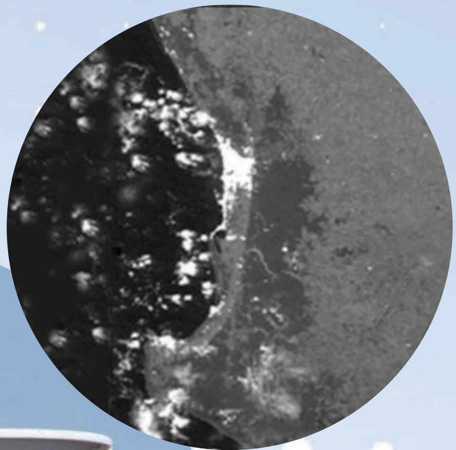
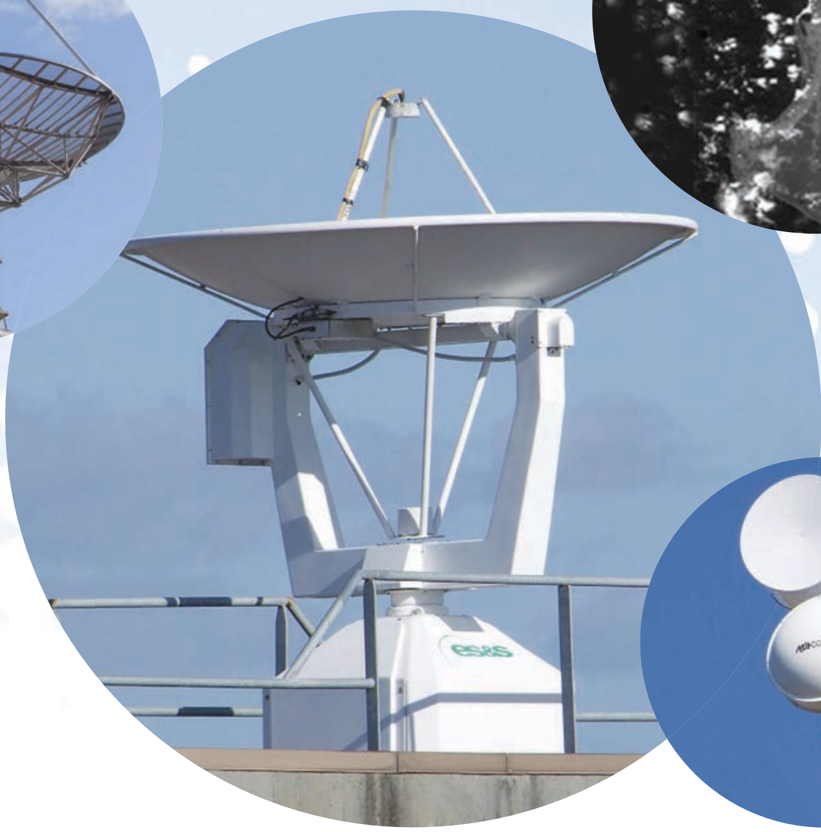
# WASTAC

Western Australian Satellite Technology and Applications Consortium

## Annual Report 2012





www.wastac.wa.gov.au

## WASTAC

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## WASTAC members

**Australian Bureau of Meteorology**
GPO Box 1289
Melbourne VIC 3001

**Curtin University**
GPO Box U1987
Perth WA 6845

**CSIRO**
Space Sciences and Technology
Astronomy and Space Science
GPO Box 664
Canberra, ACT 2601

**LANDGATE**
Leeuwin Centre for Earth Sensing Technologies
PO Box 471
Wembley WA 6913

**Geoscience Australia**
GPO Box 378
Canberra ACT 2601

**Murdoch University**
90 South Street
Murdoch
Western Australia 6150

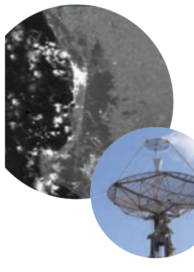
**Front Cover :**
WASTAC operate two satellite data receiving facilities. One is located at Curtin University and the other at Murdoch University. The satellite dish and microwave data relay antennas (centre and right) are those owned by WASTAC and mounted on the Science and Engineering building 204 at Curtin University.
The image of south-west Western Australia was captured by WASTAC's satellite data receiving facility located at Murdoch from the day-night band on the SUOMI NPP VIIRS instrument. The image shows the lights of Perth and the surrounding suburbs and townships from the 20th July 2012.

Photos kindly taken by S.Abbott Landgate

Editors: R. Stovold - Landgate
A.F. Pearce - Curtin University
D.Sandison - Landgate

# Contents





# WASTAC chairman's report 2012



As I sat to write the Chairman's forward, the Minister Assisting for Industry and Innovation Senator Kate Lundy announced Australia's Space Utilisation Policy at ANU's Stromlo Observatory on 9 April 2013. This policy and the underlying National Earth Observations from Space - Infrastructure Plan (NEOS-IP) will influence where and what earth observation activities are undertaken by WASTAC over the next decade. The policy  is well worth a read. The full policy announcement can be found at http://minister.innovation.gov.au/katelundy/Speeches/Pages/LaunchoftheAustralianSpacePolicy.aspx, and supporting policy documents can be found at http://www.space.gov.au/SpacePolicyUnit/Pages/default.aspx as of 30 September 2013.

A year earlier (12 April 2012), the WASTAC Board had already provided comments to the NEOS-IP executive with respect to the recommendations in the draft NEOS-IP. The final NEOS-IP reflects the comments made by WASTAC. I hope that in the near future the NEOS-IP can be released to the wider community so our stakeholders have transparency on what is planned for earth observation within the federal government during the lifetime of Australia's Space Utilisation Policy. The potential impacts of Space Utilisation Policy on WASTAC's operations will be reviewed sometime in 2013 or early 2014.

At an operational level the main development activities of WASTAC in 2012 were on receiving and processing data from the NPOESS Preparatory Project (NPP) and METOP-B. The former was launched in November 2011 and the latter was launched on 17 September 2012. With the new satellites, WASTAC recorded its second highest number of passes captured at 20,405 from 12 different satellites (this is the greatest number of satellites WASTAC has received data from). To support the best geolocation of Advanced Very High Resolution Radiometer (AVHRR) data on newer METOP satellites, WASTAC will co-fund the porting of CSIRO's Common AVHRR Processing Software (CAPS) into a modern code repository to allow it to be used more easily by WASTAC partners for past and present missions.

WASTAC also completed installation of a microwave link from the receiving dish at Murdoch to the Bureau's Perth Offices via Curtin as a business continuity measure if the AARNET links are interrupted. This is an important improvement in our systems to reduce our exposure to single points of failure as the broader community comes to expect products from satellite data to be available all of the time.

As the Operational Applications reports show, data sourced from WASTAC is contributing to the development of national scale datasets (Edward King, CSIRO), which are then converted into products that predict weather, track and monitor cyclones (Willmott et al., BOM), support agricultural production (Buchanan et al., Landgate; Santich, Landgate; Stovold et al., Landgate), and monitor changes in the oceans that surround Australia (King, CSIRO).

On the research front, Curtin University provided the lead role to the WA node of TERN Auscover, producing a 19-band atmospherically corrected product from MODIS, as well as an Australian HYPERION Archive. Geoscience Australia will embark on a project in 2013 that will map water bodies across Australia from the Landsat Archive. CSIRO will be developing an Earth Observations Informatics Platform in support of recommendations made under the NEOS-IP

WASTAC remains in a strong financial position with sufficient reserves to make modifications to existing systems as needed.

The WASTAC partners have contributed generously to the efficient running of WASTAC. Ron Craig, Mike Steber, Jackie Marsden, Joe Cudmore and Justin Pitsikas (Landgate), along with Russell Steicke (BoM), have kept the stations and processing systems running with a high degree of reliability. CSIRO maintains the high speed data link needed for near realtime processing at the Leeuwin Centre, as well as production of the NOAA Stitched Archive utilizing WASTAC data at the NCI in Canberra. Our Secretary, Richard Stovold (Landgate), has kept the decision making on track and with Alan Pearce (Curtin University) edits an excellent Annual Report. Curtin University continues to manage our accounts. Murdoch University maintains an excellent site for the X-band antenna. Geoscience Australia provides valuable national coordination and access to MODIS data from Alice Springs for WASTAC members.

As Chairman, I take pride in the major contributions WASTAC is making to advance our understanding of land, ocean and atmospheric processes within Australia.

Dr. Matthew Adams
Chair, WASTAC Board 2012

# WASTAC board for 2012

| | |
|---|---|
| Dr Matthew Adams- Chairman | Landgate |
| Mr Richard Stovold | Landgate |
| Professor Merv Lynch | Curtin University |
| Dr Doug Myers | Curtin University |
| Dr Kimberley Clayfield | CSIRO |
| Dr Edward King | CSIRO |
| Dr Anthony Rea | Bureau of Meteorology |
| Mr Andrew Burton | Bureau of Meteorology |
| Dr Adam Lewis | Geoscience Australia |
| Professor Tom Lyons | Murdoch University |

## WASTAC standing committee and proxy to the board

| | |
|---|---|
| Dr Matthew Adams - Chairman | Landgate |
| Mr Richard Stovold | Landgate |
| Professor Merv Lynch | Curtin University |
| Dr Doug Myers | Curtin University |
| Mr Andrew Burton | Bureau of Meteorology |
| Mr Russell Steicke | Bureau of Meteorology |
| Professor Tom Lyons | Murdoch University |
| Dr. Halina Kobryn | Murdoch University |
| Dr Tom Cudahy | CSIRO |

## WASTAC secretary:

| | |
|---|---|
| Mr Richard Stovold | Secretary to the WASTAC Board and Standing Committee. |

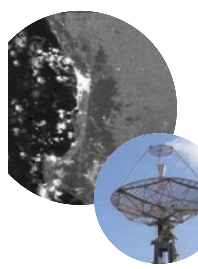
## WASTAC technical committee:

Mr Russell Steicke (Chairman)

Professor 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:

- Provide high speed access to Aqua, Terra, NOAA, SeaWiFS and FY1D 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.
- Prepare for utilisation of information from new technically and scientifically advanced sensors.
- Promote educational and research uses of WASTAC data.
- Promote use of Aqua, Terra, NOAA, SeaWiFS and FY1D data in climate studies, environmental and renewable resource management.
- Encourage WASTAC to promote awareness of products.

## Current strategies:

- Upgrade reception and processing capabilities for METOP (including AVHRR), NPP (including VIIRS) and FY3 (including MERS).
- Continue to improve the products derived from MODIS sensors.
- Advance the processing of AIRS data from Aqua and Terra.
- Improve the management and access of the WASTAC archive through collaboration with iVEC (Interactive Virtual Environment Computing Facility).
- Provide network access to other Earth Observation Satellite receiving stations in Australia.

