.R. and M.J. Lynch. (1995). Modelling Water Leaving Radiances for SeaWiFS. Abstracts of the Joint Australian Physical Oceanography Conference - Australian Meteorological and Oceanographic Society (APOC/AMOS) Conference, Lorne, Victoria, February 20-22, 1995.

Fearns, P.R. (1995). SeaWiFS - Modelling Water-Leaving Radiances. Abstract, Australian Institute of Physics, 5th Postgraduate Research Conference, Jarrahdale, 30 August - 1 September, 1995.

Hall, A. (1995). Updating the Digital Road Centreline Network Using GIS and Image Processing Technology, Cartography Honours Dissertation, School of Surveying and Land Information, Curtin University of Technology, Perth, WA, 163 pp.

Huang, X, T.J.Lyons, and R.C.G. Smith. (1995). Meteorological Impact of Replacing Native Perennial Vegetation with Annual Agricultural Species, Hydrological Processes. 9, 645-654.

Huang, X., T.J. Lyons, R.C.G. Smith, and J.M. Hacker. (1995). Estimation of Land Surface Parameters Using Satellite Data. Hydrological Processes, 9, 631-643.

Le Marshall, J.F., G.A. Mills and G.F. McNamara. (1991). Real time reception and 4-D assimilation of TOVS data in the Australian Region. Technical Proceedings of the 6th International TOVS Study Conference, Airlie, Washington. A Report from the CIMSS SSEC, University of Wisconsin - Madison, 300-304.

Le Marshall, J.F., P.A. Riley, B.J. Rouse, G.A. Mills, Z.J. Wu, P.K. Stewart and L. Smith. (1994). Real time Assimilation and Synoptic Application of Local TOVS Raw Radiance Observations. Australian Meteor. Magazine 43(3), 153-166.

Le Marshall, J.F. and G.A. Mills. (1995). Tropical Cyclone Bobby - a notable example of the impact of local TOVS data. Australian Meteor. Magazine 44(4), 293-297.

Le Marshall, J.F., J.D. Clark, D.P. Blank, P.M. Udelhofen and C. Osborne. (1996). Sounding the Australian and Antarctic atmospheres using the TOVS, AVHRR and SBUV/2 Instruments. Proceedings of the 8th Australasian Remote Sensing Conference, Canberra.

Lockhart, R. (1995). The Phytoplankton Annual Cycle and Its Impact on Deployment of the Airborne Laser Fluorescence (ALF III) Sensor. Internal Project Report, School of Physical Sciences, Curtin University of Technology.

Lockhart, R. and M.J. Lynch. (1995). Remote Sensing of Ocean Biomass Productivity off Western Australia. Abstracts of the Joint Australian Physical Oceanography Conference - Australian Meteorological and Oceanographic Society (APOC/AMOS) Conference, Lorne, Victoria, February 20-22, 1995.

Lynch, M.J. (1995). Submission to the Interdepartmental Committee on International Space. Review of the Australian National Space Programe.

Marinelli, M. (1995). An Ocean Colour Remote Sensing Study of the Phytoplankton Cycle off Western Australia. Abstract, Australian Institute of Physics, 5th Postgraduate Research Conference, Jarrahdale, 30 August - 1 September, 1995.

Marsden , A.J. (1995). Report on the visit to the Observation and Engineering Branch, Bureau of Meteorology, Melbourne, February 1-4, 1995.

Methakullachat, D. (1995). Topographic Correction of Satellite Imagery Using a DTM, MSc Thesis, School of Surveying and Land Information, Curtin University of Technology, Perth, WA, 118 pp.

Pearce, A. (1995). Research Programmes and Data Applications : CSIRO Division of Oceanography. WASTAC Annual Report 1994, 8-10.

Prata, A.J., R.P. Cechet, G.F. Rutter and J. Kingwell. (1995). The Australian Continental Integrated Ground Site Network. Proceedings of the 8th International TOVS Study Conference, Queenstown, New Zealand, 5-8 April.

Roderick, M.L., R.C.G. Smith, and G.D. Lodwick.. (1995). Annual Growth Dynamics Over Continental Scale Regions Using Satellite Derived Vegetation Indices, Proceedings of 5th International Rangeland Congress, Salt Lake City, Utah, July.

Roderick, M.L., R.C.G. Smith, and G.D. Lodwick.. (1995). Rainfall/Plant Growth Relationships Using Transfer Functions and Satellite Observations, Proceedings of 5th International Rangeland Congress, Salt Lake City, Utah, July.

Smith, R.C.G., J. Adams, D.J. Stephens and P.T. Hick. (1995). Forecasting Wheat Yield in a Mediterranean-type Environment from NOAA Satellite. Australian Journal of Agricultural Research 46, 113-125.

Suttar, C. (1995). Analysis and Interpretation of Data from the Airborne Laser Fluorosensor (ALF III). Internal Project Report, School of Physical Sciences, Technical Reports No. 1 - 9. Submitted to World Geoscience Corporation.

Underwood, G.A. (1995). A GIS-based Analysis of Rainfall over Western Australia 1880-1990, Cartography Honours Dissertation, School of Surveying and Land Information, Curtin University of Technology, Perth, WA, 126 pp.

van Burgel, J.L., J.F. Le Marshall, M.J. Lynch and J. Clarke. (1995). The Application of MSU Microwave Data to the Study of Australian Region Tropical Cyclones. Technical Proceedings of the 8th International TOVS Study Conference, Queenstown, New Zealand, April 5 - 11.