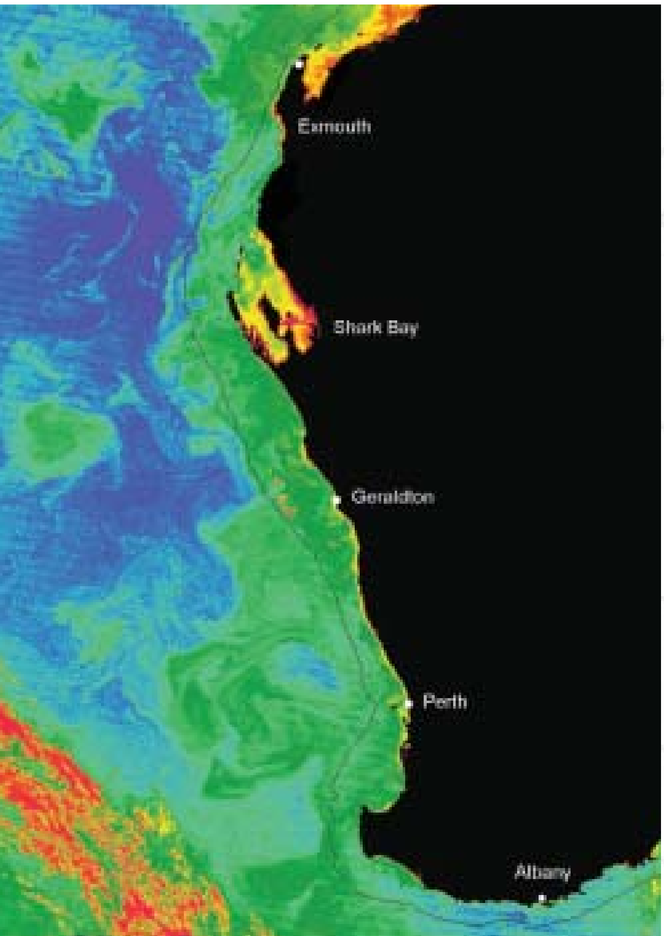
WASTAC | Western Australian Satellite Technology and Applications Consortium

Annual Report

2003



WEB : http://www.wastac.wa.gov.au

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WASTAC CHAIRMAN'S REPORT 2003

Since inception WASTAC has built an impressive archive of NOAA-AVHRR and now MODIS data.

Inspired by a recent MODIS image of the Queensland floods a meteorologist felt compelled to write that " the image ….. reminds us of the incredible capabilities of satellites in this day and age. And we're only seeing the tip of the iceberg".

Operationally we are building the processing system to reveal the "iceberg" of information in the MODIS data stream. In this quest WASTAC purchased two computers in 2003: one for CSIRO to develop the ocean capabilities and another for DLI to realise the land capabilities. In addition it provided a 12 month salary for Dr Brendon McAtee to implement NASA's global software to enable the atmospheric correction of direct broadcast MODIS within IMAPP code. Since this is not a trivial task WASTAC supported a 3 week visit by Dr Jim Davies from the University of Wisconsin IMAPP development group.

For example, our inability to correct satellite data for atmospheric and view angle effects has necessitated dependence on the empirical Normalised Difference Vegetation Index to measure green vegetation cover. With MODIS's 36 spectral bands we can move to less empirical measures by deriving the atmospheric and BRDF parameters needed to provide below-atmosphere NADIR reflectance as a standard product. This will open up the opportunity to derive a much wider range of vegetation parameters related to moisture content and total biomass. Similar opportunities exist with ocean measures.

The atmospheric parameters will also provide exciting new information such as the impact of smoke from bush fires and dust from desert storms on air quality. Similar opportunities exist with the ocean and near coastal regions. Getting from the tip of the iceberg to the rich vein of information in MODIS is not a trivial task, but the rewards to humanity from perseverance and good science are great. WASTAC is providing us a unique opportunity to pursue this vision.

Since inception WASTAC has built an impressive archive of NOAA-AVHRR and now MODIS data. To realise the potential of this historic archive WASTAC is a participant in an E-Science proposal to the Western Australia State Government. More recently the Australian Greenhouse Office has commissioned DLI to map the fire history of Australia for 1989 to 1991 from its archive to establish the baseline for carbon accounting.

Again the partners have contributed generously to the efficient running of WASTAC. Ron Craig and Sarah Foster, DLI along with Don Ward, BOM have kept the stations running with a high degree of reliability. CSIRO maintains the high speed data link needed for near real-time processing at the Leeuwin Centre. Richard Stovold, DLI as Secretary has kept the decision making on track and with Alan Pearce, CSIRO edits an excellent Annual Report. Curtin University continues to manage our accounts efficiently. Murdoch University maintains an excellent site for the X-band antenna and ACRES, Geoscience Australia have provided valuable national coordination and access to MODIS data from Alice Springs for WASTAC members.

Richard Smith
Chairman

29 May 2004

Again the partners have contributed generously to the efficient running of WASTAC.

WASTAC BOARD FOR 2003

Dr Richard Smith
(Chairman)
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Mr Richard Stovold
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Curtin University of Technology

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Mr Alan Scott
Bureau of Meteorology

Mr Ian Shepherd
Geoscience Australia

Professor Tom Lyons
Murdoch University

WASTAC STANDING COMMITTEE AND PROXY TO THE BOARD

Dr Richard Smith
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Mr Richard Stovold
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Department of Land Information

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Dr Doug Myers
Curtin University of Technology

Mr Alan Scott
Bureau of Meteorology

Mr Don Ward
Bureau of Meteorology

Mr Alan Pearce
CSIRO, Marine Research

Dr Peter Hick
CSIRO, Exploration and Mining

Professor Tom Lyons
Murdoch University

WASTAC TECHNICAL COMMITTEE:

Mr Don Ward (Chairman)

Assoc Prof Merv Lynch

Dr Doug Myers

Mr Ronald Craig

WASTAC STRATEGIC PLAN

VISION:

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

MISSION:

The mission of WASTAC is to :

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

FUTURE STRATEGIES:

- Upgrade reception capabilities for METOP (additional to AVHRR) and NPP (replacement for MODIS) satellites.
- Advance MODIS processing from Level 1b to Level 2 (below-atmosphere NADIR reflection) through introduction of atmospheric and view angle (BRDF) corrections.
- Develop real-time access to Bureau of Meteorology data on Total Column Ozone, Total Column Water Vapour and Surface Pressure for the atmospheric correction of MODIS data.
- Network access to other MODIS receiving stations in Australia.

FUTURE SATELLITE OPPORTUNITIES:

- METOP (L-band)
- NPP (Replacement for MODIS).(X-band)

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

OPERATIONAL STATUS

Don Ward , Regional Computing Manager
Bureau of Meteorology(BOM): Perth www.bom.gov.au

WASTAC facilities now embrace both L Band and X Band reception. The X Band facility at Murdoch University was commissioned on the 21st November 2001.

WASTAC L :

WASTAC L Band facilities consist of a 2.4m antenna and antenna controller at Curtin University of Technology and ingest and display computers with hard disk storage and tape archive facilities, located at the Bureau of Meteorology premises at 1100 Hay Street, West Perth. A low speed uni-directional microwave link connects the antenna to the ingest computers. A high speed microwave communications system was installed in June 1996, allowing the transmission of raw and processed satellite data between the Leeuwin Centre, Curtin University and the WA Regional Office of the BOM.

Colour and grey scale quicklook pictures are produced at the Department of Land Information (DLI) -Leeuwin Centre for Earth Sensing Technologies (LCEST) in near real time for archiving, indexing and distribution. The raw data archive is produced on 20GB DLT tape and a duplicate copy is currently produced for a national NOAA data archive program that is coordinated by CSIRO Office of Space Science and Applications (COSSA) in Canberra.

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

Software systems were upgraded late in 1999. The ingest program runs on both workstations providing display, processing and backup facilities.

The TOVS data, a subset of AVHRR, is automatically sent to the Bureau of Meteorology in Melbourne so that atmospheric temperature retrievals can be included in the global numerical weather prediction models.

Sea surface temperatures (SST) are being produced by BOM and DLI. DLI is able to produce vegetation maps and monitor fire scars in near real time.

NOAA and SeaWiFS archive information are posted to DLI's World Wide Web page. Equipment failures during the year resulted in no loss of data. Due to the dedicated efforts of DLI and BOM staff, a total of 11,388 passes were recorded for the year.

WASTAC X:

WASTAC X Band facilities consist of a 3.6m domed antenna and antenna controller computer at the Environmental Science building at Murdoch University, ingest and display computers with hard disk storage and tape archive facilities, located at DLI in Floreat Park, Perth.

The X band reception facility is directly connected to the high speed PARNET at the Murdoch node which allows data transfer to DLI and via the internet to other members of WASTAC.

Quicklook pictures are produced at LCEST in around 1 hour for archive, indexing and distribution.

The raw data archive is produced on 35 GB DLT tape.

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

Due to the dedicated efforts of DLI, Murdoch University and BOM staff, a total of 3296 X band MODIS passes were recorded for the year of which 1651 passes were from the Aqua sensor.

ARCHIVE STORAGE:

DLI is currently holding the archive on 8mm exabyte DLT and DAT tapes. Orders for digital data can be provided via the internet www.wastac.wa.gov.au <http://www.wastac.wa.gov.au/> on 8mm data tape, DAT tape, DLT tape, CD-ROM or 6250/1600bpi magnetic tape.

FUTURE DIRECTIONS:

A proposal is being prepared to provide a backup NOAA L Band reception facility as an add on to the X Band ingest facility at Murdoch University. The receiver upgrade will also enable the acquisition of data from the NPP/NPOESS satellites. Further refurbishment of the existing L Band will include antenna replacement and a receiver upgrade to downfeed METOP satellite data.

WASTAC DATA ARCHIVE

The WASTAC archive of NOAA, MODIS and SeaWiFS satellite passes, managed and maintained by the Department of Land Information (DLI) Satellite Remote Sensing Services (SRSS) group, is held at the Leeuwin Centre in Floreat,Western Australia.

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

A total of 7396 NOAA passes were archived for 2003. Passes comprised data from the NOAA 12, NOAA 14, NOAA 15 ,NOAA 16 and NOAA 17 satellites. All passes were stored on DLT tapes.

The archiving of SeaWiFS data onto 4mm data tapes commenced on 31 October 1997. During 2003, 696 SeaWiFS passes had been archived.

During 2003 1645 TERRA and 1651 AQUA passes have been archived on 100 DLT tapes comprising 2500 gigabytes of information.

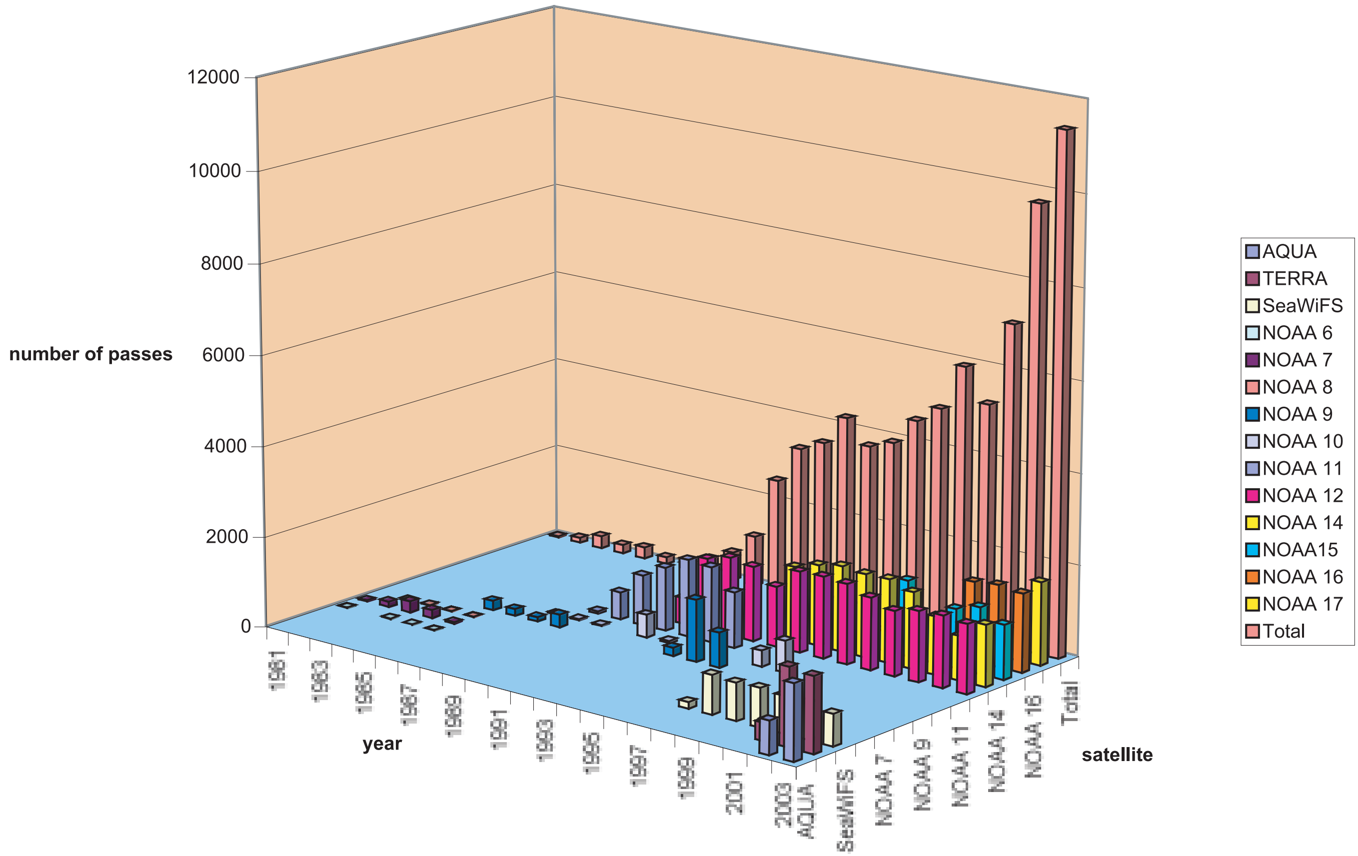
We continue to maintain the near real time quick-look archive of MODIS and NOAA-AVHRR data on the world wide web.The digital archive holds data from the present time back to 1983. A similar archive of SeaWiFS quick-look data is also held on the world wide web.