## Future satellite reception opportunities:

National Polar Orbiting Environmental Satellite System and NPP/NPOESS.

- Landsat Continuity Data Mission.
- Chinese HY3 and ZY3 satellites.
- Russian Meteor satellites.

# Operations

WASTAC maintains an L band reception facility at Curtin University and a dual X and L band facility at Murdoch University. The L band facility has been operational since 1983, although satellite tracking at Curtin (then the WA Institute of Technology) began in the late 1970s. The X band facility has been operating since 2001. WASTAC members make use of the satellite data for weather prediction, vegetation and fire monitoring, and research. WASTAC maintains an ongoing near-realtime archive of L band images beginning in 1983, and X band images from 2001.

## Curtin University – L band

The L band facility at Curtin University in Bentley consists of a 2.4m antenna and an antenna controller supplied by Environmental Systems and Services (ES&S) and dual ingestor computers running an AVHRR ingest and display system developed by the Bureau of Meteorology (BoM). There are other processing computers located at the Bureau of Meteorology in West Perth which run BoM software for image generation and product distribution.

The ingestors are isolated from the Curtin University network, but connected to the BoM in West Perth via a 100 Mbit/second microwave link. A second microwave link connects from the BoM back to Curtin University.

During 2012, the L band facility received 7194 passes – 1302 from NOAA-15, 1734 from NOAA-16, 1137 from NOAA-17, 1298 from NOAA-18, and 1723 from NOAA-19. This is an increase in the numbers from 2011, reflecting very good reliability of the system this year.

The Curtin University satellite reception facility is maintained by BoM staff.

## Murdoch University – L and X band

The X band reception facility was supplied by SeaSpace Corporation in 2001. It consists of a 3.6m antenna in a fiberglass dome, and an antenna controller computer. This facility receives data from the Aqua, Terra, MetOp 2, NPP, FY3-B, and FY1-D, as well as the L band satellites. Having two reception facilities for L band allows some satellite conflicts to be resolved.

Data from the X band facility is delivered to Landgate via AARNET. A microwave link to the BoM via the Curtin University facility provides a backup, and data is delivered to the BoM via this link.

During 2012 the X band facility received a total of 20,405 passes.

The Murdoch University satellite reception facility is maintained by Murdoch University staff.

## Applications

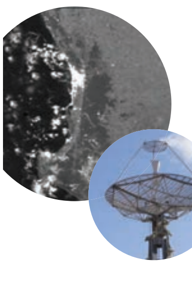
TOVS data, a subset of the AVHRR is automatically sent to the Bureau of Meteorology in Melbourne where the atmospheric temperature retrievals are ingested into global numerical weather prediction models. Sea Surface Temperature (SST) analyses are produced by the Bureau of Meteorology and Landgate. Landgate also produces vegetation maps and monitors fire scars in realtime.

## Future directions

WASTAC continues to be involved with the development of software which will allow easier on-line access to the data stored at the iVEC site in Technology Park, Bentley.

Investigations into the possible upgrade of the Curtin University reception facility to dual L and X band capability are continuing.

*Russell Steicke, Regional Computing Manager (WA), Bureau of Meteorology*



# WASTAC data archive

The WASTAC archive of all current satellite passes is managed and maintained by Landgate's Satellite Remote Sensing Services (SRSS) group and held at the Leeuwin Centre at Floreat in Perth. The SRSS Group actively manages the daily archive and management systems that have been installed to ensure rapid and reliable delivery of WASTAC satellite data for research and wider community use. This archive forms the basis for the development, processing and delivery of a range of products listed in the Operational and Research applications section of this report.

A total of 20,405 passes were archived at Curtin and Murdoch in 2012.

The near realtime quick-look archive of MODIS and NOAA-AVHRR data continues to be maintained on the world wide web. This digital archive extends back to 1983. A similar archive of SeaWiFS quick-look data is also held on the Web.

The archive of MODIS, NOAA and SeaWiFS data can be viewed at:

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

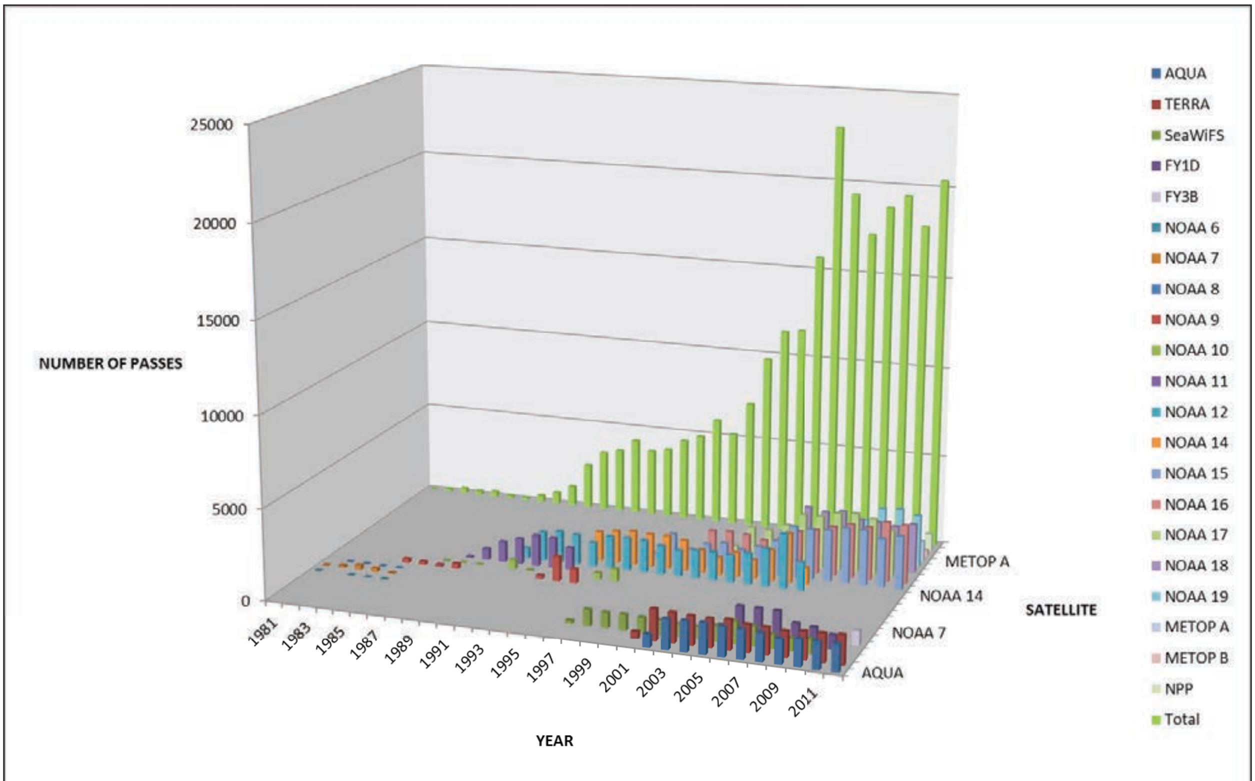
http://www.rss.dola.wa.gov.au/newsite/modisql/MODISql.html

http://www.rss.dola.wa.gov.au/newsite/seawifsql/SeaWiFSql.html

Landgate currently holds the archive on 8mm exabyte and DAT tapes. 20Gb DLT tapes were introduced as the archive medium in late 2000 for the L band data and since the commissioning of the facility in 2001. X band data has been archived on DLT 35Gb tapes and since this year on on-line mass storage devices.

Duplicate copies of the raw data archive are produced for a national archive program that is coordinated by the CSIRO Office of Space Science and Applications (COSSA) in Canberra.

Total archived passes 1981-2012



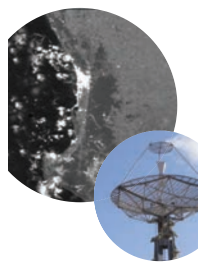

Total Archived Passes 1981 - 2012

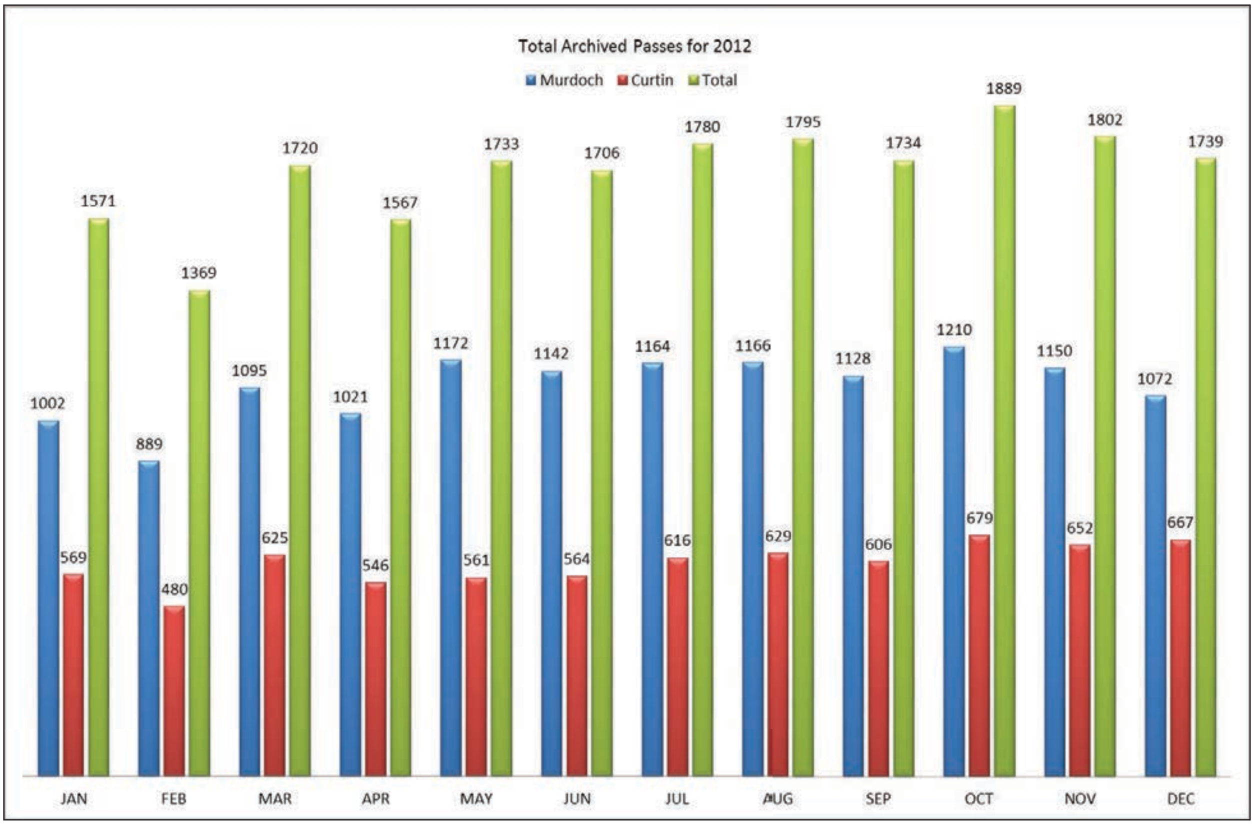
## Total archived passes 1981-2012

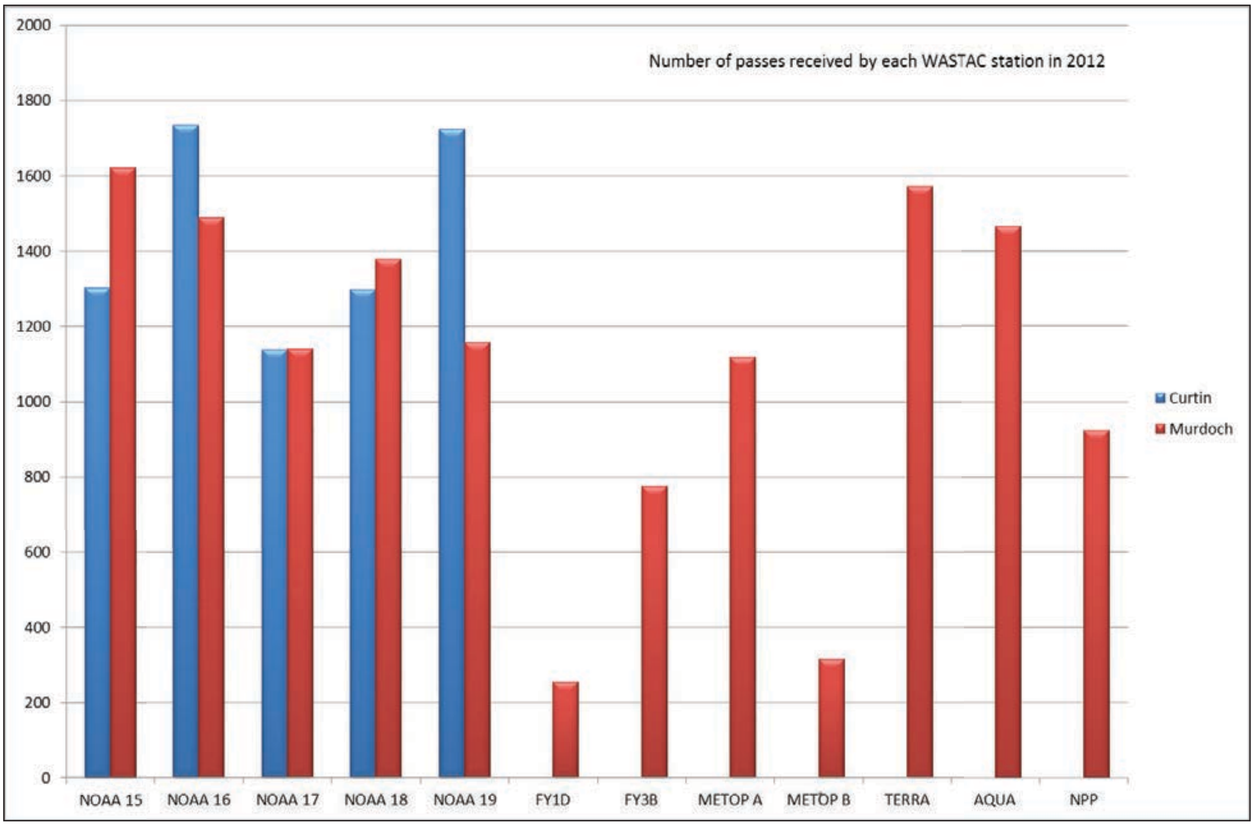
| | AQUA | TERRA | FY3B | METOP A | METOP B | NPP | SeaWiFS | FY1D | NOAA 6 | NOAA 7 | NOAA 8 | NOAA 9 | NOAA 10 | NOAA 11 | NOAA 12 | NOAA 14 | NOAA 15 | NOAA 16 | NOAA 17 | NOAA 18 | NOAA 19 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | | | | | | | | | 5 | 22 | | | | | | | | | | | | 27 |
| 1982 | | | | | | | | | | 115 | 1 | | | | | | | | | | | 116 |
| 1983 | | | | | | | | | 12 | 244 | 12 | | | | | | | | | | | 268 |
| 1984 | | | | | | | | | 7 | 179 | 4 | | | | | | | | | | | 190 |
| 1985 | | | | | | | | | 7 | 33 | 4 | 212 | | | | | | | | | | 256 |
| 1986 | | | | | | | | | | | | 151 | | | | | | | | | | 151 |
| 1987 | | | | | | | | | | | | 97 | 18 | | | | | | | | | 115 |
| 1988 | | | | | | | | | | | | 280 | 25 | 53 | | | | | | | | 358 |
| 1989 | | | | | | | | | | | | | 21 | 601 | | | | | | | | 622 |
| 1990 | | | | | | | | | | | | | | 1103 | | | | | | | | 1103 |
| 1991 | | | | | | | | | | | | | 506 | 1399 | 575 | | | | | | | 2480 |
| 1992 | | | | | | | | | | | | | 47 | 1693 | 1571 | | | | | | | 3311 |
| 1993 | | | | | | | | | | | | 183 | | 1656 | 1720 | | | | | | | 3559 |
| 1994 | | | | | | | | | | | | 1362 | | 1227 | 1641 | | | | | | | 4230 |
| 1995 | | | | | | | | | | | | 770 | | | 1326 | 1615 | | | | | | 3711 |
| 1996 | | | | | | | | | | | | | 354 | | 1780 | 1776 | | | | | | 3910 |
| 1997 | | | | | | | 142 | | | | | | 694 | | 1797 | 1876 | | | | | | 4509 |
| 1998 | | | | | | | 859 | | | | | | | | 1763 | 1828 | 432 | | | | | 4882 |
| 1999 | | | | | | | 822 | | | | | | | | 1589 | 1839 | 1663 | | | | | 5912 |
| 2000 | | | | | | | 843 | | | | | | | | 1427 | 1681 | 905 | 341 | | | | 5197 |
| 2001 | | 390 | | | | | 811 | | | | | | | | 1548 | 1271 | 1292 | 1733 | | | | 7045 |
| 2002 | 734 | 1710 | | | | | 780 | | | | | | | | 1579 | 976 | 1455 | 1789 | 709 | | | 9732 |
| 2003 | 1651 | 1645 | | | | | 696 | | | | | | | | 1521 | 1351 | 1200 | 1728 | 1827 | | | 11388 |
| 2004 | 1665 | 1602 | | | | | 680 | | | | | | | | 1727 | 1058 | 1481 | 1524 | 1797 | | | 11534 |
| 2005 | 1705 | 1577 | | | | | 863 | 553 | | | | | | | 2101 | 1706 | 1904 | 1743 | 2212 | 1339 | | 15703 |
| 2006 | 1635 | 1639 | | | | | 1239 | 1683 | | | | | | | 3030 | 2761 | 2823 | 2240 | 2883 | 2989 | | 22922 |
| 2007 | 1615 | 1512 | | | | | 1092 | 1678 | | | | | | | 1571 | 952 | 2777 | 2442 | 2869 | 2839 | | 19347 |
| 2008 | 1553 | 1495 | | | | | 787 | 1673 | | | | | | | | | 2844 | 2711 | 3165 | 2985 | | 17213 |
| 2009 | 1327 | 1411 | | | | | 687 | 1132 | | | | | | | | | 3055 | 2951 | 3254 | 2622 | 2306 | 18745 |
| 2010 | 1454 | 1516 | | | | | 793 | 1040 | | | | | | | | | 3061 | 2895 | 3054 | 2567 | 3058 | 19438 |
| 2011 | 1485 | 1537 | | | | | | 751 | | | | | | | | | 2692 | 3282 | 2527 | 2453 | 3128 | 17855 |
| 2012 | 1465 | 1571 | 775 | 1118 | 316 | 924 | | 255 | | | | | | | | | 2923 | 3223 | 2278 | 2677 | 2880 | 20405 |

## Total archived passes for 2012

| | | NOAA 15 | NOAA 16 | NOAA 17 | NOAA 18 | NOAA 19 | FY1D | FY3B | METOP A | METOP B | TERRA | AQUA | NPP | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JAN | C | 82 | 142 | 87 | 111 | 147 | | | | | | | | 569 |
| | M | 143 | 134 | 132 | 108 | 122 | 105 | | | | 134 | 124 | | 1002 |
| | | | | | | | | | | | | | | 1571 |
| FEB | C | 52 | 135 | 87 | 78 | 128 | | | | | | | | 480 |
| | M | 122 | 129 | 119 | 116 | 116 | 69 | | | | 112 | 106 | | 889 |
| | | | | | | | | | | | | | | 1369 |
| MAR | C | 129 | 146 | 66 | 135 | 149 | | | | | | | | 625 |
| | M | 137 | 139 | 78 | 123 | 116 | 81 | | 99 | | 138 | 116 | 68 | 1095 |
| | | | | | | | | | | | | | | 1720 |
| APR | C | 128 | 146 | 83 | 53 | 136 | | | | | | | | 546 |
| | M | 123 | 140 | 98 | 100 | 87 | 0 | 43 | 95 | | 133 | 125 | 77 | 1021 |
| | | | | | | | | | | | | | | 1567 |
| MAY | C | 126 | 151 | 96 | 47 | 141 | | | | | | | | 561 |
| | M | 150 | 135 | 128 | 114 | 55 | 0 | 110 | 114 | | 138 | 136 | 92 | 1172 |
| | | | | | | | | | | | | | | 1733 |
| JUN | C | 131 | 142 | 107 | 41 | 143 | | | | | | | | 564 |
| | M | 130 | 131 | 123 | 126 | 69 | 0 | 104 | 110 | | 131 | 129 | 89 | 1142 |
| | | | | | | | | | | | | | | 1706 |
| JUL | C | 121 | 144 | 101 | 105 | 145 | | | | | | | | 616 |
| | M | 128 | 123 | 129 | 120 | 98 | 0 | 99 | 111 | | 132 | 133 | 91 | 1164 |
| | | | | | | | | | | | | | | 1780 |
| AUG | C | 115 | 150 | 71 | 145 | 148 | | | | | | | | 629 |
| | M | 139 | 134 | 93 | 113 | 115 | 0 | 88 | 119 | | 132 | 134 | 99 | 1166 |
| | | | | | | | | | | | | | | 1795 |
| SEP | C | 106 | 139 | 82 | 138 | 141 | | | | | | | | 606 |
| | M | 133 | 133 | 95 | 112 | 86 | 0 | 100 | 115 | | 133 | 126 | 95 | 1128 |
| | | | | | | | | | | | | | | 1734 |
| OCT | C | 105 | 148 | 124 | 148 | 154 | | | | | | | | 679 |
| | M | 140 | 99 | 119 | 111 | 108 | 0 | 84 | 103 | 96 | 132 | 126 | 92 | 1210 |
| | | | | | | | | | | | | | | 1889 |
| NOV | C | 101 | 144 | 118 | 144 | 145 | | | | | | | | 652 |
| | M | 144 | 97 | 27 | 118 | 95 | 0 | 81 | 124 | 109 | 129 | 116 | 110 | 1150 |
| | | | | | | | | | | | | | | 1802 |
| DEC | C | 106 | 147 | 115 | 153 | 146 | | | | | | | | 667 |
| | M | 132 | 95 | 0 | 118 | 90 | 0 | 66 | 128 | 111 | 127 | 94 | 111 | 1072 |
| | | | | | | | | | | | | | | 1739 |
| | | 2923 | 3223 | 2278 | 2677 | 2880 | 255 | 775 | 1118 | 316 | 1571 | 1465 | 924 | 20405 |
| | | | | | | | | | | | | | | |
| | Curtin | 1302 | 1734 | 1137 | 1298 | 1723 | | | | | | | | 7194 |
| | Murdoch | 1621 | 1489 | 1141 | 1379 | 1157 | 255 | 775 | 1118 | 316 | 1571 | 1465 | 924 | 13211 |