Web addresses to view this archive of MODIS, NOAA and SeaWiFS data online are:

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

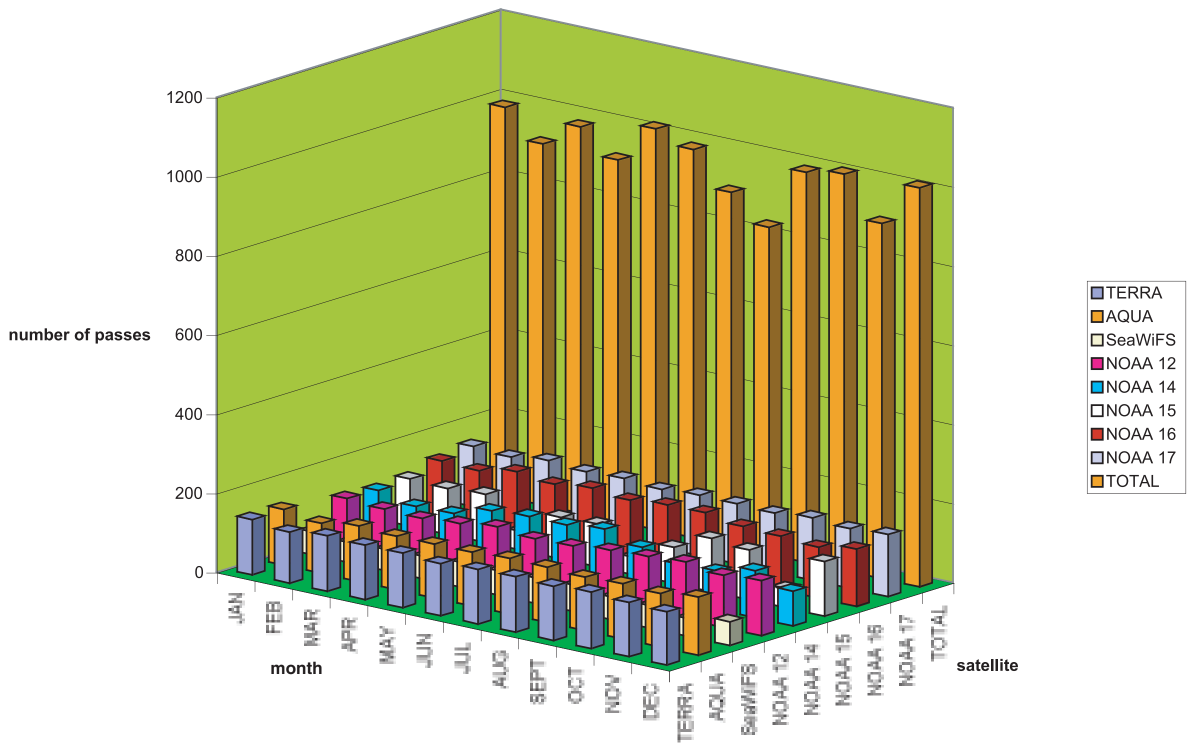
We continue to maintain the near real time quick-look archive of MODIS and NOAA-AVHRR data on the world wide web. The digital archive holds data from the present time back to 1983. A similar archive of SeaWiFS quick-look data is also held on the world wide web.

TOTAL NUMBER OF PASSES HELD IN THE WASTAC ARCHIVE - LEEUWIN CENTRE



	AQUA	TERRA	SeaWiFS	NOAA6	NOAA7	NOAA8	NOAA9	NOAA10	NOAA11	NOAA12	NOAA14	NOAA15	NOAA16	NOAA16	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	-	-	-	-	-	-	-	-	1003	-	-	-	-	-	1103
1991	-	-	-	-	-	-	-	506	1399	575	-	-	-	-	2480
1992	-	-	-	-	-	-	-	47	1693	1571	-	-	-	-	3311
1993	-	-	-	-	-	-	183	-	1656	1720	-	-	-	-	3559
1994	-	-	-	-	-	-	1362	-	1227	1641	-	-	-	-	4230
1995	-	-	-	-	-	-	770	-	-	1326	1615	-	-	-	3711
1996	-	-	-	-	-	-	-	354	-	1780	1776	-	-	-	3910
1997	-	-	142	-	-	-	-	694	-	1797	1876	-	-	-	4509
1998	-	-	859	-	-	-	-	-	-	1763	1828	432	-	-	4882
1999	-	-	822	-	-	-	-	-	-	1589	1839	1663	-	-	5912
2000	-	-	843	-	-	-	-	-	-	1427	1681	905	341	-	5197
2001	-	390	811	-	-	-	-	-	-	1548	1271	1292	1733	-	7045
2002	734	1710	780	-	-	-	-	-	-	1579	976	1455	1789	709	9732
2003	1651	1645	696	-	-	-	-	-	-	1521	1351	1200	1728	1827	11388

WASTAC DATA ARCHIVE 2003



	TERRA	AQUA	SeaWiFS	NOAA12	NOAA 14	NOAA 15	NOAA 16	NOAA 17	TOTAL
JAN	140	141	58	119	115	119	140	152	984
FEB	129	126	51	113	95	116	136	146	912
MAR	140	140	54	110	98	122	154	158	976
APR	137	135	57	118	125	48	143	150	913
MAY	138	136	63	130	132	105	154	154	1012
JUN	132	136	62	121	131	108	144	147	981
JUL	138	141	64	123	141	44	153	153	893
AUG	140	140	67	133	116	91	154	152	826
SEP	137	135	58	138	94	134	140	149	985
OCT	143	139	57	145	97	126	136	158	1001
NOV	137	135	45	132	119	49	129	151	897
DEC	134	147	60	139	88	138	145	157	1008

OPERATIONAL APPLICATIONS

Locally-received AVHRR, SeaWiFS and MODIS satellite data are being used for a variety of routine environmental products by the WASTAC partners. This section summarises these applications which are playing an increasingly important role in natural resource management both in Western Australia and nationally.

BUREAU OF METEOROLOGY

Compiled by Anthony Rea & David Griersmith

Sea Surface Temperatures

The sea-surface temperature (SST) algorithms used by the Australian Bureau of Meteorology (Bureau) use a combination of NOAA HRPT data from WASTAC, Crib Point, Casey and Darwin for each orbit of NOAA -17, -16, -15 and -12. However, recent problems with NOAA-16 have resulted in its removal from operational processing. The algorithms were developed from empirical relationships (originally based on McClain et al. 1985) between satellite observed brightness temperatures and temperatures measured directly near the sea surface. Surface values can be from ship inlet sensors, floating buoys or manually-taken measurements.

The algorithms currently in use are the Global Multi-Channel Sea Surface Temperature (MCSST) algorithms derived by NOAA/NESDIS, publicly available from http://noaasis.noaa.gov/NOAASIS/ml/sst.html (link visited 7/4/04). Current Bureau work in progress is on updating this algorithm to the Non-Linear SST (NLSST) which has improved performance, particularly in atypical atmospheres.

Recent changes to the system include the experimental implementation of navigation using the Common AVHRR Processing System (CAPS). The CAPS system, using the Clift navigation model and orbital information from CSIRO Marine Research (Hobart), is impressive since it consistently provides a navigational accuracy of around 1 pixel.

Verification of the computed SST fields is carried out automatically after each individual orbit is processed. SST temperatures are compared to ship and buoy sea-temperature observations which are co-located in both space and time. Observations within 3 hours of the nominal AVHRR image time are accepted. The results of the comparisons are produced in both graphical and tabular formats and are accessible via the Bureau internal web. Statistics for this verification system have been kept since July 1999. Typical RMS errors (usually around 1K) for the satellite-observed minus ship/buoy observed SSTs are shown in Figure 1, with a typical bias (for September 2003 to March 2004) of -0.14 (NOAA-17), -0.86 (NOAA-16), 0.03 (NOAA-15), -0.16 (NOAA-12) degrees. (Note: NOAA-16 performance was affected by an AVHRR scan motor failure).

SST products produced by the Bureau are available to the general public free of charge (via the browse service at http://www.bom.gov.au/nmoc/archives/SST/) or by subscription for higher resolution data. Examples of both products are given in Figures 2 and 3.

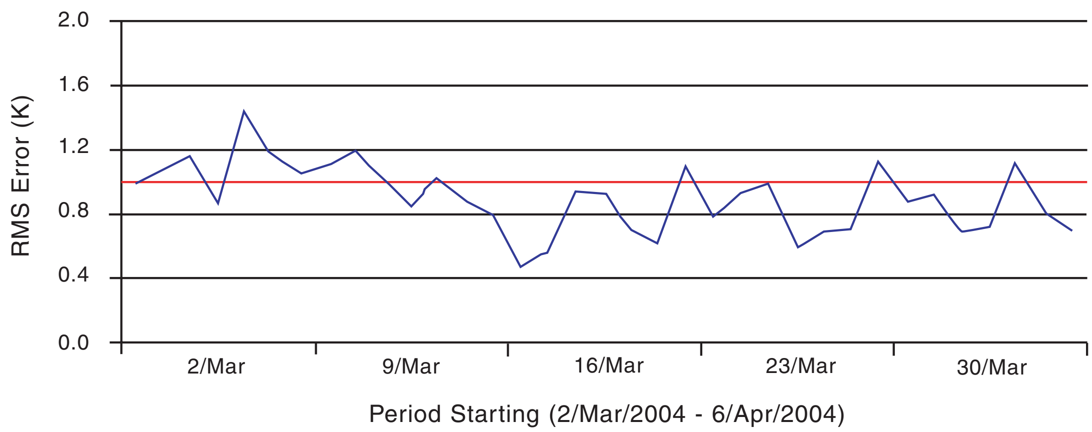
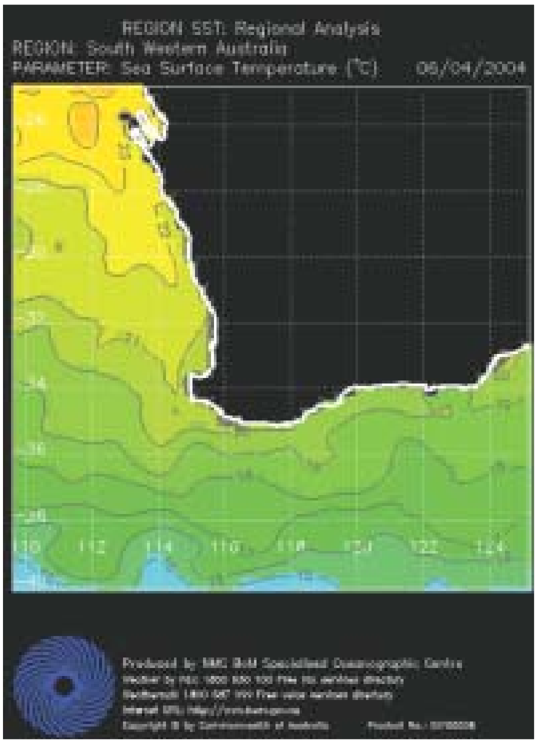


Figure 1. Average RMS error computed by taking the sum of the squares of the SST errors (satellite versus ground truth), dividing by the number of observations, subtracting the square of the bias, and taking the square root. The red line on the graph represents an RMS error of 1.0 degrees Kelvin.

OPERATIONAL APPLICATIONS (continued)



Recent improvements to the system include the implementation of navigation using the Common AVHRR Processing System (CAPS) which has removed the need for manually correcting the image registration.

Figure 2. Daily regional contour map of satellite-derived SSTs in degrees Celsius, on a 0.25 degree grid. This product is available to the public by subscription.

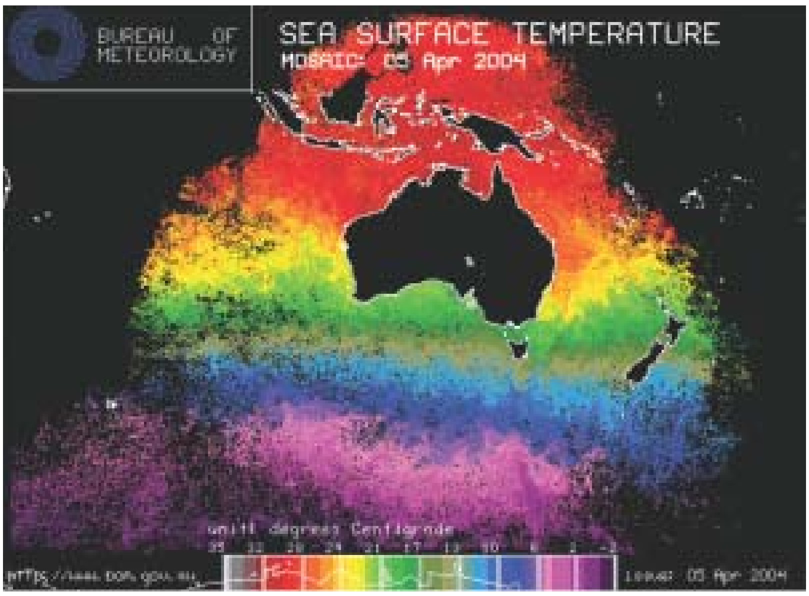


Figure 3. SST product available free to the public via a browse service on the Bureau web site (www.bom.gov.au). The image shows SSTs at 1:5 resolution.

Weather Modelling / Forecasting

The Bureau's present operational global assimilation system utilises a One-Dimensional Variational (1D-VAR) retrieval of both NOAA-15 and NOAA-16 AMSU-A and HIRS radiances, utilising 1D radiances as available from NESDIS. An extended version of this global system allows the full forward calculation of ATOVS radiance first guess values in the 1D-VAR retrieval scheme still using level 1D ATOVS radiances. In the immediate future, use of 1C radiances will be examined where each instrument (HIRS or AMSU-A or B) in the ATOVS instrument package will be treated as a separate observation. Processing of locally-derived data can deliver both 1C and 1D radiances which are desirable in support of early cut-off regional assimilation. The Bureau is currently implementing operational processing of HRPT data received at WASTAC, Darwin, Casey and Crib Point to level 1C/1D using the ATOVS and AVHRR Processing Package (AAPP) from EUMETSAT.

The online 1D-VAR ATOVS radiance retrieval scheme, implemented operationally within the global system (GASP), has also been integrated with the Bureau's Limited area Assimilation and Prediction System (LAPS), as part of the effort to unify the data assimilation component of the local and global forecasting systems. The 1D-VAR retrievals are used over the sea and at pressures < 100 hPa over land. Work is underway to test the 1D-VAR system in an extended version of LAPS with an increased number of vertical levels and the model top raised to 0.1 hPa, following similar extensions to GASP. This eliminates the need for NESDIS retrievals and will facilitate the use of locally received and processed ATOVS radiances whose timeliness will improve the amount of data available to the operational LAPS system.

NDVI/ GCI

Normalised Difference Vegetation Index (NDVI) products are produced by the Bureau of Meteorology for the Australian region using measurements from channels 1 and 2 of the AVHRR instrument on board the NOAA-16 satellite. The differential reflectance in these bands provides a means of monitoring density and vigour of green vegetation growth using the spectral reflectivity of solar radiation.

Typically two sequential daytime orbits covering most of Australia are available for processing in near real time each day. Monthly Maximum Value Composite (MVC) NDVI maps in Mercator projection are produced by taking the highest value for each pixel for the month from all the daily composites created from the individual orbits. This minimises data gaps in any particular composite due to cloud interference or missing data and overcomes some of the systemic errors that reduce the index value. See Figure 4 for an example of the Bureau's NDVI product.

Recent improvements to the system include the implementation of navigation using the Common AVHRR Processing System (CAPS) which has removed the need for manually correcting the image registration. The CAPS system, using the Clift navigation model and orbital information from CSIRO Marine Research (Hobart), provides navigation accuracy of around 1 pixel.

Due to the apparent failure of the AVHRR on NOAA-16, the Bureau has begun generating NDVI data from NOAA-17. This is expected to become the operational product if the problems with NOAA-16 cannot be rectified.