Total Archived Passes for 2012
Murdoch
Curtin
Total
JAN 1002 569 1571
FEB 889 480 1369
MAR 1095 625 1720
APR 1021 546 1567
MAY 1172 561 1733
JUN 1142 564 1706
JUL 1164 616 1780
AUG 1166 629 1795
SEP 1128 606 1734
OCT 1210 679 1889
NOV 1150 652 1802
DEC 1072 667 1739


Number of passes received by each WASTAC station in 2012
0
200
400
600
800
1000
1200
1400
1600
1800
2000
NOAA 15
NOAA 16
NOAA 17
NOAA 18
NOAA 19
FY1D
FY3B
METOP A
METOP B
TERRA
AQUA
NPP
Curtin
Murdoch

# Operational applications 2012



A variety of operational marine, terrestrial and atmospheric products have been developed using locally-received satellite data from the AVHRR, SeaWiFS and MODIS sensors. The principal agencies involved are the Bureau of Meteorology,CSIRO and Satellite Remote Sensing Services group in Landgate.

## Bureau of Meteorology, Melbourne

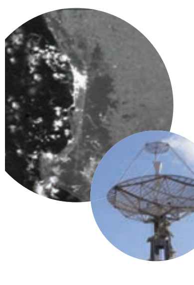
### Compiled by Mike Wilmott, Ian Grant, Leon Majewski, David Howard and staff of the severe weather warning section of WA

The Bureau of Meteorology has an extensive satellite data reception network within the Australian and the Antarctic continents. This satellite network supports the operations of the Bureau with important and timely information on the state of the atmosphere and ocean from west of the continent over the Indian Ocean to the east of the continent over the Pacific Ocean. The network also allows the gathering of important information from the tropics to the South Pole. Part of this extensive network includes the L-Band and X-Band reception systems operated by WASTAC. The WASTAC systems form an integral part of the network where data from these systems along with data from the rest of the network are used in a range of application areas including numerical weather prediction, the generation of forecasts and warnings, analysis and post analysis of severe weather events and oceanography.

### 1. Normalised difference vegetation index (NDVI)

The Normalised Difference Vegetation Index (NDVI) is widely used to monitor vegetation dynamics at a continental scale. The Bureau provides national maps and data grids of monthly NDVI calculated from AVHRR data on its climate web pages. These products are provided both as NDVI itself and as NDVI standardised anomaly, which expresses the departure of NDVI from the long term mean for the month. The Bureau also distributes NDVI data through the AusCover web portal, a data service for satellite-derived datasets of biophysical variables over the Australian land mass that was developed by the Terrestrial Ecosystem Research Network. The underpinning collection of AVHRR data held at the Bureau has national coverage, having been acquired by WASTAC and other Australian agencies, with most of the historical data having been collated by CSIRO.

The dynamics of NDVI tend to follow that of rainfall with a lag, as vegetation responds to the moisture availability. January 2012 saw significant inland flooding affect Queensland and New South Wales. The strong greening response to the associated rainfall is evident in the high values of NDVI anomaly across those two states in February 2012 (Figure 1). In contrast, from April onwards rainfall was near average over much of Queensland and below average over most of the southern mainland. The NDVI anomalies for November 2012 (Figure 1) are consistent with this, with Queensland returning closer to neutral, while southern Australia, particularly South Australia and southwestern Western Australia, are less green than is normal for that time of year.



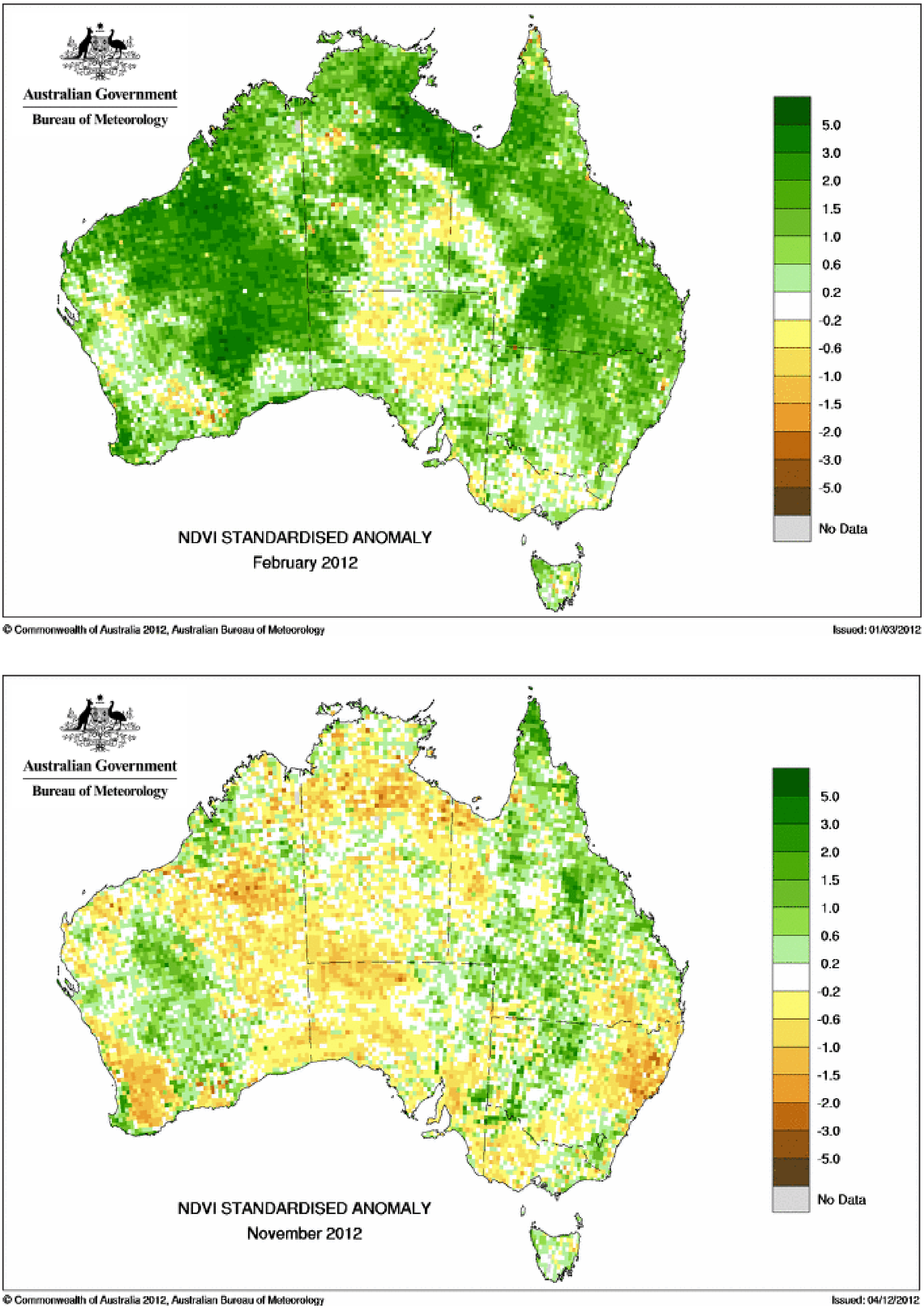



*Figure 1: The national NDVI standardised anomaly maps for February 2012 (top) and November 2012 (bottom), produced from AVHRR data. These national maps, state maps at a finer resolution and data grids are available at the Bureau of Meteorology's climate web pages.*

## 2. Atmospheric data for numerical weather prediction

### 2.1. The Advanced TIROS Operational Vertical Sounder (ATOVS)

The ATOVS suite of instruments on board the NOAA and MetOp satellites provides information on the vertical profiles of temperature and moisture in the atmosphere. The all-weather microwave component of ATOVS provides the biggest impact on Numerical Weather Prediction (NWP) skill of any single data type, adding several days of predictability in the southern hemisphere (Simmons and Hollingsworth 2002; Hollis 2004). The Bureau's NWP system is the Australian Community Climate and Earth System Simulator (ACCESS), which is a local implementation of the United Kingdom Met Office Unified Model used for NWP and climate modeling. Global ATOVS coverage is provided by the United States (from NOAA satellites) and Europe (from MetOp), but with delays of three to six hours, which misses the cut-off for some operational NWP systems. In 2012, local ATOVS reception from WASTAC, Darwin and Crib Point provided the Bureau with NOAA-15, -17, -18 and -19 coverage over the Australian region within 30 minutes of the start of acquisition. An upgrade to the Bureau's ACCESS NWP model has allowed the assimilation of significantly more ATOVS data, with the short data cut-off window of the APS1 ACCESS-R12 system accepting more ATOVS data than the old APS0 version of the system, as shown in Figure 2.