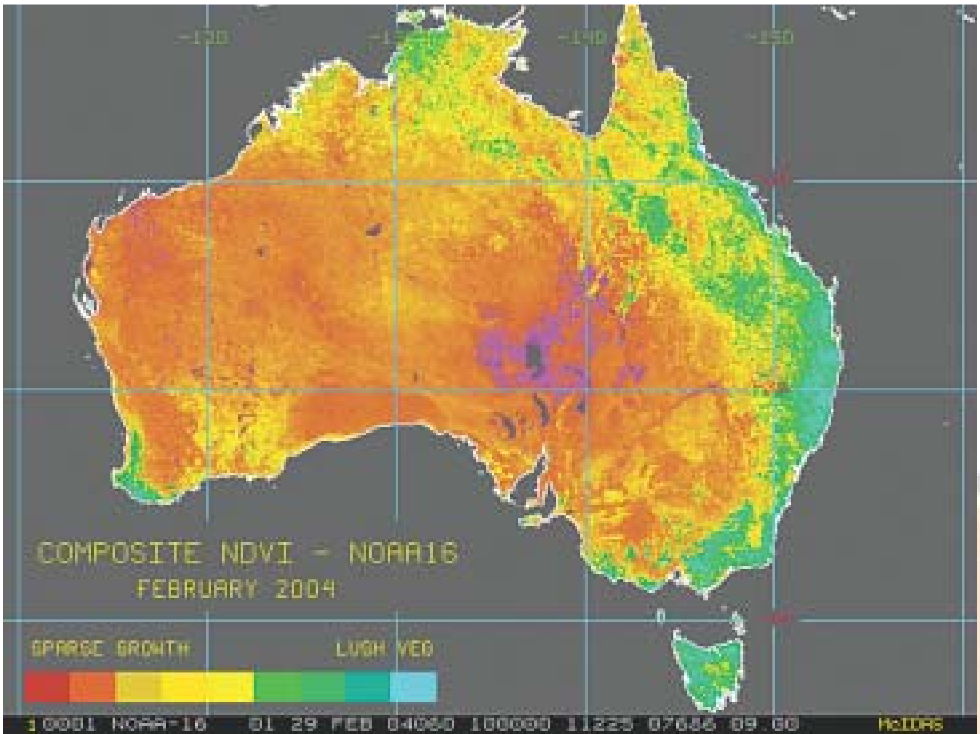


Figure 4. An example of the Bureau's Maximum Value Composite NDVI product.

OPERATIONAL APPLICATIONS (continued)

In addition to NDVI, the Bureau now provides a Grassland Curing Index (GCI) product derived from NOAA AVHRR data. The product was developed at CSIRO Atmospheric Research and utilises best-practice techniques for navigation, calibration and atmospheric correction. The result is a high-quality product which is of great use to a range of customers including regional fire services and various power generation and distribution companies. The product is currently available for Victoria and for South Australia. An example of the Victorian product is given in Figure 5.

The Victorian GCI imagery is produced as part of a cooperative agreement involving the Bureau of Meteorology, the Country Fire Authority and the CSIRO where the Bureau operationally runs the software, via its Central Computing Facility and relevant operational staff, CSIRO provides the software and the CFA provides validation data and other support.

The product is generated once per day from an afternoon pass of the NOAA-16 satellite, between 04 and 06 UTC (around 3-5pm EDST). In cases where a single NOAA pass does not completely cover the target area (a 'split pass') the product is not generated. Due to the orbital characteristics of the satellite this will happen once every 9 days for each region.

A NOAA-17 version of the product has been prepared for the 2004/2005 fire season. Current plans are to expand the product to all states and territories. Due to calibration and sun-angle differences compared to NOAA-16, and regional differences in vegetation type, further calibration of this product will be required before it is made available for operational use.

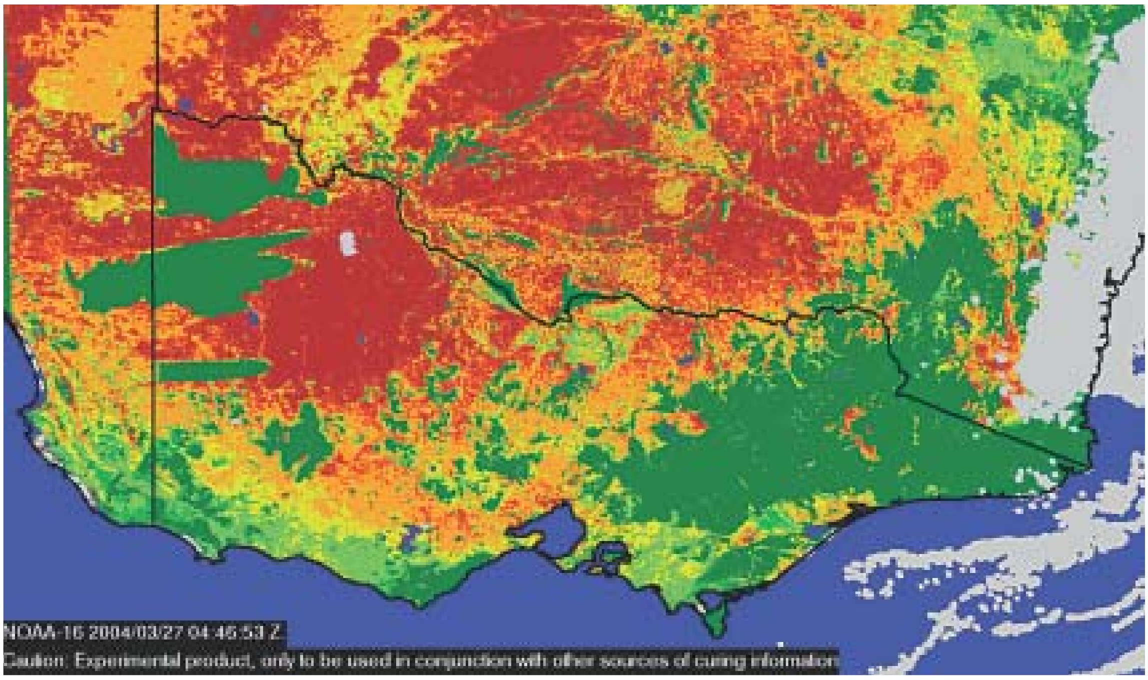


Figure 5. An example of the Bureau's Grassland Curing Index (GCI) product.

VOLCANIC ASH

The Volcanic Ash Advisory Centre (VAAC) in Darwin provides warnings on volcanic ash for the aviation industry for an area that extends over much of the Southeast Asia region. Data from WASTAC are used to complete the coverage of Darwin's area of responsibility. By way of example, in 2002 Darwin issued a total of 224 advices covering the area south of 10°N between longitudes 100°E to 160°E.

The Volcanic Ash Advisories (VAAs) issued are based on an initial report or detection of a volcanic eruption or ash cloud, an analysis of satellite data to identify and track the ash cloud, and a short term forecast of the ash movement based on upper level winds and a numerical dispersion model. In the event of a volcanic eruption the provision of timely warnings is critical if the risk of an aircraft encounter with the ash is to be minimised.

FOG / LOW CLOUD

The fog/low cloud program developed by the Bureau of Meteorology Research Centre is aimed at improving our understanding and forecasting capability for fog, which is critical to efficient and safe aircraft operations. The low cloud software mosaics AVHRR infrared imagery onto a latitude-longitude grid, using near real-time NOAA-15 and -16 satellite data received at WASTAC and Melbourne. Products are available within 10 minutes of the satellite pass being received, and are geometrically calibrated to within one pixel (1 km).

Daytime low cloud detection is produced using NOAA-15 data. Daytime detections are obtained by taking advantage of the high reflectivity of water clouds in the 3.7 micron channel compared to lower reflectivity and higher emissivity of the ground. If the 3.7 micron channel is warmer than the 11 micron channel by approximately 14K, then cloud is flagged. Subsequent checks eliminate cloud that is too cold or (where the ground is visible) too high off the ground.

Nighttime low cloud detection is performed using channels 3 and 4 from NOAA-15, -16 and -17 data. Emittance of low altitude water clouds (with small droplets) at nighttime approximates blackbody emittance in NOAA channel 4, but not in channel 3, therefore $T3 < T4$. Clouds composed of large droplets and/or ice crystals are not detected.

Recent improvements to the software include improved cloud height assignment with the use of topography and a land-sea mask, use of temperature rather than brightness values (for greater thermal resolution) and better quality control. For example, nominally low cloud pixels (from ch3 - ch4 test) are rejected, and shown in red on the cloud mask. The cloud mask was also improved to better detect low cloud pixels. See Figure 6 for an example of a cloud mask.

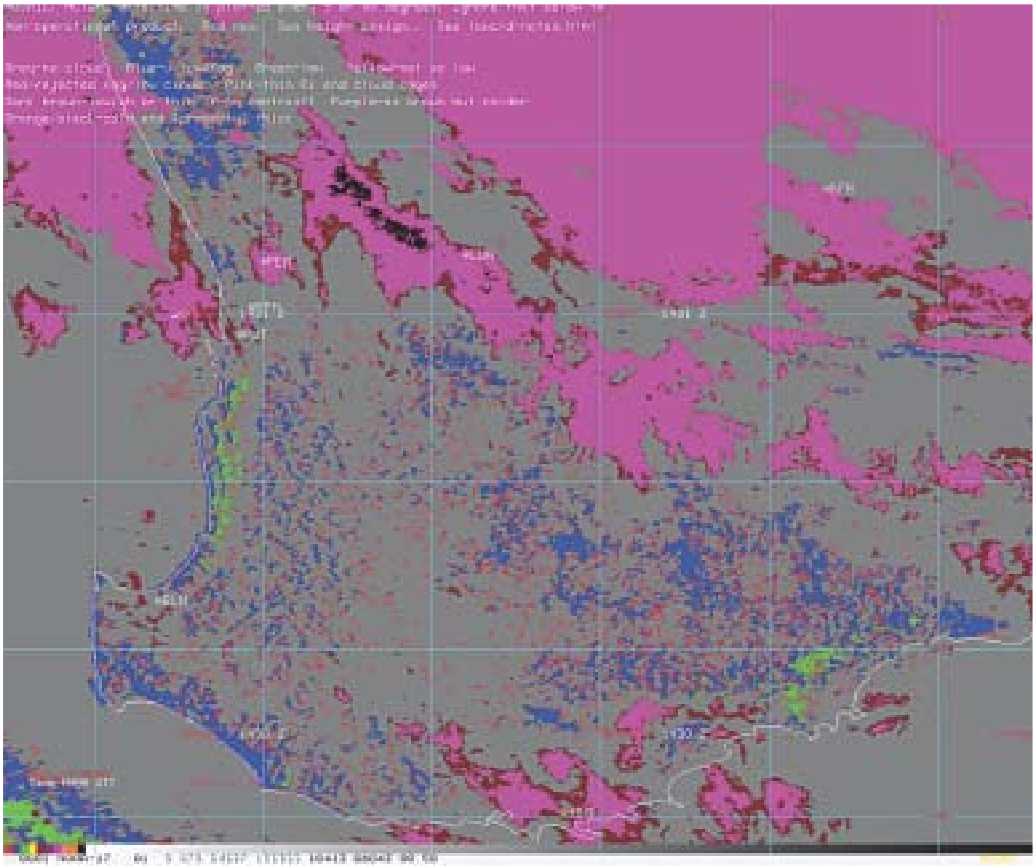


Figure 6. Cloud mask of the southern portion of Western Australia, 6 April 2004. Colours on the cloud mask mean: grey no cloud detected; red rejected fog / low cloud; blue very low cloud/fog; green low cloud; yellow low cloud but tops clearly distinct from ground (ex ch3-ch4); brown dull cloud - low and/or thin (ex neighbouring pixel check); purple bright cloud - mid and/or thick (ex neighbouring 'surface' check); magenta/pink cirrus and cloud edges; orange cold cloud - ice or large water droplets; black cold cloud - probable ice.

OPERATIONAL APPLICATIONS (continued)

CYCLONE MONITORING

The Bureau's Western Australian Regional Forecasting Centre in Perth provides warnings of tropical cyclones whenever the need arises from its Tropical Cyclone Warning Centre (TCWC). The AVHRR data are used to assist in the monitoring of fine detail of tropical cyclones and supplement the positioning of these large systems by radar, GOES-9 imagery and NWP analysis. It is also a critical back-up to GOES-9 imagery noting that the replacement for GMS-5, Japan's Multifunctional Transport Satellite MTSAT-1R is yet to be launched. As an example, Figure 7 shows a tropical cyclone near Western Australia.

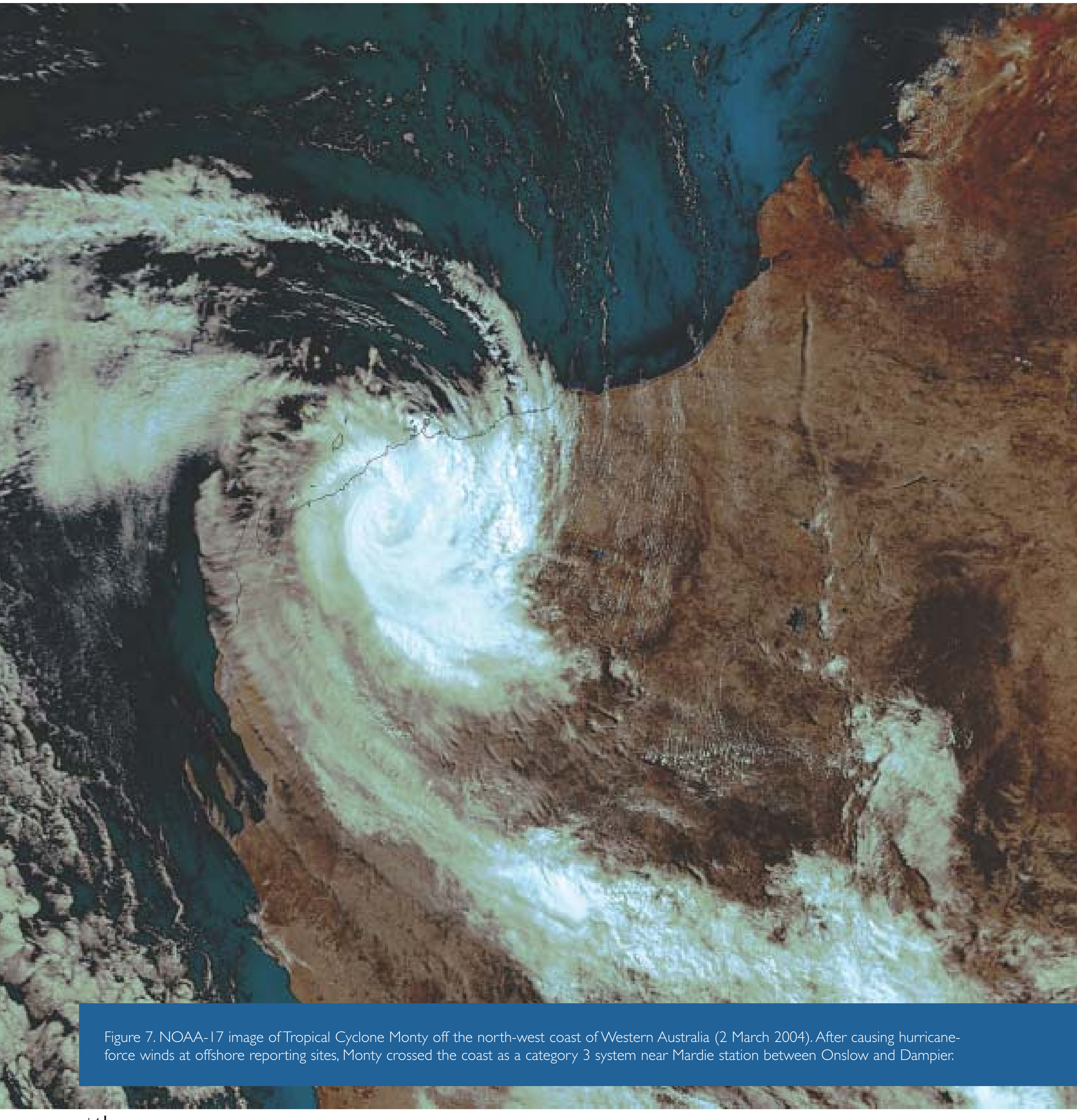


Figure 7. NOAA-17 image of Tropical Cyclone Monty off the north-west coast of Western Australia (2 March 2004). After causing hurricane-force winds at offshore reporting sites, Monty crossed the coast as a category 3 system near Mardie station between Onslow and Dampier.

FIRE WEATHER FORECASTING

The Bureau issues Fire Weather warnings as part of its public weather forecast and warning service. In support of this service the Bureau has developed fire detection algorithms for use with AVHRR data. The data received from WASTAC provides coverage for Western and South Australia. See Figure 8 for a hotspot image of fires near Perth in early 2003.

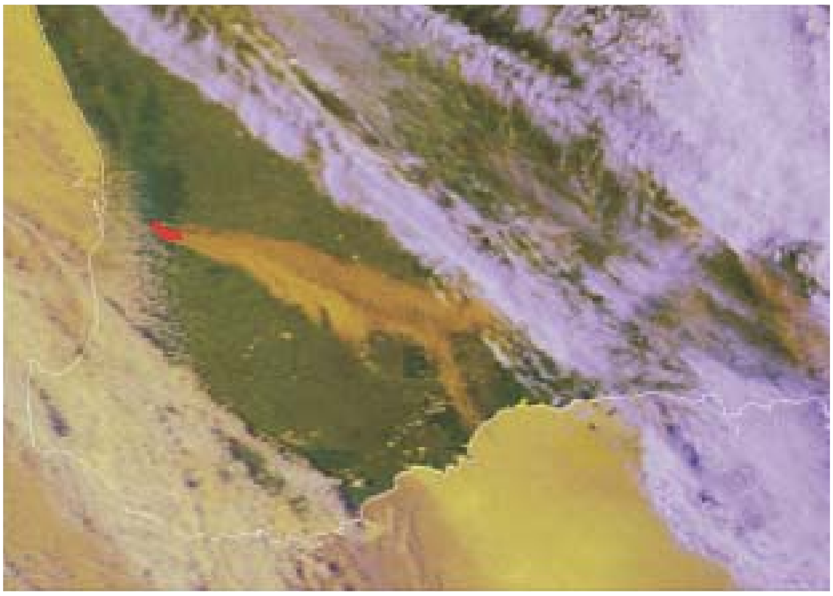


Figure 8. A NOAA-12 image of fire hotspots (coloured red) near Perth on 11 January 2003.

MODIS DATA

The Bureau is using the IMAPP (International MODIS and AIRS Processing Package) software from University of Wisconsin for experimental processing of MODIS high resolution imagery from Hobart, and is working toward establishment of operational systems which would use the WASTAC X-band antenna MODIS data in real time for several operational products in support of forecasting, including fog/low cloud detection.

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OPERATIONAL APPLICATIONS (continued)

DEPARTMENT OF LAND INFORMATION (SATELLITE REMOTE SENSING SERVICES)

Fire Fax and Email Service

Mike Steber

During 2002 DLI operated a fax service delivering fire maps to pastoralists and government agencies (Figure 1). Due to the fact that many pastoralists now have access to a broadband service DLI decided to offer an email service as well as the fax service. This year 40 pastoral stations and government agencies signed up for these services, including several pastoral stations from the Northern Territory; 11 of these used the fax service and 29 the email service. By the end of December 2003, over 1100 fax and email maps had been transmitted.

Feedback received by SRSS showed that many pastoralists found that the service was very important because it helped improve their management of fires and saved time. They were also interested in getting NDVI images. In 2004 DLI may trial a new service offering fortnightly NDVI images in several different formats.

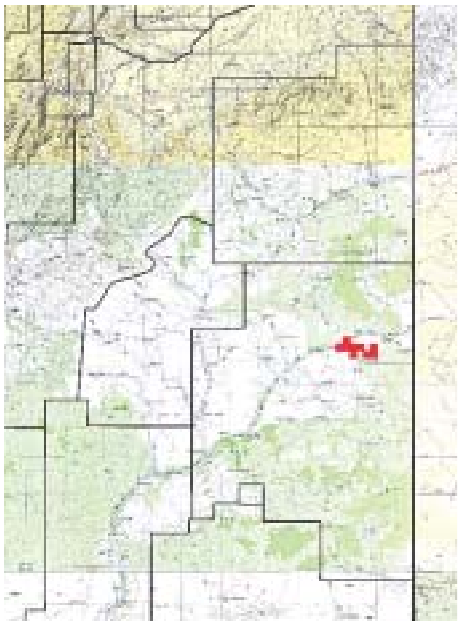


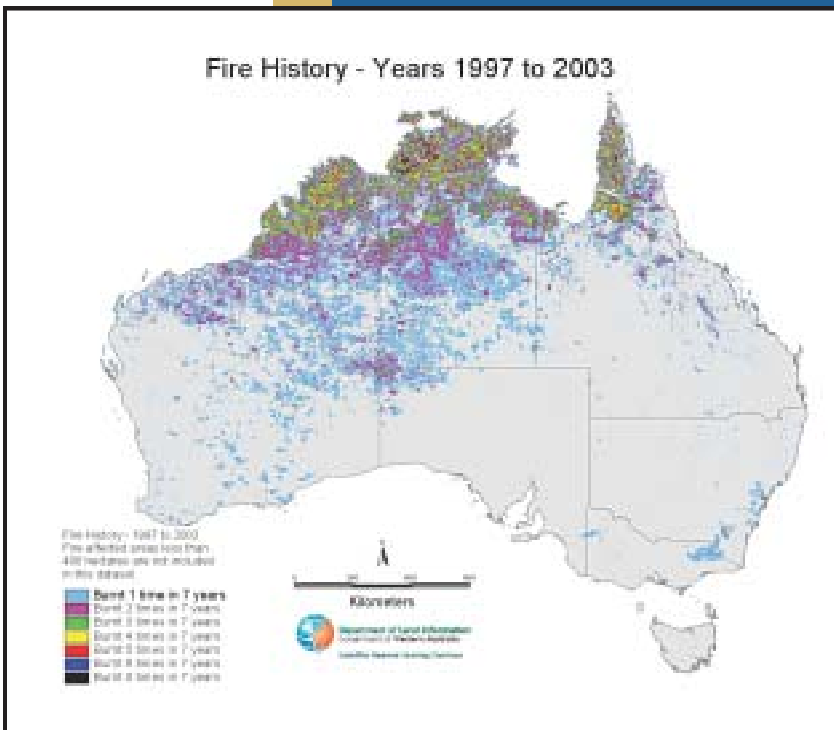
Figure 1: Fire email product for 24/11/03 showing fires on Nicholson station in the Kimberley region of Western Australia.

Fire Scar Mapping

Belinda Heath

Satellite Remote Sensing Services have mapped fire scars from NOAA-AVHRR since 1993. The first continental mapping project commenced in 1998; the data were collected for Environment Australia and appeared in the State of the Environment Report 2002. The ground resolution of NOAA-AVHRR is 1km^2, thus fire scars less than 400 hectares are not included in this dataset. The fire scars are manually digitised every nine days when the satellite is at nadir, which limits the atmospheric and geolocation errors. The fire scar vectors are imported into a GIS where they are analysed with various spatial datasets and area burnt is calculated.

The map (Figure 2) shows the number of times an area has burnt in six years. There is a high frequency of burn in the tropical savannas, some regions burn every year. There is also a high level of prescribed burning in the Northern Territory and Kimberley region of Western Australia in the early dry season, which promotes pasture growth and manages the risk of late season wildfire. The frequency of burn in southern regions of Australia is low when compared to the north. Many of the fire scars in the south are less than 400 hectares and are therefore not included in the dataset. Fuel load builds very slowly in the south thus return burns are limited. The tropical savannas in comparison have rapid fuel build up due to the monsoonal rains assisting vegetation growth, and so return burn time is swift.



Fiqure 2: Fire scar history Map of Australia for the period 1997-2002

Fire Scar and Fire Hotspot Mapping from Modis – Yampi Military Training Area

Miquel Tovar

As part of a joint project with CALM and FESA, SRSS provided daily digital fire hotspot maps of the Yampi Military training area derived from the MODIS satellite. On two different dates, morning and afternoon image maps were produced indicating active fire fronts and smoke plumes in relation to previous fire affected areas (SRSS have a extensive archive of all areas burnt across Australia since 1994 at 1 km resolution). On the 21st October five fronts were spotted across a distance of almost 60 km (Figures 3 and 4).

The maps were valuable in the identification of active hot spots to plan fire control actions (back burning and fire break lines) and infrastructure protection. The total area burnt in about 15 days was larger than 400 000 hectares. The Yampi Military Training Area has little grazing of native vegetation. This (together with recent culling of feral donkeys) would have contributed to higher fuel loads and the big impact of the fire event .

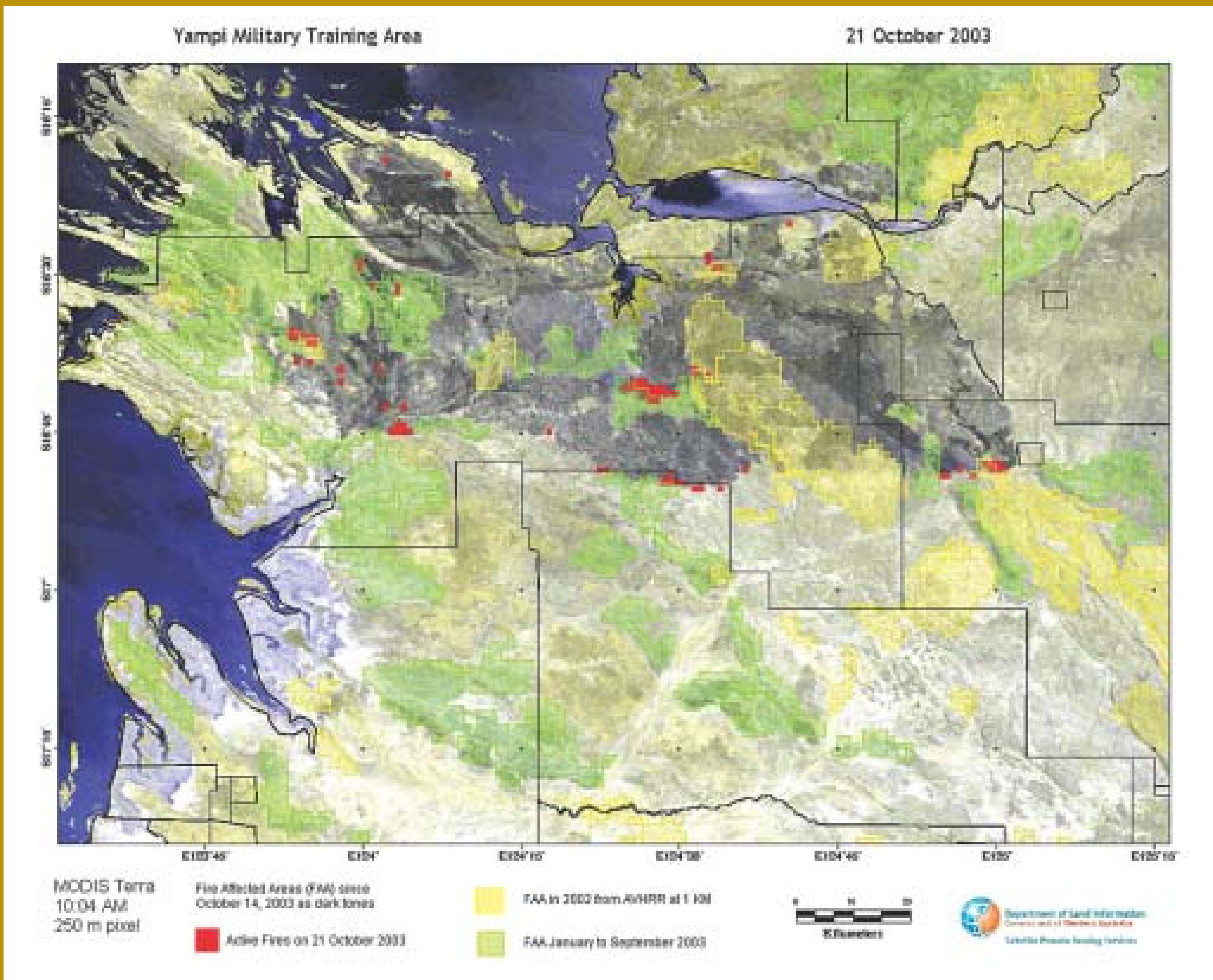


Figure 3: MODIS image of 21 October 2003, 10:04am over the Yampi Military Training Area. Fire affected areas show as the dark tones. Smoke plumes are clearly visible in light blue.

OPERATIONAL APPLICATIONS (continued)

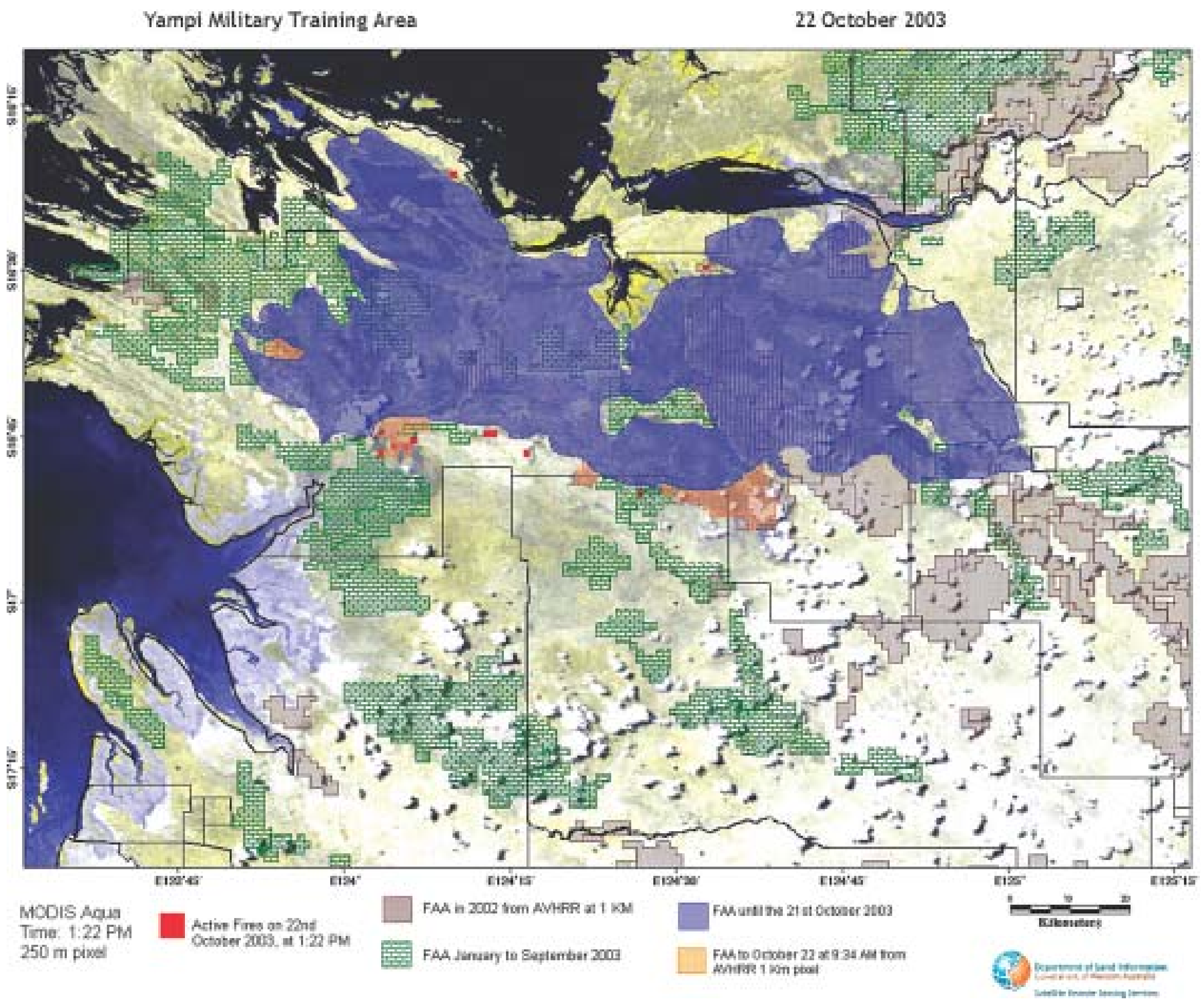


Figure 4: MODIS image of 22 October 2003, 1:22pm over the Yampi Military Training Area. Fire affected areas (FAA) are depicted from the AVHRR sensor in 2002 and the MODIS sensor in 2003 to the present incident.