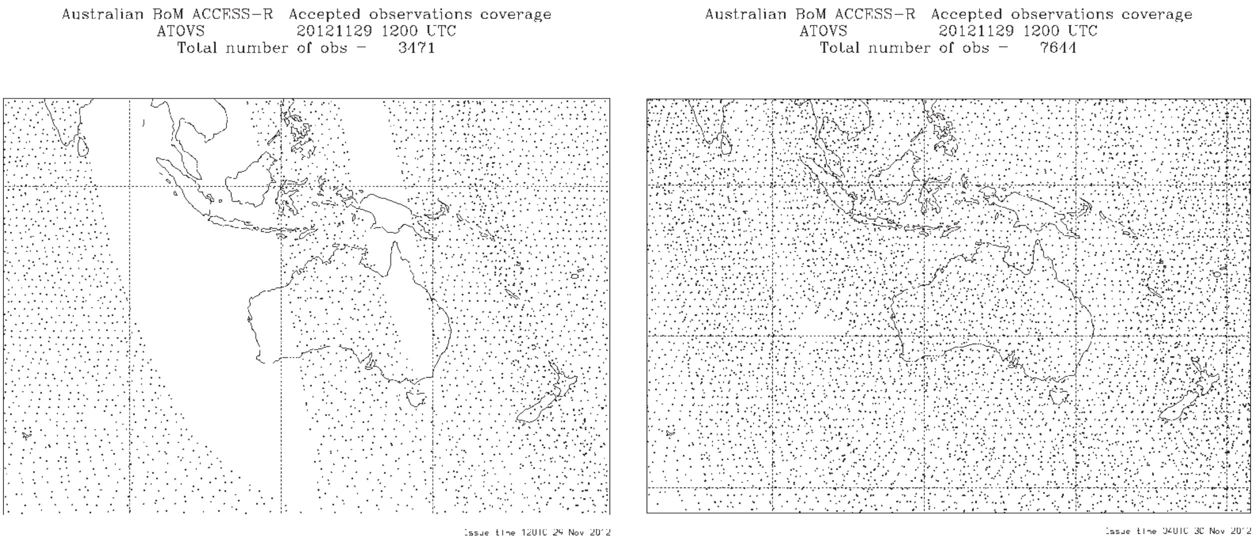



*Figure 2: Comparison of accepted ATOVS observations for APS0 ACCESS-R (left) and APS1 ACCESS-R (right).*

All countries running global NWP systems require global-coverage ATOVS data as a key input; however, there are significant delays (of 3 hours or more) associated with global data streams sourced from the United States. This has stimulated the development of a rapid ATOVS dissemination service, facilitated by the World Meteorological Organisation's Space Programme. The Regional ATOVS Retransmission Service (RARS) facilitates the delivery of locally-received ATOVS data, from 38 stations across the globe, providing data with a 30-minute latency over 74 per cent of the globe. The Bureau participates in and coordinates the Asia-Pacific (AP) RARS. In addition to contributing data through five local ATOVS reception facilities, including WASTAC, AP-RARS coordinates the data from ten international AP-RARS sites, including New Zealand, Singapore, China, Japan, Hong Kong and Korea. The coverage of AP-RARS stations is provided in Figure 3. (see http://www.bom.gov.au/australia/satellite/rars.shtml)

### 2.2. MODerate resolution Imaging Spectroradiometer (MODIS) and Atmospheric Infrared Sounder (AIRS) Data

The large number of spectral bands carried by the MODIS instrument on the Terra and Aqua spacecraft enables the derivation of a range of atmosphere and surface products. These include information on the spatial distribution of water vapour, temperature, cloud phase (ice or water) and cloud top properties (pressure, temperature, particle size). Products are generated using the International MODIS and AIRS Processing Package (IMAPP) software from the University of Wisconsin and delivered to forecasters via a developmental web-based system. Additionally, various triplets of MODIS spectral bands can be displayed as false-colour images to highlight particular atmospheric features. For instance, Figure 4 and Figure 5 show false-colour MODIS images from WASTAC for 11 January 2012 which highlight, respectively, pre-frontal smoke and dust over western inland Australia, and severe storms.

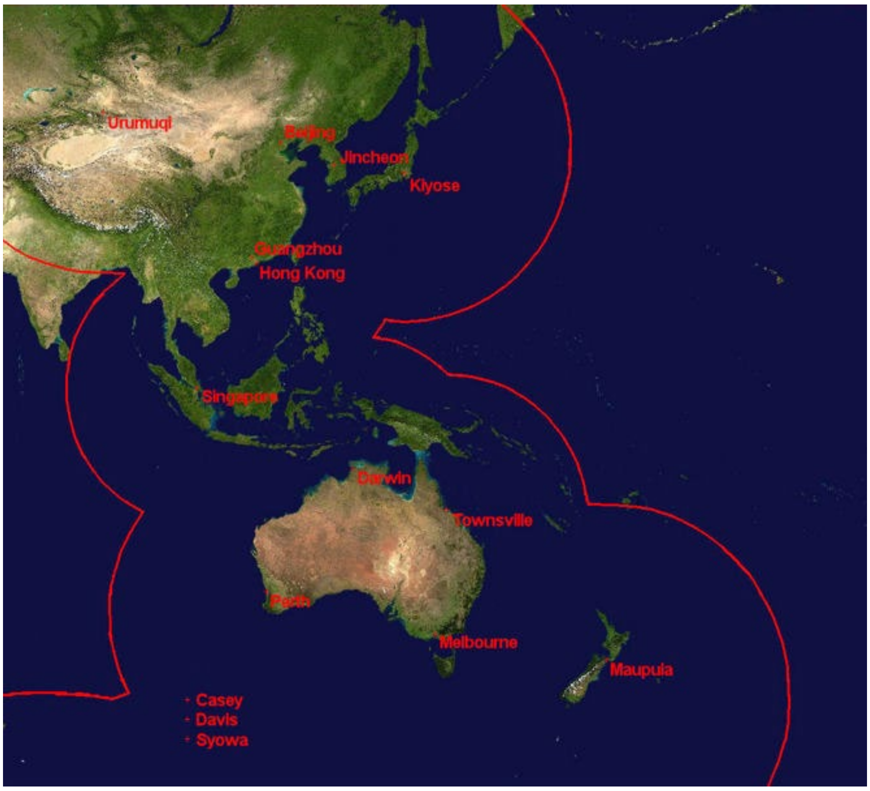



*Figure 3: AP-RARS sites*

As many multispectral imagers are made available to the meteorological community, from various satellites, the relationships between spectral response of the atmosphere and conceptual meteorological models are being used to provide meteorologists with better ways of viewing the atmosphere. As an example, by singling out certain wavelengths that show, say, only high level clouds, those that best show land masses and those that best show mid level cloud, composites of these "greyscale" images can be combined using the red, green and blue "guns" of visual display units to provide coloured images that will highlight certain parts of the image. As can be seen in Figure 6, the combination of certain spectral bands can be used to show areas of high, mid and low level clouds, but more importantly, the technique can be used to show areas of suspended dust which is a hazard to aviation. This dust area can usually been seen in normally unenhanced imagery, but is confused with cloud. The ability to distinguish the dust from the cloud so readily provides the meteorologist with one more tool to assist in the analysis and forecasting of the atmosphere.

Finally, using similar combinations of spectral channels within the visible wavelengths, spectacular true colour images can be produced which are informative about the weather situation. The RGB composite shown in Figure 7 highlights severe tropical Cyclone Heidi.

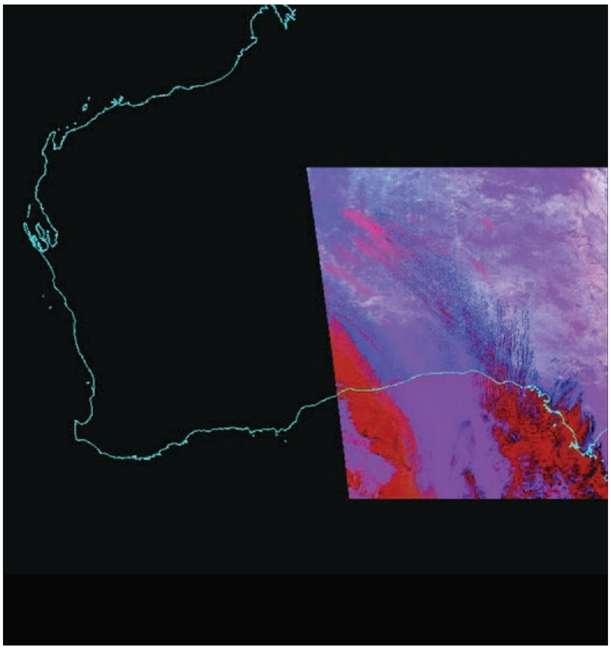


*Figure 4: Showing pre-frontal smoke and dust over western inland Australia*

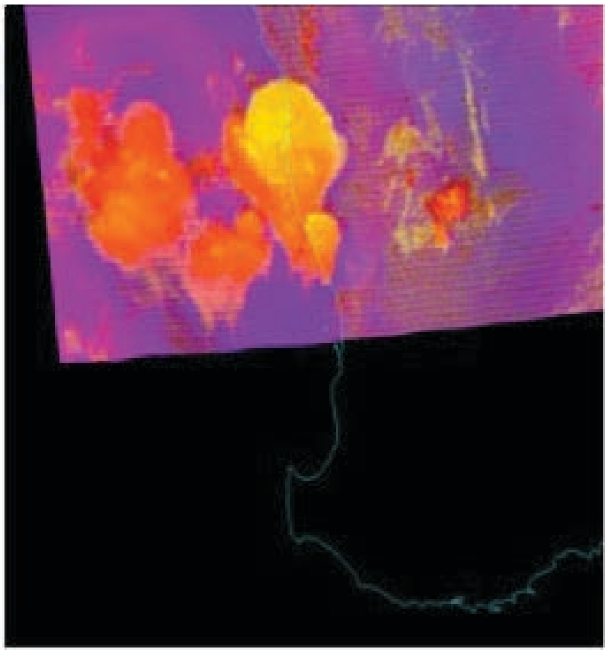


*Figure 5: Detection of Severe Storms.*

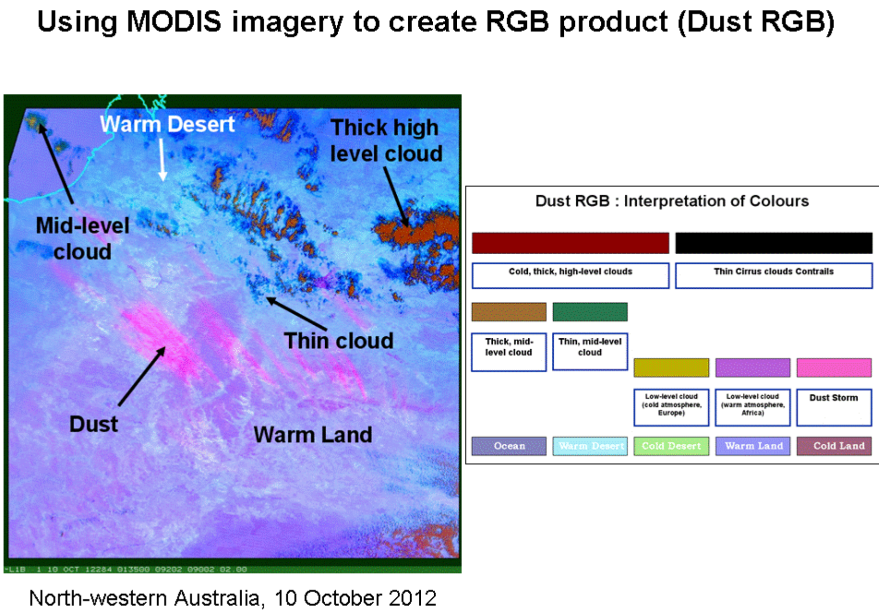



*Figure 6: Presentation slide from Bodo Zeschke's talk on the practical use of RGB imagery for forecasters.*

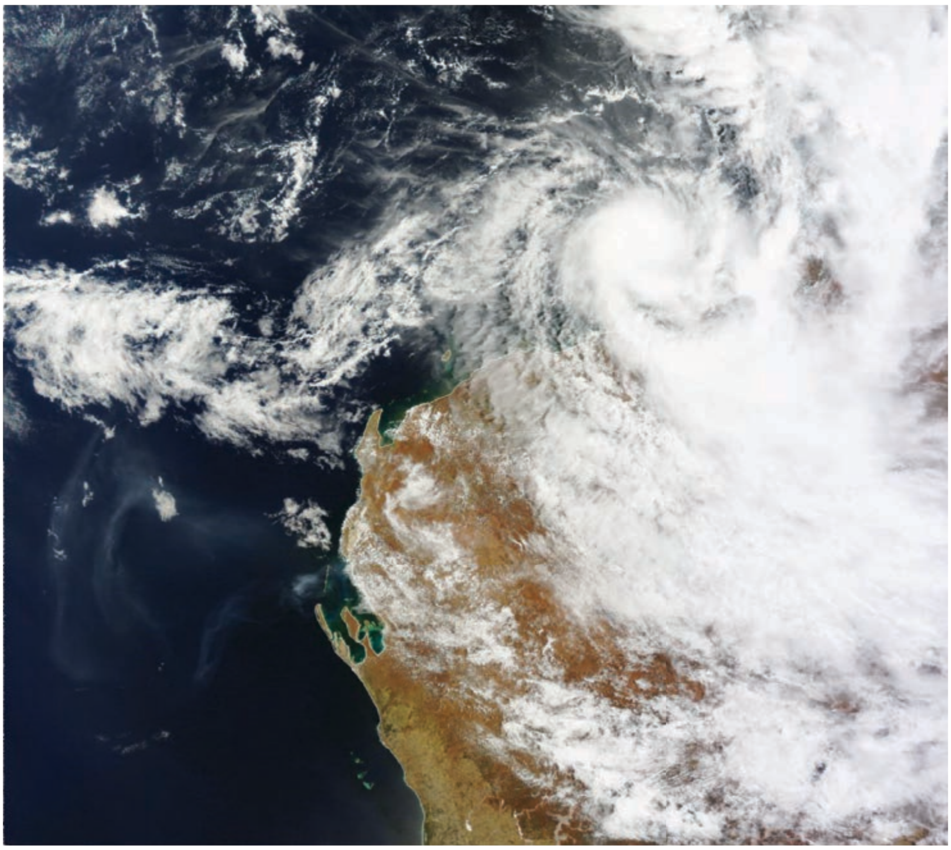


*Figure 7: RGB composite image for 11 January 2012.*

The Aqua satellite also carries the Atmospheric Infrared Sounder (AIRS), which provides atmospheric temperature and moisture profiles at high spectral resolution. Image products describing the temperature and moisture structure of the atmosphere are also produced by IMAPP software for delivery to forecasters. AIRS data have shown major positive NWP impact overseas (Tobin et al 2006), and are being assimilated operationally in the Bureau's ACCESS NWP system. Figure 8 highlights the impact of AIRS on model 1000-hPa Anomaly Correlations for the southern hemisphere for a case study period. This was the first of a series of experiments which, even at this early stage (2004), showed that there was a significant positive impact made using this data.

### 2.3. NPP VIIRS and CrIS Data

The Suomi National Polar-orbiting Partnership (NPP) satellite is the first of the next generation of US polar orbiting meteorological satellites. NPP was launched on 28 October 2011 and carries five instruments: the Advanced Technology Microwave Sounder (ATMS), the Cross-track Infrared Sounder (CrIS), the Ozone Mapping and Profiler Suite (OMPS), the Visible Infrared Imaging Radiometer Suite (VIIRS), and Clouds and the Earth's Radiant Energy System (CERES). WASTAC has provided sample NPP data to enable the Bureau to test its systems to process these new instrument data sets. The processed CrIS and ATMS sounder data will benefit the Bureau's NWP system by adding a further suite of observational data that may be assimilated by the ACCESS model. The new VIIRS imagery will provide forecasters with the ability to visualize new channels, such as the day/night band, and create new products such as nighttime fog.

## 3. Sea surface temperature (SST)

The Bureau produces moderate-resolution sea surface temperature (SST) products in near real time from AVHRR sensors on-board the POES platforms. The POES data are captured using the network of L-Band receivers around Australia, including the WASTAC L-Band receivers, and Antarctica.

As these SST products are incorporated in operational systems, it is important that both the service level and product performance are routinely monitored. In 2012, 99% of SST data was processed and delivered within 3 hours to the Bureau's operational Global and Regional Australian Multi-Sensor SST analyses (GAMSSA and RAMMSA, respectively).

The Bureau's routine monitoring, which compares SST products to temperature observations from a network of ships and drifting buoys, demonstrated an increase in bias across the 2011/12 period.

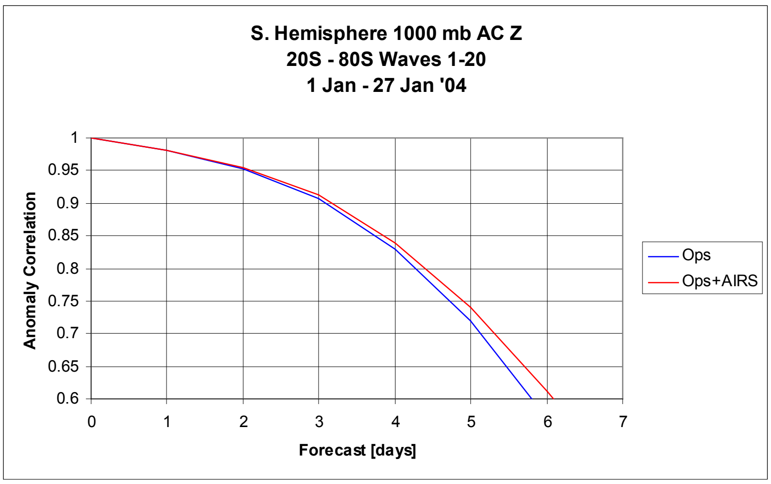
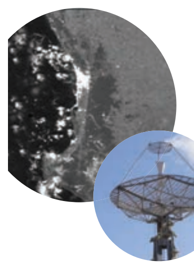



*Figure 8: 1000hPa Anomaly Correlations for the Global Forecast System (GFS) with (Ops.+AIRS) and without (Ops.) AIRS data, Southern hemisphere, January 2004. Graph provided by John Le Marshall.*



During 2012, with the support of IMOS, the Bureau's SST processing system was updated to incorporate more robust SST algorithms (Griffin, in prep.) and improved monitoring and logging. Additionally an experimental SST field using a consistent algorithm across both day and night (Griffin, in prep.) has been added to the output field to assist studies of diurnal variability (Beggs, 2012). These results will be presented to the 14th Group for High Resolution SST (GHRSST) Science Team Meeting in June 2013.

As reported previously, the Bureau's SST products have been formatted following the GHRSST Data Processing Specification (GDS) and are compatible with the Integrated Marine Observing System (IMOS) web portal and Australian Oceans Distributed Active Archive Centre (AO-DAAC).

## 4. Tropical cyclone monitoring

The Western Australian Regional Forecasting Centre, situated in Perth operates one of the Bureau's three Tropical Cyclone Warning Centres (TCWC), the others operating from the Northern Territory Regional Forecasting Centre in Darwin and the Queensland Regional Forecasting Centre in Brisbane. (See Figure 9).

Tropical cyclones (TC) are a major destructive force causing extensive wind damage, flooding from storm surges and embedded cumulonimbus and sometimes loss of life. Hence, it is extremely important to monitor these tropical cyclones (systems) closely using remotely sensed data. The exact nature of these systems, including the intensity and direction of movement are usually not determined by just one data source. Hourly satellite imagery from MTSAT-2 (operated by the Japan Meteorological Agency), Feng Yun 2 East