Sea Surface Temperature (SST)

Mike Steber

SRSS and CSIRO Marine Research continued their collaborative project producing Sea Surface Temperature (SST) images from WASTAC's NOAA-AVHRR satellite data for the fishing industry, state and federal agencies. Customised SST images and standard SST images are purchased through "Fishing Hotspots" on DLI's Land Online website (www.landonline.com.au/hotspots -- Figure 5).

A new web site is currently being developed by a Canberra based company called Earthinsite which will feature SST imagery for the entire continent. This imagery will be sourced from SRSS in near real time. As part of this development SRSS is implementing cloud detection routines to improve the quality of the data.

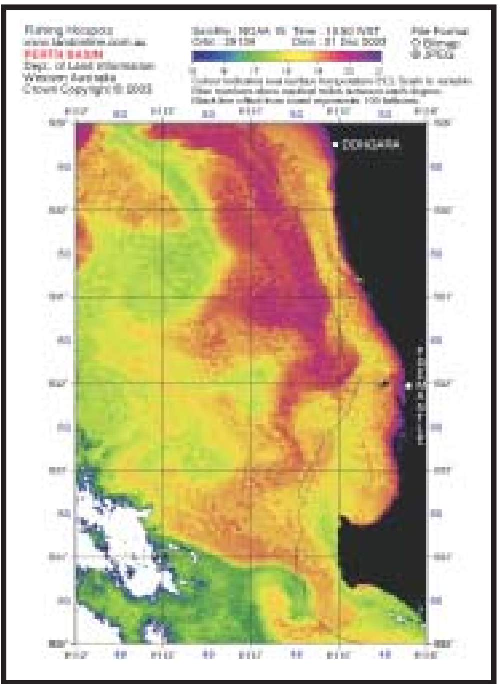


Figure 5: Fishing Hotspots product from NOAA 15 29134 dated 21/12/03 18:50 WST showing the southward-moving Leeuwin Current.

Pasture Growth Rate Mapping

Richard Stovold, Arjen Tjalma, Sarfraz Khokhar, Adrian Allen, Graham Donald[1]
[1]CSIRO Livestock Industries.

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

The PGR project provides farmers and decision makers with timely estimates of regional pasture growth rates for the south western corner of Western Australia. The Satellite Remote Sensing Services (SRSS) group's role is to provide specialist services including data acquisition, image processing and web delivery. SRSS are accessing NOAA/AVHRR data at 1 km resolution and for season 2003, MODIS 250 m resolution data, from the WASTAC archive in Perth and Alice Springs and processing the data into fortnightly NDVI composites to show the greenness of pastures. The NDVI composites are then combined with weekly climatic data supplied by the Bureau of Meteorology to give weekly estimates of PGR within Local Government Areas (LGA) as depicted in Figure 6. A new seven day predicted PGR product has been developed for season 2003.

Improvements to the model development and testing are being undertaken by CSIRO Livestock Industries in conjunction with Agriculture Western Australia which is supplying field validating information. A new PC-based interpretation tool has been developed by Fairport Technologies to chart weekly PGR for each pasture and compare it with forecasted PGR for the following week. The data are being regularly emailed to the client's PC every week for season 2004.

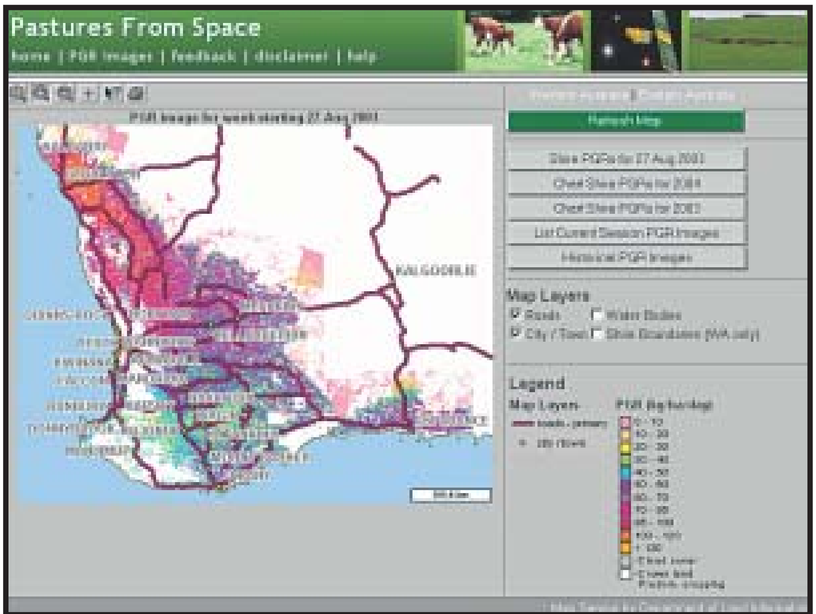


Figure 6: Map of south west Western Australia showing Pasture Growth Rate (PGR) on 27th August 2003 in kg/ha/day.

OPERATIONAL APPLICATIONS (continued)

The PGR information for season 2004 is now posted to a new public viewable website (www.pasturesfromspace.csiro.au) every week throughout the pasture growing season. PRG maps at low resolution and a weekly mean PGR value per LGA are posted to the website for the farmer to view. For more detailed higher resolution information at paddock scale, farmers can subscribe via Fairports FarmWatch website. Using the PGR tool, the land manager is able to better manage fertiliser use and to target grazing to improve fine wool production and achieve more efficient feed conservation.

The PGR information also has important applications for agribusiness, regional shires, banking and finance sectors. Potential uses include rural strategic planning, insurance, land valuation and assessment and futures forecasting. The Pastures From Space programme is currently being extended and verified across high winter rainfall areas of south eastern Australia as shown in Figure 7

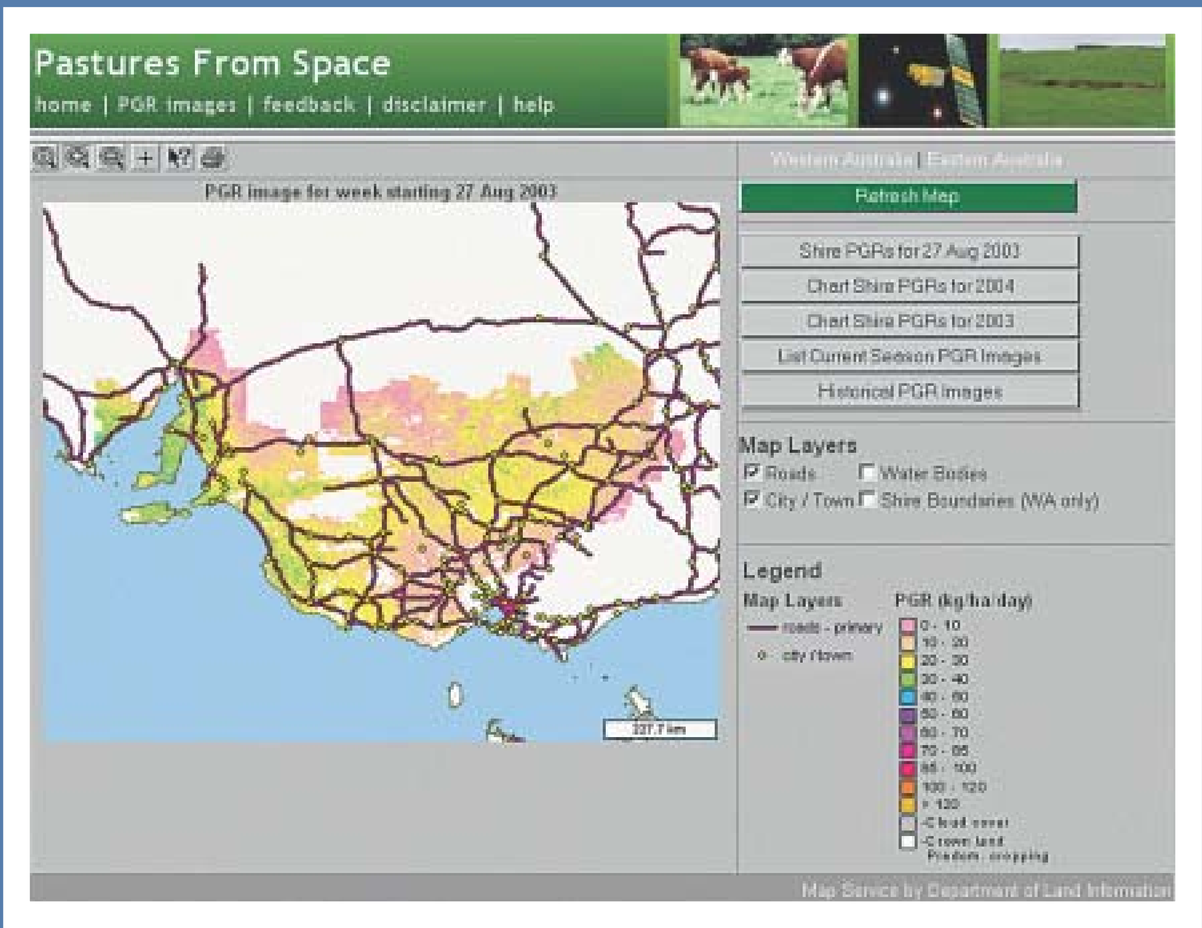


Figure 7: Map of south eastern Australia showing Pasture Growth Rate (PGR) on 27th August 2003 in kg/ha/day.

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

RESEARCH DEVELOPMENTS

The operational applications described in the previous section are underpinned by ongoing research developments, and this section reviews highlights of the research activities being undertaken by the WASTAC partners.

CSIRO MARINE RESEARCH

Sea Surface Temperatures in Shark Bay and Growth of Snapper

Alan Pearce and Nadia Tapp[1]
[1]Western Australian Fisheries Department, Perth, WA

As part of a Fisheries Department/Edith Cowan University study on the growth of juvenile snapper in Shark Bay, satellite sea-surface temperatures (SSTs) were derived for two regions in the western gulf of the Bay. NOAA-AVHRR data were obtained from WASTAC for a cloudfree image in each month between June 2000 and May 2001 (a period when trawl surveys had been undertaken). Sea surface temperatures were then extracted for a 14*10 pixel area in Denham Sound (central latitude 25°44'S) and a 11*13 pixel region in Freycinet Estuary (26°22'S) from the 12 datasets.

The seasonal cycles showed distinct differences between the annual amplitude and phase in the two regions (Figure 1). In the northern region (Denham Sound), the temperature varied from a low of 19.9° in July up to 25.7°C in March (a range of 5.8°C); in the shallower southern region (Freycinet Estuary), the corresponding range was 17.4°C (July) to 26.1°C (February), or 8.7°C. These differences probably reflect both air-sea heat exchange and advective/mixing processes; the water in the northern region was deeper and would have experienced better exchange with the open ocean than the southern region. Spatial variability (note the standard deviation bars in Figure 1) was also greater in the northern region than in the south.

It was postulated that these temperature differences are probably responsible for differing growth rates in the northern and southern populations of juvenile snapper (in their first year of life) in the western gulf of Shark Bay.

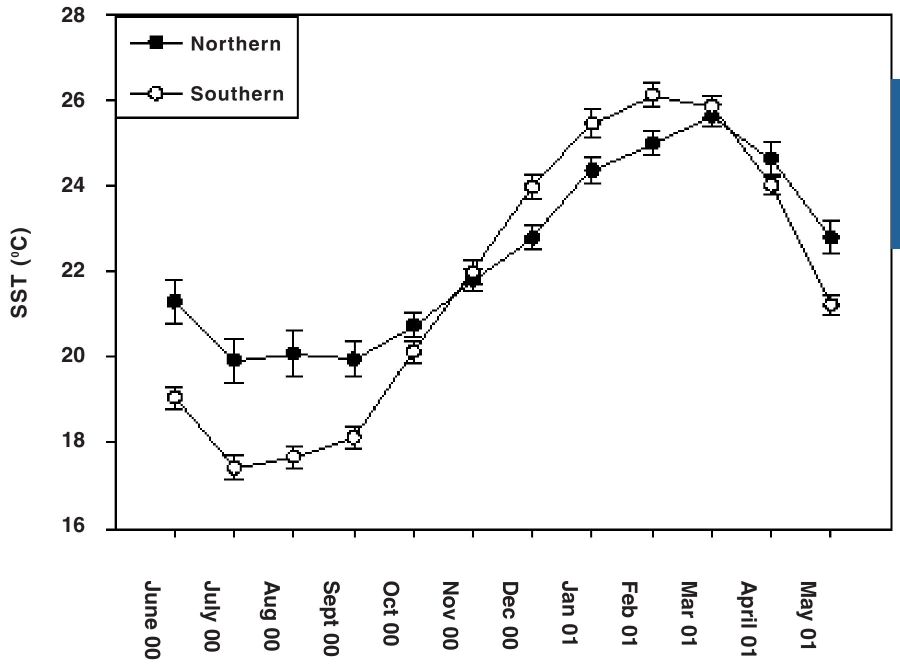


Figure 1: Monthly sea-surface temperatures (with spatial standard deviation bars) in Denham Sound in the north (filled circles) and Freycinet Estuary in the south (open circles) in 2000/2001.

RESEARCH DEVELOPMENTS (continued)

Time-series Sea Surface Temperatures off Two Rocks

Alan Pearce

Monthly oceanographic transects are being undertaken across and beyond the continental shelf off Two Rocks (some 50km north of Fremantle) as part of a biophysical study under the CSIRO Strategic Research Fund for the Marine Environment (SRFME). Physical, nutrient and biological sampling are being carried out at five sites across the shelf at stations A (20m water depth), B (40m), C (100m), D (200m) and E (in 1000m water).

To provide some continuity between the monthly transect surveys, digital NOAA-16 SST transects were extracted from AVHRR data on a daily basis (cloud permitting) for these five sites during 2002, using the Non-Linear SST algorithm. Monthly averages were then derived (Figure 2). Despite the month-to-month variability resulting from just a single year's data, there were clear differences in the temperature structure across the transect. The annual temperature extremes (and months) at three of the stations were:

Station	Minimum (Month)	Maximum (Month)	Range
A	17.7 (Sept.)	22.7 (Feb.)	5.0
C	19.0 (Sept./Oct.)	22.5 (Mar.)	3.5
E	18.6 (Nov.)	22.4 (Mar.)	3.8

The seasonal SST range near the coast was appreciably greater than that further offshore, and tended to lead the offshore peaks by a month. As in the case of the Shark Bay temperatures described above, these temperature extremes were the result of both air-sea heat flux (heating and cooling the shallow inshore waters more rapidly than the deeper shelf and offshore waters) and advection of water by currents (the warm southwards Leeuwin Current along the shelf-break in the autumn/winter months, and the cooler northwards inshore Capes Current in summer). Figure 3 shows the Leeuwin Current and its associated meanders and warm eddies during the September 2003 survey.

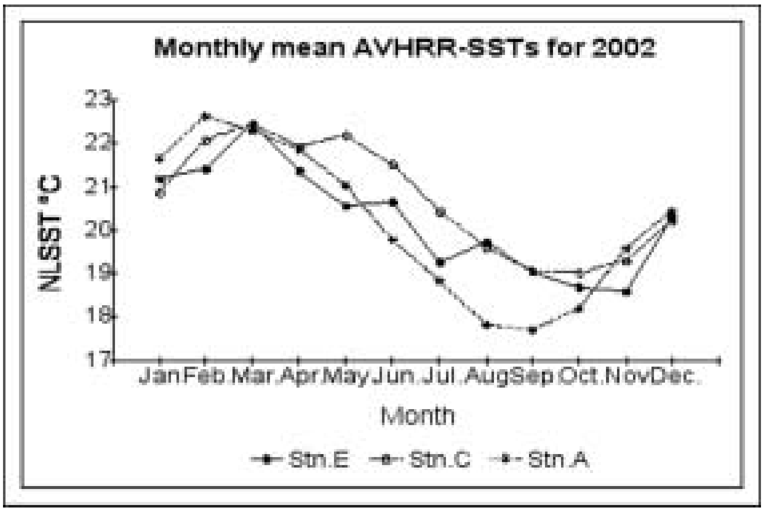
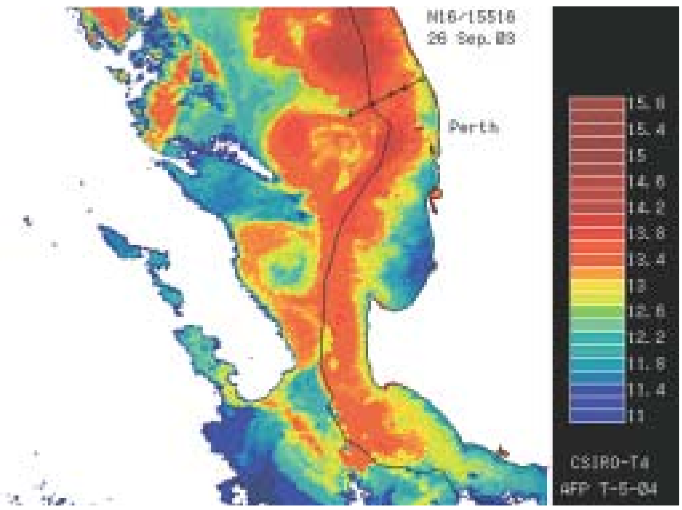


Figure 2: Monthly mean satellite-derived SSTs at the three SRFME Transect stations A (inshore, asterisks), C (outer shelf, open circles) and E (offshore deep water, filled circles) for 2002.

Figure 3: AVHRR satellite image of the Leeuwin Current (red/yellow) off the southern West Australian coast on 26th September 2003, matching the SRFME Two Rocks Transect survey on that date. The image shows the brightness temperature in AVHRR Band 4 which has not been atmospherically corrected. The 5 "x"s mark the Transect oceanographic stations, and the curved black line is the approximate edge of the continental shelf.



Remote Sensing Data Processing

Peter Fearns

The remote sensing tasks within the CSIRO SRFME project have developed to a stage where remotely sensed data may be routinely accessed from the WASTAC archive and ingested into semi-automated processing streams. These processing streams are able to deliver remotely sensed geophysical products to a number of the core SRFME research groups.

The Ocean Colour research group is undertaking routine water sampling of coastal waters with the aim of validating SeaWiFS and MODIS ocean colour products, and the Biophysical research group carries out similar work across the continental shelf into deeper oceanic waters on a monthly basis. Data collected during these trips are also used to validate the satellite ocean colour products and the sea surface temperatures from both AVHRR and MODIS.

The various field programmes not only collect data in the near-surface waters but instruments are also lowered into the water to provide profile measurements of numerous parameters throughout the water column. These profiles enable us to build up a picture of the structure of the ocean, and thus link remotely sensed estimates of near-surface characteristics to structures and processes within the water column. Figure 4 shows a cross section of chlorophyll fluorescence measurements made along a transect off Two Rocks, clearly depicting the "deep chlorophyll maximum" layer just below the step in the bathymetry.

Activities are also underway to process high spatial resolution hyperspectral satellite data with the aim of developing new remotely sensed products for shallow coastal waters.

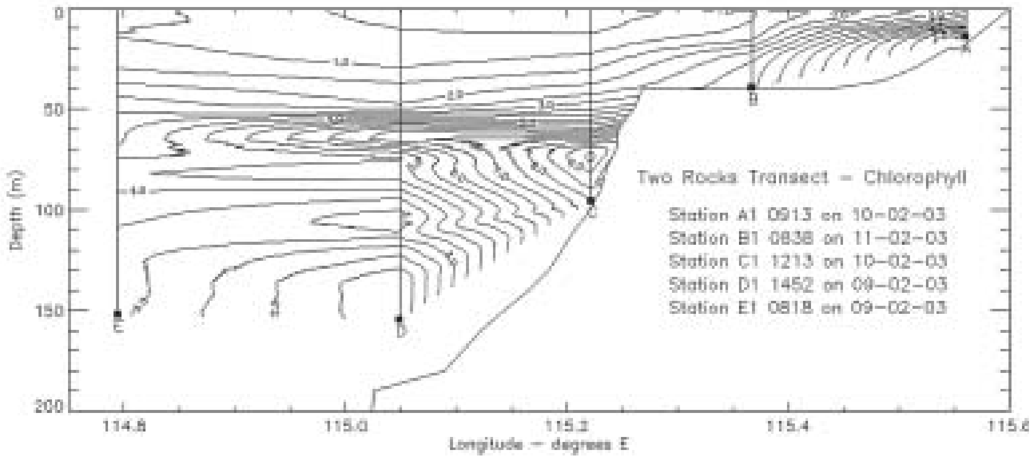


Figure 4: Vertical section of chlorophyll concentration along the SRFME Two Rocks Transect in February 2003.

References

Tapp, N. (2003). Do size differences of juvenile snapper (Pagrus auratus) in two regions of Shark Bay, Western Australia, reflect different environmental conditions? M.Sc. thesis, School of Natural Sciences, Edith Cowan University, October 2003.

RESEARCH DEVELOPMENTS (continued)

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

MODIS Ocean Colour Product Validation

Wojciech Klonowski, Leon Majewski, Peter Fearns[1], Tim Harriden[1] and Lesley Clementson[2]
[1] CSIRO Marine Research, Floreat, WA
[2] CSIRO Marine Research, Hobart, TAS

To fully utilise the capabilities of MODIS, validation of intermediate and value added products must be undertaken. Currently, validation is being carried out by Curtin University and CSIRO Marine Research through the SRFME joint venture. Coastal waters near Two Rocks (31.50°S;115.57°E; Figure 1) have been sampled monthly since February 2002 with measurements of physical, biological and bio-optical properties between the sea surface and seabed. The sampling is generally limited to the continental shelf, but four times a year a more extensive survey encompassing deeper waters out to 31.86°S;114.78°E is conducted.

Temperature, salinity and fluorescence have been sampled underway from surface waters along the transect as well as through the water column at selected sites for all SRFME field experiments. Water samples are collected for analysis and provide results on pigment composition and concentration, total suspended material and absorption coefficients for dissolved and particulate material. On a select number of voyages, optical measurements have been collected using a Zeiss-based hyperspectral radiometer (developed and calibrated at Curtin University) as well as a Biospherical PRR-600 and/or HOBILabs HydroRad-2.

The monthly SRFME field trips to Two Rocks have created a platform for product validation in a coastal, Case 2, regime while the excursions into deeper waters in the same region have provided opportunities to undertake optical measurements and perform product validation in Case 1 waters.

The MODIS-Aqua water-leaving radiance products (L_{WN}) from the near coincident overpass have been overlaid (blue bars) on the plots of HydroRad-2 derived L_{WN} (Figure 2). The MODIS and HydroRad-2 results at the deep site (stations C2 and E) are very promising, suggesting that the atmospheric correction routine is performing well in deep, Case 1, waters. The shallow sites (stations A and B), however, display a significant difference between the MODIS and HydroRad-2 results, most likely due to the influence of the bottom signal. Quantifying the influence of the benthic cover is the subject of another study underway at Curtin (see Coastal Water Algorithm Development and Validation). The addition of HPLC results to the optical validation results will allow validation and further refinement of the bio-optical algorithms employed in the ocean processing software.

Acknowledgements
This work is supported by the Strategic Research Fund for the Marine Environment (SRFME).

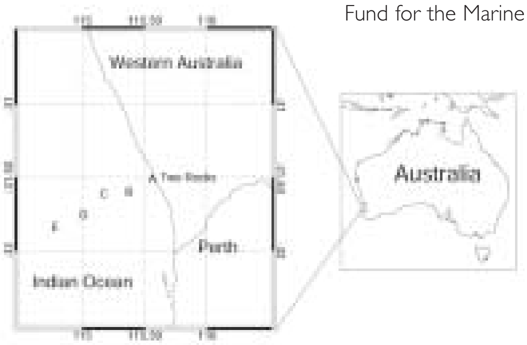


Figure 1: The deep water transect A to E extends from near Two Rocks (31.54°S, 115.56°E) to deep ocean waters (31.86°S, 114.78°E). The coastal transect extends only as far as station C.

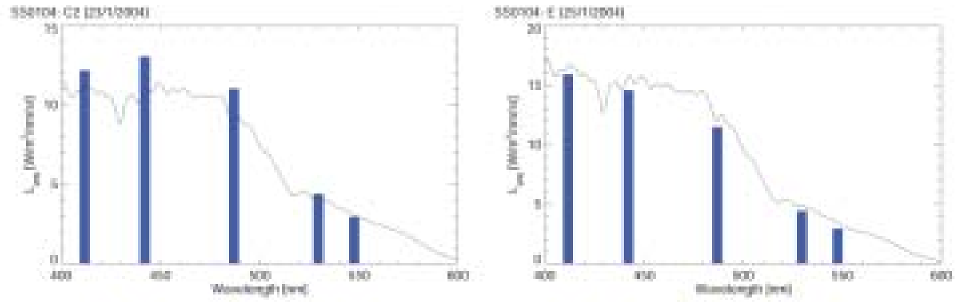


Figure 2: Comparison of in-water (HydroRad) and MODIS-Aqua water-leaving radiance for stations C and E.

Coastal Water Algorithm Development and Validation

Wojciech Klonowski, Mervyn Lynch, Brendan McGann, Peter Fearns[1], Lesley Clementson[2], Arnold Dekker[3]
[1]CSIRO Marine Research, Floreat, WA
[2]CSIRO Marine Research, Hobart, TAS
[3]CSIRO Land and Water, Canberra, ACT

Most human/ocean interactions occur at the ocean's edge, and monitoring of this coastal zone is of major interest for fisheries, habitat and marine park management.
With recent advances in satellite technologies, specifically reduction in footprint size and increased spectral resolution, remote sensing techniques can be applied to coastal management programs.

The task of monitoring such a vast region is best handled through remote sensing and a coordinated validation program. However, this task is made more difficult due to the nature of coastal waters which tend to have complex optical materials present in the water column (Case 2 waters). The shallowness of the observed area means that there may also be some contribution from the benthic cover to the retrieved signal, that is, a bottom signal.

The influence of this bottom signal on remotely sensed data products must be quantified.

An above-water hand-held hyperspectral radiometer has been developed and calibrated at Curtin University. The instrument has been deployed on a number of SRFME validation cruises. The resulting measurements are input to an optimisation model that retrieves the optical properties of the water column as well as the water depth (Figure 3) and bottom cover type. So far, the model has been tested for water depth retrieval and chl-a concentration, and there is ongoing research into CDOM, suspended sediments and bottom classification.

Acknowledgements
This work is supported by the Strategic Research Fund for the Marine Environment (SRFME).

Determination of Marine Bioregions Using MODIS

Leon Majewski and Mervyn Lynch

MODIS data products have many environmental applications, one of which may be the determination of bioregions. Bioregions may be regarded as a system of related, inter-connected ecosystems. More specifically, they are assemblages of flora, fauna and the supporting geophysical environment contained within distinct but dynamic spatial boundaries.

The "distinct but dynamical" nature of bioregions means they are hard to quantify using standard ground-based procedures. This is especially the case for ocean bioregions. This work considers the use of MODIS data products for the characterisation of marine bioregions.

MODIS ocean products (including sea surface temperature and chlorophyll-a concentration) are used in the classification procedure. For instance, the SST product provides information regarding the geophysical and climatic processes while the chl-a product yields information on organism distribution. As a first approximation, a bioregion will have similar characteristics. By this definition, similarity in the mean, variance and phase of any inherent cycles present within a MODIS product in a spatially contiguous region would indicate the presence of a bioregion (Figure 4).

The determination of bioregions can aid in the management of WA marine resources, both coastal and pelagic, through accurate classification of the bioregions, depiction of what is the 'normal' cycle of particular products and what is an anomaly. They may also be used for marine park identification and monitoring.

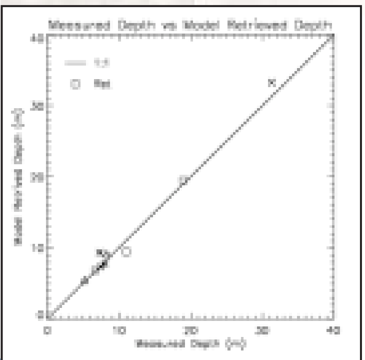


Figure 3: Comparison of the measured and model retrieved depth.

RESEARCH DEVELOPMENTS (continued)

Development of a MODIS Primary Production Product

Leon Majewski, Mervyn Lynch, Brendan McGann, Peter Fearns1, Lesley Clementson[2], Arnold Dekker[3]
[1] CSIRO Marine Research, Floreat, WA
[2] CSIRO Marine Research, Hobart, TAS
[3] CSIRO Land and Water, Canberra, ACT

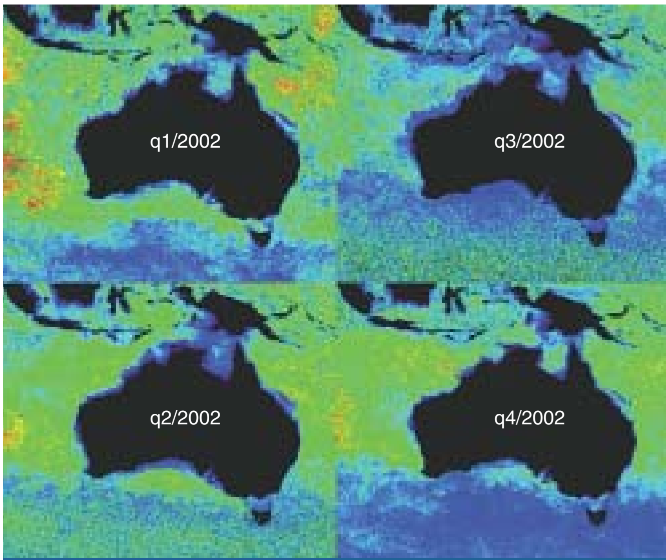


Figure 4: The determination of bioregions from the MODIS chlorophyll product may be achieved through the ratio of the mean to standard deviation of the product.