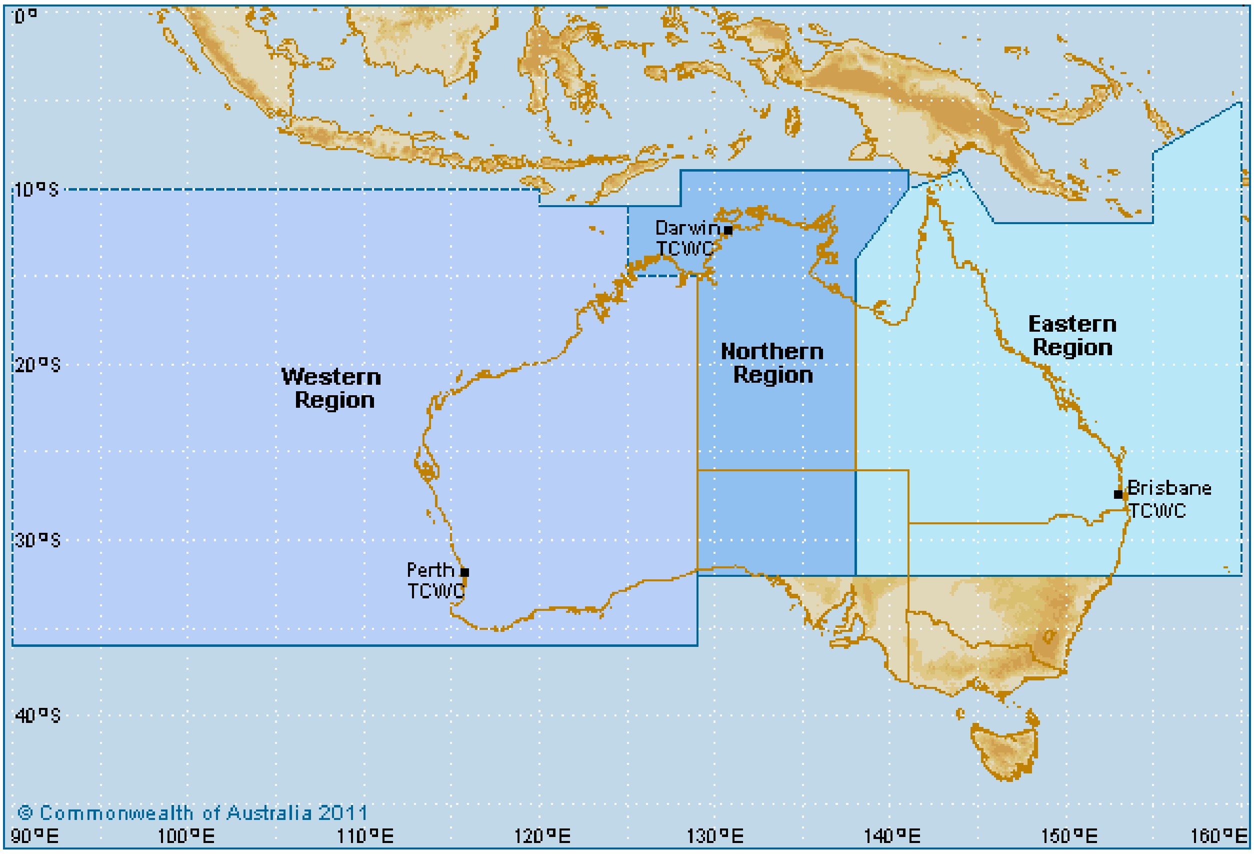



*Figure 9: The three Tropical Cyclone Warning Centres and their areas of responsibility. To the west of the Western Region, the area of responsibility falls to La Reunion*

| Tropical Cyclone | Period (2012) | Max Intensity | Impact on Coast or Other Aus. Territory | Means of Detection |
|---|---|---|---|---|
| | | | | |
| **Heidi** | 10 – 12 Jan 2012 | Cat 2 | Moderate | Satellite |
| **Iggy** | 23 Jan – 1 Feb 2012 | Cat 2 | Slight | Satellite |
| **Koji** | 05 – 08 Mar 2012 | Cat 2 | Nil | Satellite |
| **Lua*** | 09 – 18 Mar 2012 | Cat 4 | Significant | Satellite |
| **Mitchell** | 27 - 31 Dec 2012 | Cat 1 | Slight | Satellite |

* Classified as Severe Tropical Cyclone

*Table 1. List of Tropical Cyclones for the Period January 2012 to December 2012*

and Feng Yun 2 West (operated by the China Meteorological Administration) are used to monitor the movement and development of these systems whilst they are out at sea. As these systems approach the coastline of Australia more detailed data are required and so the forecasters usually use RADAR data and higher resolution satellite data (e.g. NOAA data or Moderate resolution imaging spectrophotometer (MODIS) data) to assist in the analysis of the severity of these systems. Having these data available and being able to predict with accuracy how these systems will evolve provides the forecaster with the ability to warn the public of the potentially impending danger with large lead times so that the public are able to take refuge, prepare their properties or make other arrangements with plenty of time to spare.

Since the WASTAC L-Band and X-Band provides this higher resolution data, it is obvious that the WASTAC ingestion and processing systems are extremely important to the fine detail analysis for the monitoring of these severe weather events.

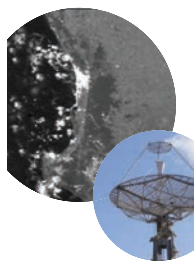
For the period 1 January 2012 to 31 December 2012, there were five tropical cyclones that entered or formed within Perth TCWC's area of responsibility (See Table 1). Of these, the most severe tropical cyclone that threatened the Australian coastline was Severe Tropical Cyclone Lua.

## Tropical Cyclone Mitchell (27 – 31 December 2012)

A weak low formed in the monsoon trough during 27 December near 14S 114E. The low moved to the southwest and gradually intensified, reaching tropical cyclone strength on the morning of 29 December near 17S 111E. Mitchell moved in a general southerly track and was downgraded below tropical cyclone strength late on 30 December when it was over 400km west northwest of Carnarvon.

Tropical Cyclone Mitchell (see Figure 10 and 11) was a short-lived category 1 system well off the Western Australian coast, having no significant impact on the coastline.

For further information on Tropical Cyclones, please see: http://www.bom.gov.au/cyclone/index.shtml



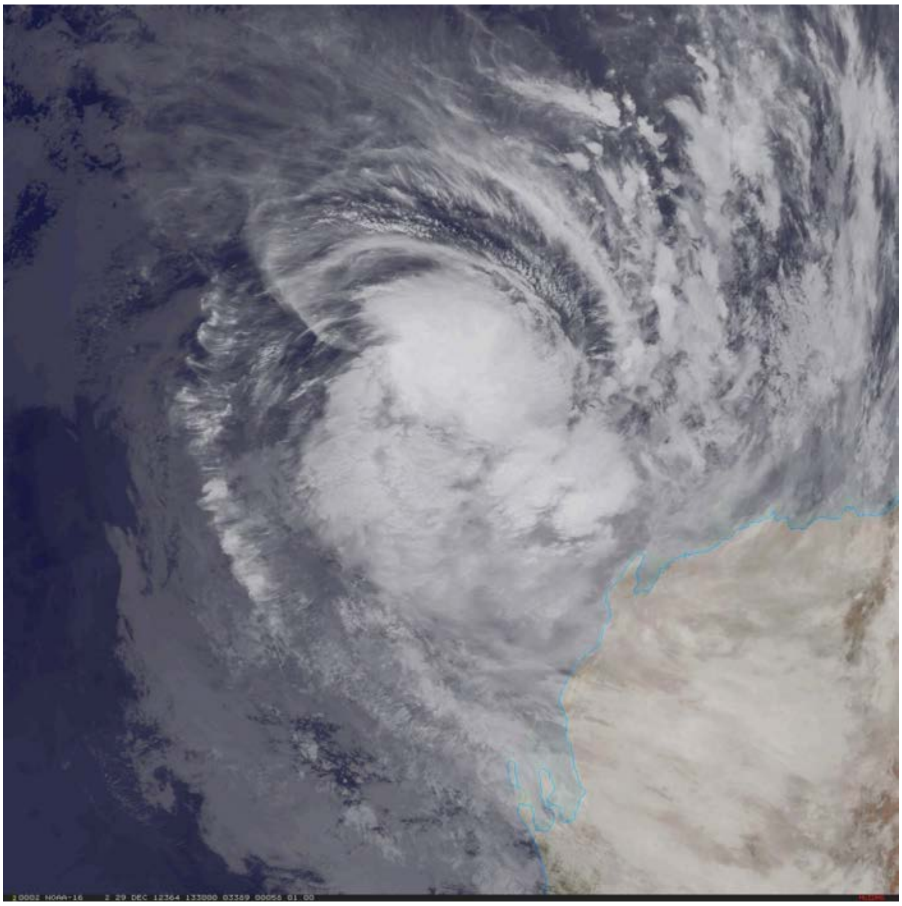


*Figure 10: Tropical Cyclone Mitchell off the Western Australian Coast. The image shows the lack of organisational structure within the cloud mass. TC Mitchell was a short lived Category 1 system. Image taken from NOAA-16, 13:30 UTC, 29 December 2012.*

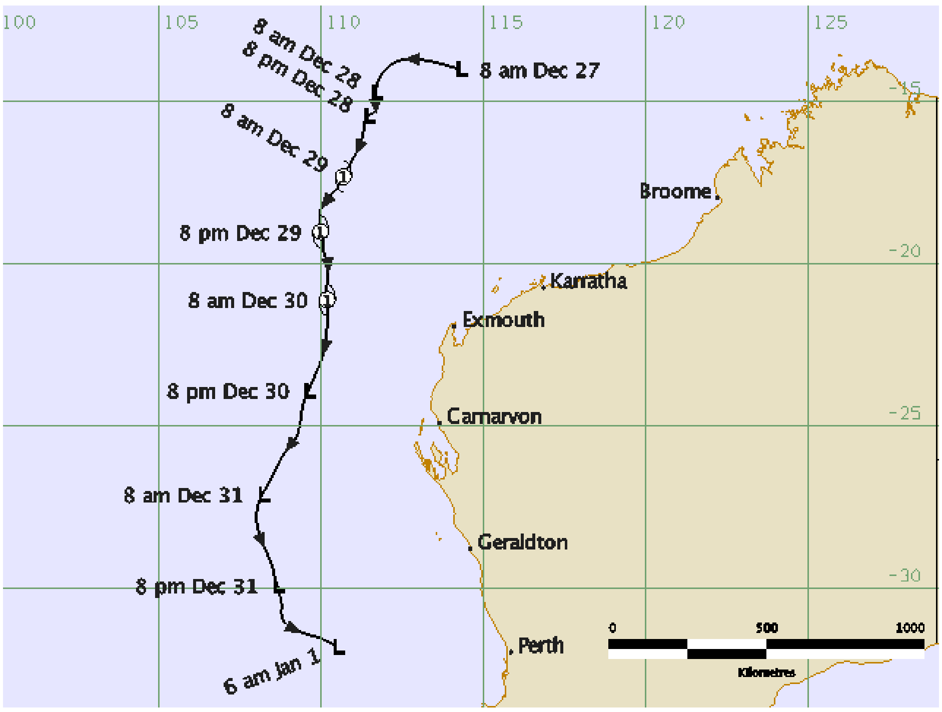



*Figure 11: The operational track of TC Mitchell showing development from a tropical low to a category 1 tropical cyclone and finally its decay into a sub tropical low when it passed over cooler waters.*

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Beggs,H. 2012, Overview of the GHRSST Tropical Warm Pool Diurnal Variability Project, Joint Workshop on Tropical Warm Pool and High Latitude SST Issues, Melbourne, 5-9 March 2012

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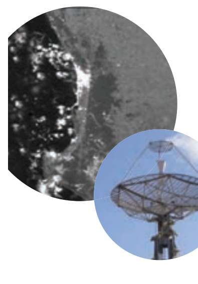
Tobin, D. C., Revercomb, H. E., Knuteson, R. O., Lesht, B. M., Larrabee Strow, L., Hannon, S. E., Feltz, W. F., Moy, L. A., Fetzer, E. J., and Cress, T. S , 2006, Atmospheric Radiation Measurement site atmospheric state best estimates for Atmospheric Infrared Sounder temperature and water vapor retrieval validation, Journal of Geophysical Research, Vol. 111, 2006



# CSIRO, Canberra

Edward King

## National MODIS Base Data Collection

CSIRO and WASTAC-partner Geoscience Australia (GA), with the support of the Integrated Marine Observing System (IMOS) and the Terrestrial Ecosystem Research Network (TERN), has created a comprehensive archive of MODIS data for Australia. The National Computational Infrastructure (NCI) in Canberra hosts the data collection which includes historical data from start-of-mission for both Terra and Aqua spacecraft. The archive is maintained in near real time by the direct ingestion of contemporary MODIS overpasses received by WASTAC, GA, the Australian Institute of Marine Science (AIMS) and the Bureau of Meteorology, supplemented by data downloaded from NASA in the US.