Phytoplankton primary production is basically a measure of how much photosynthesis is occurring within the marine ecosystem. This work aims to develop a remotely sensed primary production product using MODIS data. To accomplish this, we need to express primary production as a function of the bio-optical properties of phytoplankton and the physical properties in the surrounding environment that can be measured by remote means. The task is somewhat complicated in shallow Case 2 waters by the presence of various benthic covers (e.g. reefs and sea grasses) and other optically active constituents.

Previously chlorophyll-a concentration alone was used as an indicator of primary production, but this proved too simplistic to describe the variability present in field measurements. The most recent algorithms also include other factors such as the amount and spectral nature of light incident on the sea surface and how this light is attenuated through the water column. Physical factors such as the water temperature are used as an indicator of the photosynthetic rate.

A number of global primary production algorithms have been implemented, but some preliminary investigations have indicated that a local algorithm is required. This project aims to provide a validated, local, primary production algorithm.

Acknowledgements
This work is supported by the Strategic Research Fund for the Marine Environment (SRFME).

An Ocean Colour Remote Sensing Study of the Phytoplankton Cycle off the West Australian Coast

Marco Marinelli, Mervyn J Lynch and Alan Pearce[1]
[1] CSIRO Marine Research, Floreat, WA

The lack of upwelling-favourable conditions in the southeastern Indian Ocean results in the majority of the southeastern Indian Ocean surface waters being nutrient-poor, which is reflected in the generally low productivity of this region. Several areas either on or close to the Western Australian coastline and south of the adjacent Indonesian islands are notably more productive. Measurements of chlorophyll-a concentration, the major photosynthetic pigment contained in phytoplankton, may be directly related to oceanic bioproductivity. Using data collected by the Coastal Zone Color Scanner (CZCS) between 1979-86, this project aimed to understand the spatial and temporal changes that occurred in chlorophyll-a abundance in the southeastern Indian Ocean.

The highest seasonal mean concentrations occur in Summer (January-March) and Autumn (April-June), the former occurring in waters of the North West Shelf and the latter in coastal areas of Western Australia south of North West Cape. Concentrations observed in the offshore oceanic regions are mostly low, with the exception of the adjacent Indonesian islands and an area directly south of Albany (possibly due to northwards flow of subantarctic nutrient-rich waters). A considerable interannual variation was also noted, with the highest mean chlorophyll concentrations occurring in 1981, 1982 and 1983.

The influence of the forcing terms on chlorophyll-a appears to vary significantly between the waters of the North West Shelf and the Western and southwestern Australian coastline. This is most notable in the interseasonal variations. The changes observed interannually and their influence on chlorophyll-a are not easily discernible, but there may be some connection with the La Nina/El Nino related variations in both currents and winds.

The initial CZCS work is now being extended using data from SeaWiFS and MODIS to evaluate the relationship over an extended interval and to test the consistency of the contribution of the various forcing terms to explaining the temporal variance in the biological response of the ocean off the Western Australian coast.

Early Detection of Conditions Suitable for Tropical Cyclone Development

Gregory S. Hamilton and Mervyn J Lynch

The social and economic effect of tropical cyclones on the north of Western Australia is significant. Many of the systems that eventually impact on the region develop over regions of the Timor Sea that can only be adequately monitored using satellite remote sensing techniques. Early detection and accurate forecasting enable planners to take appropriate action to mitigate the effects of these systems.

The antecedent conditions required for tropical cyclone development are well known. A variety of remote sensing platforms were used to monitor potential cyclogenesis conditions in remote parts of the Timor Sea. These satellite products included sea surface temperature, sea surface winds and total precipitable water derived from several operational satellites including AVHRR, GMS and DMSP. Applying data from these satellites to three case studies demonstrated a clear ability to recognise early signs of a cyclone developing. This work was further extended by the development of an index (the 'Hamilton Index' for want of a name) which was applied to the case studies to provide an indication of an area having enhanced cyclogenetic potential.

Atmospheric Correction of Satellite Observations of Ocean Colour with the Navy Aerosol Model

Jim Davies, Mervyn Lynch and Ian Barton[1]
[1] CSIRO Marine Research, Hobart, TAS

An over-ocean atmospheric correction scheme was developed and validated. The atmospheric correction scheme employed the Navy aerosol model for the aerosol component. A fundamental difficulty was exposed in atmospheric correction schemes that rely on the extrapolation of aerosol optical properties that are retrieved in the near infrared region and then applied to the visible portion of the spectrum.

Modelling Ocean Colour

Peter Fearns[1], Mervyn Lynch and John Parslow[2]
[1] CSIRO Marine Research, Floreat, WA
[2] CSIRO Marine Research, Hobart, TAS

Algorithms relating satellite-measured reflectance or water-leaving radiance to in-water constituent concentrations have been developed by empirical means. Understanding the underlying relationships between constituent optical properties and water-leaving radiance has led to improvements in the form of concentration retrieval algorithms developed by empirical means. Still, there is as yet no algorithm in operational use derived from an analytical development. Current knowledge has progressed to the point where analytical expressions can predict reasonable water-leaving radiance values, but discrepancies between modelled and measured signals are yet to be satisfactorily explained.

The research project undertakes an investigation of the relationship between the reflectance and the two quantities water absorption and backscattering properties. These are related by a quantity f which is a function of optical and geometrical parameters, and the project includes a modeling study of f.

A further element of the study concerns the Q factor which describes how the ratio of the in-water upwelling irradiance to the water-leaving radiance varies with the direction of observation of the latter. A Monte Carlo model explored these relationships and related Q to chlorophyll concentration and solar zenith angle.

An Investigation of Cloud Properties using NOAA TOVS and MODIS Sensors

Helen Chedzey[1], Mervyn Lynch, Paul Menzel[1], and Brendan McGann
[1] Satellite Applications Branch, NOAA NESDIS, University of Wisconsin, Madison

The study of cloud properties has recently been enhanced with the additional spectral information available on the MODIS sensor. Nevertheless, the less sophisticated earlier generation satellites provide longer-term observations of cloud properties which may provide valuable insights into trends in cloud radiometric properties, cloud amount and cloud heights. The objective of this study therefore is twofold:

1) to analyse archival satellite data sets (eg from the NOAA TOVS instrument) over several decades to search for climate change signatures.
2) to use sensors such as MODIS to track changes in cloud properties as the clouds advect across the oceans, across latitude and as they cross land-sea interfaces where the changes in surface forcing may make discernable adjustments in some of the cloud properties that we observe from these new sensors.

Time permitting, the information gained will be applied to a study of the NW Australian cloud bands.

RESEARCH DEVELOPMENTS (continued)

Remote Sensing of Great Barrier Reef Waters

Matthew Slivkoff, Mervyn Lynch, Miles Furnas[1] and Brendan McGann
[1] Australian Institute of Marine Sciences, Townsville, QLD.

The application of satellite data to the monitoring and management of shallow water systems such as barrier reefs is still evolving as a science. We need to learn more about how to use satellite products effectively and to identify indicators of change and the associated sensitivities. Implicit in this research is the need to validate the satellite products with in situ bio-optical observations taken while observing appropriate protocols. In this work a portable dual channel hyperspectral spectrometer is being constructed and will be deployed to assist in the development of shallow water algorithms. These algorithms will need to include retrieval of the substrate reflectance, the water depth and the concentration of pigments and other coloured constituents.

Chlorophyll Production in Indonesian Waters.

Umi Zakiyah[1], Mervyn Lynch and Brendan McGann
[1] University of Brawijaya, Indonesia

Following the acquisition of data from several cruise programs in Indonesian waters, an analysis of the spatial and temporal variability primarily of chlorophyll is now being undertaken. The work is progressing by establishing the regional variability in seasonal forcing (river runoff, Monsoonal winds, wind driven upwelling etc) and then relating these to chlorophyll observations from the SeaWiFS sensor.
Supported by AusAID

Characterisation of Ocean Waters using SeaWiFS Data

Brendon McAtee and Mervyn Lynch

The aim of this project was to develop and validate algorithms designed to estimate subsurface reflectance. Following the development of appropriate algorithms, the predictions were provided for a number of selected sites in the Australian EEZ to investigate variability among the sites and also the variability over the annual cycle at a specific site. Validation cruise work was initiated with participation from Curtin University, CSIRO and DSTO.

The Estimation of Aerosol Optical Depths over the Ocean

Jackie Marsden[1], Mervyn Lynch and Ross Mitchell[2]
[1] Department of Land Information, Perth, WA
[2] CSIRO Atmospheric Research, Canberra, ACT

The thrust of this work was to attempt an analytical solution of the radiative transfer equation for the aerosol optical depth inclusive of first and second order Rayleigh (R) and Mie (M) scattering processes. As well as the processes R-R and M-M, the coupled events R-M and M-R were included. The appropriate algorithms were implemented and data sets from NOAA AVHRR processed to yield optical depth fields. The validation of these satellite products included solar photometer data sets for the Cape Grim Baseline Station in Tasmania.

The Determination of Aerosol Optical Thickness and Land Surface BRDF

Frank Yu, Mervyn Lynch and Brendan McGann

One of the key requirements for agencies remotely sensing the land surface environment is an accurate so-called atmospheric correction scheme and an algorithm that determines the bidirectional reflectance of the surface. This work has progressed in two stages. Firstly, to use geostationary data sets (multiple observations per day) to produce an overdetermined system of equations that may then be inverted to simultaneously recover aerosol optical thickness and the BRDF. In this work it was necessary to stabilise the inversion procedure using regularisation methods. Secondly, the goal was to apply a similar scheme to the foregoing to polar orbiting satellite data such as is available from MODIS and SeaWiFS. This latter stage of the work is more problematic because there are less observations to work with and certainly they are not available at hourly intervals throughout the day as was the case with the geostationary sensors.

DEPARTMENT OF LAND INFORMATION
(SATELLITE REMOTE SENSING SERVICES)

From Raw Data to Standardised Surface Reflectances

Stefan Maier

Before algorithms can be applied to suit a certain application, raw satellite data (Figure 1) have to undergo various pre-processing steps.

The first step is the radiometric and geometric calibration, which removes the sensor-specific artifacts by taking into account sensor sensitivity and scanning geometry (Figure 2).

Until recently the standard processing stopped at this stage, but with the new generation of sensors like MODIS it is possible to proceed further. The light that reaches the satellite sensor from the land surface is influenced by the atmosphere that lies in between. If this influence was always the same, it would not be a problem. However, as there are changes with observation geometry (i.e. illumination and viewing direction) and the state of the atmosphere (e.g. water vapour content, ozone content, type and amount of aerosols), it has to be corrected. The MODIS sensor has spectral bands specifically designed to derive information about the atmosphere. Utilising this information it is possible to automatically correct the atmospheric effect on the bands used for land surface applications (Figure 3).

Figure 1: Raw MODIS data from two consecutive Aqua orbits on the 22/11/2003 covering Western Australia (upper. 14:20 WST; lower. 12:43 WST), showing Bands 1/4/3 as RGB. The images are geometrically distorted and show striping.

Figure 2: The MODIS data of Figure 1 after radiometric and geometric calibration. The image is bluish and has low contrast due to the scattering and absorption of light by the atmosphere.

RESEARCH DEVELOPMENTS (continued)

After the atmospheric correction, the boundary between the two orbits is still visible because of the different observation geometries. In the western orbit, the ground is observed in the backscatter direction (i.e. the sun is behind the sensor) and the sensor thus mainly observes sunlit areas on the ground. In the eastern orbit, by contrast, the sensor observes the ground in the forward-scatter direction (i.e. the sun is opposite the sensor) and thus observes mainly shadow areas. This effect is corrected by standardising the reflectances to a nadir viewing (vertically downward) geometry (Figure 4).

Figure 3: MODIS data after atmospheric correction (applied to land pixels only). The join between the two orbits is clearly visible in the lower right of the image.

MODIS Direct Broadcast Surface Reflectance Development

Brendon McAtee

In November 2003, WASTAC initiated the task of implementing a scheme for operationally producing atmospherically-corrected surface reflectance in near real time (direct broadcast) from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite sensor. Direct broadcast surface reflectance data have a range of applications including fire detection and emergency management as well as in agriculture through projects such as Pastures From Space. Existing software developed by NASA for compiling archives of surface reflectance data for the global science community, through the Goddard Space Flight Centre's Distributive Active Archive Center (DAAC), is being modified so as to run in the operational environment of DLI as part of the International MODIS/AIRS Processing Package (IMAPP). The project, which is on track for completion in late 2004, will place WASTAC at the forefront of the distribution and application of direct broadcast MODIS data both within Australia and internationally.

Figure 4: MODIS atmospherically and observation-geometry corrected reflectances (corrections applied to land pixels only).

WASTAC ANNUAL REPORT FINANCIAL STATEMENTS

WASTAC L-BAND BUDGET 2004

Estimated expenditure for the year January 2004 – December 2004

		PER ANNUM $ 2004	$ 2003
1.	Telstra Rental	7000	7000
2.	Data Tapes	2000	7000
3.	System maintenance/repairs	6000	6000
4.	Telecommunications lic/maint of facility	1500	1500
5.	Consultants	2000	2000
6.	Sundry consumables	1500	1500
7.	Travelling – Airfares	3000	3000
8.	Provision for major equipment	12000	7000
9.	Annual Report	5000	5000
	TOTAL:	**$40,000**	**$40,000**

Estimated income/revenue for the year January 2004– December 2004

		2004	2003
1.	Contributions received ($10,000 each)	40000	40000
2.	Interest	6000	6000
	TOTAL INCOME:	**$46,000**	**$46,000**

Extra-ordinary expenditure January 2004 – December 2004

		2004	2003
1.	Capital Reserve:		
1.1	Antenna replacement and componentry	150,000	150,000
1.2	Receiver upgrade for METOP satellite	30,000	
	TOTAL:	**$180,000**	**$150,000**

WASTAC X-Band BUDGET 2004

Estimated expenditure for the year January 2004 – December 2004

		PER ANNUM $ 2004	$ 2003
1.	Data Tapes	5,000	10,000
2.	System maintenance	15,000	20,000
3.	System repairs	4,000	4,000
4.	Consultants,product development	70,000	25,000
5.	Sundry consumables	2,000	5,000
6.	Travelling – Airfares	8,000	5,000
7.	Provision for major equipment	15,000	15,000
	TOTAL:	**$119,000**	**$84,000**

Estimated income/revenue for the year January 2004 – December 2004

		2004	2003
1.	Annual Contributions ($20,000 each from BoM.DLI,CSIRO,Geoscience Aust)	80,000	80,000
2.	Interest	6,000	4,000
	TOTAL INCOME:	**$86,000**	**$84,000**

Additional committed expenditure January 2004 – December 2006

		2004	2003
1.	Withholding payment to SeaSpace Corp. 13 Oct.2006	31,815(exl GST)	31,815(exl GST)
2.	Contract for Research and development	-	50,000
3.	Receiver upgrade for NPP/NPOESS satellies	150,000	
	TOTAL:	**$181,815**	**$81,815**

INDEPENDENT AUDITOR'S REPORT – L BAND

We have audited the attached financial statements for the year ended 31 December 2003 and in our opinion they fairly represer transactions of the Consortium pertaining to L-Band for the year then ended, the financial status as at 31 December 2003 and associated cash flows. The statements are based on proper accounts and records.

Jasey Ng CPA

Performance Auditor
Department of Land Information

21 May 2004

INDEPENDENT AUDITOR'S REPORT – X BAND

We have audited the attached financial statements for the year ended 31 December 2003 and in our opinion they fairly represent the transactions of the Consortium pertaining to X-Band for the year then ended, the financial status as at 31 December 2003 and associated cash flows. The statements are based on proper accounts and records.

Emphasis of Matter

Without qualification to the opinion expressed above, attention is drawn to the following matter:

Joint Venture Agreement for X-Band

A formal joint venture agreement for the operation of X-Band has not been signed yet at the time of audit. The audit of the attached financial statements was based on financial information and advice provided by the Consortium's agent (Curtin University of Technology) to report the financial performance and position of X-Band separately from those of L-Band.

Jasey Ng CPA

Performance Auditor
Department of Land Information

21 May 2004

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY
AND APPLICATIONS CONSORTIUM L BAND

STATEMENT OF FINANCIAL PERFORMANCE FOR THE PERIOD 1 JANUARY TO 31 DECEMBER 2003

	NOTE	2003 $	2002 $
INCOME			
Contributions Received	4	30,000	50,000
Sundry Income		-	36
Interest Received		6,657	5,947
TOTAL INCOME		**36,657**	**55,983**
EXPENDITURE			
Data Tapes and Disks		6,250	2,413
Printing, Stationery & Photocopying		4,360	5,141
System Maintenance/Repairs		5,138	-
Telephone		7,595	6,532
Telecommunications License of Facility		1,058	1,030
Consultants		-	183
Desktop Equipment		-	10,798
Aarnet charges		-	97
Depreciation		6,473	7,557
TOTAL EXPENDITURE		**30,874**	**33,751**
NET SURPLUS / (DEFICIT)		**5,783**	**22,232**

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATIONS CONSORTIUM L BAND

STATEMENT OF FINANCIAL POSITION AS AT 31 DECEMBER 2003

	NOTE	2003 $	2002 $
CURRENT ASSETS			
Cash at Bank		201,750	189,494
TOTAL CURRENT ASSETS		**201,750**	**189,494**
NON - CURRENT ASSETS			
Computer Equipment	2a, 5	7,100	9,811
Other Equipment	2b, 5	42,004	45,766
TOTAL NON-CURRENT ASSETS		**49,104**	**55,577**
TOTAL ASSETS		**250,854**	**245,071**
CURRENT LIABILITIES		-	-
NON-CURRENT LIABILITIES		-	-
TOTAL LIABILITIES		-	-
NET ASSETS		**250,854**	**245,071**
EQUITY			
Retained Profits/(Losses)	3	250,854	245,071
TOTAL EQUITY		**250,854**	**245,071**

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATIONS CONSORTIUM L BAND

CASH FLOW STATEMENT FOR THE 12 MONTHS TO 31 DECEMBER 2003

	2003 $	2002 $
INFLOWS		
Contributions Received	30,000	50,000
Sundry Income	-	36
Interest Received	6,657	5,947
TOTAL INFLOWS	36,657	55,983
OUTFLOWS		
Data Tapes and Disks	6,250	2,413
Printing, Stationery & Photocopying	4,360	5,141
System Maintenance/Repairs	5,138	-
Telephone	7,595	6,532
Telecommunications License of Facility	1,058	1,030
Consultants	-	183
Equipment	-	26,468
Aarnet charges	-	97
TOTAL OUTFLOWS	24,401	41,864
EXCESS OF INFLOWS OVER OUTFLOWS	12,256	14,119
CASH AT BEGINNING OF PERIOD	189,494	175, 375
CASH AT END OF PERIOD	201,750	189,494

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY
AND APPLICATIONS CONSORTIUM L BAND

NOTES TO AND FORMING PART OF THE FINANCIAL STATEMENT FOR THE PERIOD 1 JANUARY TO 31 DECEMBER 2003

1. STATEMENT OF ACCOUNTING POLICIES

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

1a. General Methodology

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

Where necessary, comparative figures for the previous year have been adjusted to conform with changes in presentation and classifications made in the current year.

1b. Depreciation

Equipment presented in these financial statements is depreciated in accordance with the following methodology

Other Equipment	12.5% reducing balance method
Computer Equipment	25% reducing balance method. Desktop Computer Equipment is fully expensed in the month of purchase. This differs from Curtin University where only personal desktop computers costing less than $5,000 are expensed in the month of purchase

	2003 $	2002 $
2. NON CURRENT ASSETS		
2a. Computer Equipment (at cost)	191,553	191,553
Accumulated Depreciation	(184,453)	(181,742)
TOTAL COMPUTER EQUIPMENT	**7,100**	**9,811**
2b. Other Equipment (at cost)	208,590	208,590
Accumulated Depreciation	(166,586)	(162,824)
TOTAL OTHER EQUIPMENT	**42,004**	**45,766**
TOTAL NON CURRENT ASSETS	**49,104**	**55,577**
3. RETAINED PROFITS/(LOSSES)		
Retained Profits/(Losses) at beginning of period	245,071	222,839
Net Surplus/(Deficit) for the period	5,783	22,232
RETAINED PROFITS/(LOSSES) AT END OF PERIOD	**250,854**	**245,071**

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY
AND APPLICATIONS CONSORTIUM L BAND

NOTES TO AND FORMING PART OF THE FINANCIAL STATEMENT FOR THE PERIOD 1 JANUARY TO 31 DECEMBER 2003

4. CONTRIBUTIONS RECEIVED

	2003 $	2002 $
Department of Land Information (formerly Department of Land Administration)	10,000	10,000
Bureau of Meteorology	10,000	10,000
CSIRO-Earth Observation Centre	10,000	10,000
Curtin University of Technology for 2001	-	10,000
Curtin University of Technology for 2002	-	10,000
TOTAL CONTRIBUTIONS RECEIVED	**30,000**	**50,000**

5. FIXED ASSETS SCHEDULE

2003 Asset Class	**Computer Equipment $**	**Other Equipment $**	**Total $**
Carrying amount at beginning of period	9,811	45,766	55,577
Additions	-	-	-
Disposal	-	-	-
Depreciation	(2,711)	(3,762)	(6,473)
Accumulated depreciation disposal	-	-	-
Carrying amount at end of period	**7,100**	**42,004**	**49,104**

2002 Asset Class	**Computer Equipment $**	**Other Equipment $**	**Total $**
Carrying amount at beginning of period	13,070	34,394	47,464
Additions	-	15,670	15,670
Disposal	-	-	-
Depreciation	(3,259)	(4,298)	(7,557)
Accumulated depreciation disposal	-	-	-
Carrying amount at end of period	**9,811**	**45,766**	**55,577**

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATIONS CONSORTIUM X BAND

STATEMENT OF FINANCIAL PERFORMANCE FOR THE PERIOD 1 JANUARY TO 31 DECEMBER 2003

	NOTE	2003 $	2002 $
INCOME			
Contributions Received	4	80,000	230,000
Interest Received	5	16,157	-
TOTAL INCOME		**96,157**	**230,000**
EXPENDITURE			
Outsourced Work		-	987
Travel		874	4,156
Printing, Stationery & Photocopying		-	774
Depreciation		61,577	66,486
Maintenance of Equipment		10,004	7,800
Equipment purchase		14,408	17,142
Telecommunications License of Facility		-	2,358
IDM Media Costs		9,250	-
TOTAL EXPENDITURE		**96,113**	**99,685**
NET SURPLUS / (DEFICIT)		**44**	**130,315**

STATEMENT OF FINANCIAL POSITION AS AT 31 DECEMBER 2003

	NOTE	2003 $	2002 $
CURRENT ASSETS			
Cash at Bank		196,466	198,475
TOTAL CURRENT ASSETS		**196,466**	**198,475**
NON - CURRENT ASSETS			
Other Equipment	2, 6	482,344	480,291
TOTAL NON-CURRENT ASSETS		**482,344**	**480,291**
TOTAL ASSETS		**678,810**	**678,766**
CURRENT LIABILITIES		-	-
NON-CURRENT LIABILITIES		-	-
TOTAL LIABILITIES		-	-
NET ASSETS		**678,810**	**678,766**
EQUITY			
Retained Profits/(Losses)	3	678,810	678,766
TOTAL EQUITY		**678,810**	**678,766**

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY
AND APPLICATIONS CONSORTIUM X BAND

CASH FLOW STATEMENT FOR THE 12 MONTHS TO 31 DECEMBER 2003

	2003 $	2002 $
INFLOWS		
Contributions Received	80,000	230,000
Interest Received	16,157	
TOTAL INFLOWS	**96,157**	**230,000**
OUTFLOWS		
Outsourced Work	-	987
Travel	874	4,156
Printing, Stationery & Photocopying	-	774
Mechanical and Equipment Maintenance	10,004	7,800
Final Payment on X Band Satellite Receiving Station	63,630	-
Equipment purchase	14,408	17,142
Telecommunications License of Facility	-	2,358
IDM Media cost	9,250	
TOTAL OUTFLOWS	**98,166**	**33,217**
(SHORTAGE)/EXCESS OF INFLOWS OVER OUTFLOWS	**(2,009)**	**196,783**
CASH AT BEGINNING OF PERIOD	**198,475**	**1,692**
CASH AT END OF PERIOD	**196,466**	**198,475**

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY
AND APPLICATIONS CONSORTIUM X BAND

NOTES TO AND FORMING PART OF THE FINANCIAL STATEMENT FOR THE PERIOD 1 JANUARY TO 31 DECEMBER 2003

1. STATEMENT OF ACCOUNTING POLICIES

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

1a. General Methodology

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

Where necessary, comparative figures for the previous year have been adjusted to conform with changes in presentation and classifications made in the current year.

1b. Depreciation

Equipment presented in these financial statement is depreciated in accordance with the following methodology

Other Equipment	12.5% reducing balance method
Computer equipment	25% reducing balance method. Desktop Computer Equipment is fully expensed in the month of purchase. This differs from Curtin University where only personal desktop computers costing less than $5,000 are expensed in the month of purchase

	2003 $	2002 $
2. NON CURRENT ASSETS		
Other Equipment (at cost)	616,913	553,283
Accumulated Depreciation	(134,569)	(72,992)
TOTAL OTHER EQUIPMENT	**482,344**	**480,291**
TOTAL NON CURRENT ASSETS	**482,344**	**480,291**
3. RETAINED PROFITS/(LOSSES)		
Retained Profits at beginning of period	678,766	548,451
Net Surplus/(Deficit) for the period	44	130,315
RETAINED PROFITS/(LOSSES) AT END OF PERIOD	**678,810**	**678,766**
4. CONTRIBUTIONS RECEIVED		
Annual Membership-Department of Land Information	20,000	20,000
Annual Membership-CSIRO	20,000	20,000
Annual membership-Bureau of Meteorology	20,000	20,000
Annual Membership-Geoscience Australia	20,000	20,000
AUSLIG	-	50,000
Bureau of Meteorology- Seaspace	-	100,000
TOTAL CONTRIBUTIONS RECEIVED	**80,000**	**230,000**
5. INTEREST RECEIVED		
For period June to November 2001	8,044	-
For period December 2001 to May 2002	1,671	-
For period June to November 2002	3,567	-
For period December 2002 to May 2003	2,875	-
TOTAL INTEREST RECEIVED	**16,157**	**-**

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY
AND APPLICATIONS CONSORTIUM X BAND

NOTES TO AND FORMING PART OF THE FINANCIAL STATEMENT FOR THE PERIOD 1 JANUARY TO 31 DECEMBER 2003

6. FIXED ASSET SCHEDULE

2003 Asset Class	**Other Equipment** **$**
Carrying amount at beginning of period	480,291
Additions	63,630
Disposal	-
Depreciation	(61,577)
Accumulated Depreciation Disposal	-
Carrying amount at end of period	482,344

2002 Asset Class	**Other Equipment** **$**
Carrying amount at beginning of period	546,759
Additions	-
Disposal	-
Depreciation	(66,468)
Accumulated Depreciation Disposal	-
Carrying amount at end of period	480,291

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATIONS CONSORTIUM L BAND

EQUIPMENT AS AT 31 DECEMBER 2003

ASSET #	DESCRIPTION	ORIGINAL COST	ACCUMULATED DEPRECIATION	WRITTEN DOWN VALUE
COMPUTER EQUIPMENT				
01358800	SYSTEM SATELLITE TRACKING STATION	110,000	110,000	-
02478800	2.3 GB 8 MM EXABYTE	6,272	6,272	-
02552700	TAPE DRIVE 2 GBYTE X801A	6,840	6,840	-
02553701	ACQNR	3,800	3,800	-
02585200	PAINTJET XL C1602A	2,425	2,425	-
02629700	CARTRIDGE SYSTEM 2.5 G BYTE 8 M	4,950	4,950	-
03914000	MICROWAVE COMMUNICATION SYSTEM	57,266	50,166	7,100
TOTAL COMPUTER EQUIPMENT		**191,553**	**184,453**	**7,100**
OTHER EQUIPMENT				
01358700	SATELITE STATION TRACKING	140,000	124,830	15,488
01948500	POWER CONDITIONER	2,000	1,720	286
02009000	MA 23 CC	20,365	17,450	2,976
02553700	RECEIVER NOAA I/F FORMAT	19,500	16,056	3,516
03852500	CX-FSIP4 CISCO 4 PORT S/INTER	7,440	4,758	2,738
03852501	PA-7KF-E1/75 CISCO DUAL E1 G70	3,400	2,174	1,251
03852502	CABE1 BNC FSIP MIP-CEI BNC 75	215	137	79
05132000	RADIO NETWORK BUREAU TO CURTIN	15,670		15,670
TOTAL OTHER EQUIPMENT		**208,590**	**166,586**	**42,004**
TOTAL EQUIPMENT		**400,143**	**351,039**	**49,104**
DESKTOP COMPUTER EQUIPMENT (EXPENSED)				
03904000	HEWLET PACKARD 715/64 WORKSTATION	25,208		
03923700	LYNXPACK 6000E DDS2 4/8GB TAPE	2,098		
03923800	LYNXPACK 6000E DDS2 4/8GB TAPE	2,098		
04085100	9GB DIS DRIVE	2,435		
04522800	WIDE DISK DRIVES	2,164		
04536800	AMSUCARD FOR INST P/C	6,765		
04619200	MONITOR	834		
05131500	DLT 4000 TAPE DRIVE	2,950		
05131600	DLT 4000 TAPE DRIVE	2,950		
05131700	LINUX PC	4,263		
TOTAL DESKTOP COMPUTER EQUIPMENT (EXPENSED)		**51,765**		

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATIONS CONSORTIUM X BAND

EQUIPMENT AS AT 31 DECEMBER 2003

ASSET #	DESCRIPTION	ORIGINAL COST	ACCUMULATED DEPRECIATION	WRITTEN DOWN VALUE
OTHER EQUIPMENT				
4857100	X-BAND SATELLITE RECEIVING STATION	553,283	134,569	418,714
	FINAL PAYMENT ON X BAND SATELLITE RECEIVING STATION (new)	63,630	-	63,630
TOTAL OTHER EQUIPMENT		**616,913**	**134,569**	**482,344**

ASSET #	DESCRIPTION	ORIGINAL COST
DESKTOP COMPUTER EQUIPMENT (EXPENSED)		
05131800	LINUX PC-COMDEK	4,818
05131900	DLT 8000	7,375
05429500	DELL POWEREDGE 1600CC SERVER (new)	7,204
05429600	DELL POWEREDGE 1600SC SERVER (new)	7,204
TOTAL DESKTOP COMPUTER EQUIPMENT (EXPENSED)		**26,601**