The basic data unit in the collection is Level-0 PDS data in 5-minute granules. Level-0 data was chosen since it has had the least processing applied (so is unlikely to need revision) and because it is foundational for all other products. This means that whenever the MODIS instrument calibrations are adjusted, typically every 6-12 months now, the products can be regenerated locally from the Level-0 data, rather than having to download multiple terabytes from the US each time. The enormous processing capacity available at the NCI is fundamental to this strategy. Upon ingest the overpasses received locally (from Australian reception stations) are split into 5-minute granules aligned with the NASA granules, and all data within a 5-minute window is merged to progressively create a best-quality granule over the course of each day.

The most recent 6-months of data are held online at the NCI for fast access whilst the older data is in near-line storage (a migrating filesystem). To facilitate faster retrieval, this near-line archive is arranged so that all the granules for a single day for either Aqua or Terra, by day or by night, are grouped together. An installation is maintained of the latest versions of the NASA SeaDAS processing system, together with the necessary spacecraft ephemeris and auxiliary data (eg atmospheric correction fields) to enable the most up to date processing of the archive.

These data are being used primarily by IMOS to create daily 1km resolution ocean colour products and by TERN for daily high resolution terrestrial surface reflectances. These data sets in turn support the creation of higher level derived products such as net primary productivity in the ocean and reflectance products adjusted for bidirectional effects on the land. In addition to these core applications, the data sets are available as a resource for Australian researchers for use at the NCI or elsewhere. Several projects have taken advantage of this; a notable example is the eReefs collaboration which is producing an integrated marine water quality monitoring system for the Great Barrier Reef.

## Australian SeaWIFS Archive

The SeaWIFS sensor carried on the SeaStar satellite routinely acquired accurately calibrated reflectance data at 1km resolution between 1997 and 2010. These data provide the first daily moderate resolution imagery capable of delivering ocean colour products. Scenes received by WASTAC in Perth, the Australian Institute of Marine Science (AIMS, Townsville) and CSIRO Marine and Atmospheric Research (CMAR, Hobart) between 1997 and 2007 have been collected and stitched together by CMAR to assemble a comprehensive 1km archive for this instrument. Together these data provide near complete coverage of the Australasian region (Figure 12).

With the support of IMOS, the archive is held at the NCI in Canberra and consists of the merged passes stored as ~13000 L1B swaths, and a L2 archive of ocean colour products, computed using the recent SeaDAS 6.4 processing suite, also in swath format. Selected products, including chlorophyll using the NASA OC3 and OC4 algorithms, total suspended matter and light attenuation at 490nm have been extracted and remapped onto map grids to facilitate use.

Although the primary focus is on the ocean colour imagery, the L1B data are complete and include land areas. All the data are available for use by Australian researchers in both marine and terrestrial applications.

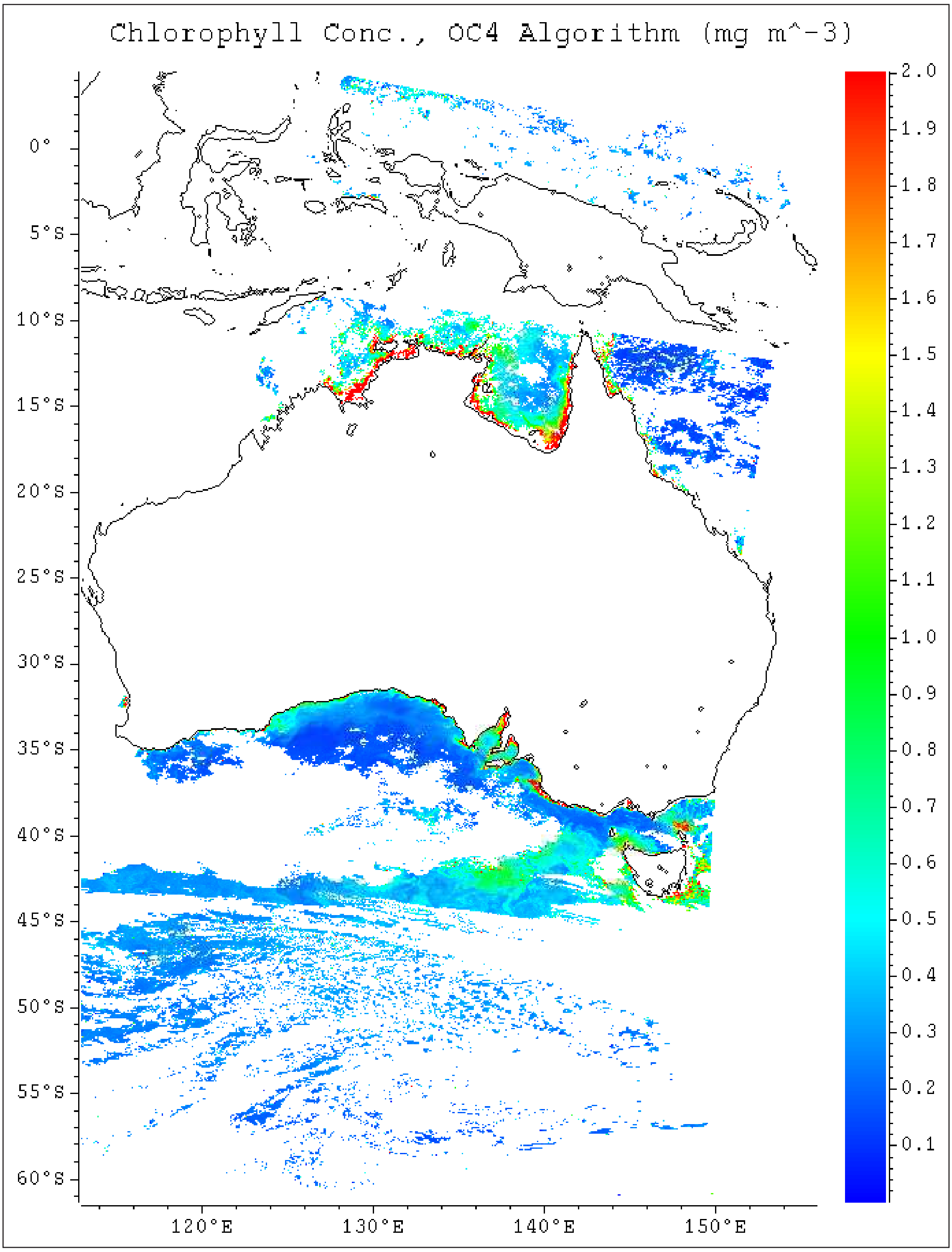



*Figure 12. A 1km Chlorophyll map for Australia on 2004/02/18 derived by merging SeaWIFS data recorded in Queensland, Tasmania and Perth.*

## Extending the Australian NOAA/AVHRR Data Set

As reported in previous years, CSIRO continues to operate a facility to stitch together the NOAA/AVHRR imagery collected daily in Hobart, Melbourne, Townsville, Darwin, Perth and Alice Springs by WASTAC, its partners, and AIMS. This system is operated at the CSIRO High Performance Computing Centre in Melbourne and ingests and processes data from each of the contributing stations to progressively build up more complete and higher quality data sets which are immediately made publicly available over the web. This stitched data set is used by WASTAC for several applications, it forms the basis for the IMOS sea surface temperature (SST) products created by the Bureau of Meteorology, and is used in the creation of the Australian vegetation index product delivered by TERN/AusCover.

In 2012, the data processing system was ported to the Bureau of Meteorology for use in improving the NOAA/AVHRR data set derived from reception stations in the Antarctic. These data in turn are used to produce a higher quality Southern Ocean SST product.

The operation of this system by CSIRO, supported by the agencies that run the reception stations and contribute the data, has now resulted in a high quality national NOAA/AVHRR archive extending from April 1992 to the present.

# Landgate, Satellite Remote Sensing Services, Floreat

## Inland flooding associated with cyclone Rusty

### Andrew Buchanan and Mario Ferri

Tropical Cyclone Rusty was initially classed as a category four system however as it passed over the Pilbara coast on Wednesday afternoon $27^{th}$ February 2013 it was downgraded into a category three system. Pardoo station, north of Port Hedland, felt the full force of ex-tropical cyclone Rusty with associated widespread flooding, loss of livestock and damaged buildings.The most dramatic effect of the passage of Cyclone Rusty was the resultant flooding of the De Grey catchment. The De Grey catchment hosts a number of remote communities, stations and small portions of the Great Northern Highway.

For this event Landgate's FloodMap service was able to capture the flood waters associated with the passage of Cyclone Rusty. The flood information was captured primarily to support disaster mitigation efforts of the Department of Fire and Emergency Services and the Bureau of Meteorology.
Due to the heavy cloud associated with the cyclone, radar imagery (COSMO-SkyMed) was ordered in order to see the flood water through the cloud. This radar data is used to supplement the information provided by the routine capture of surface water occurrence by the MODIS sensors.

According to Department of Water records, the peak flow of the De Grey river was in the afternoon of the $1^{st}$ March 2013. Even though the radar capture took place early in the morning of the $2^{nd}$ March 2013 significant areas of surface water were captured by the radar data. On inspection of the relatively coarse (250m spatial resolution) MODIS infra-red data there was very good agreement between the two sets of surface water capture. A decision was made to combine the MODIS and the radar into one shape file so as to capture a cumulative surface water record for the $1^{st}$ and $2^{nd}$ March 2013. The results of this capture are displayed in the graphic Figure 13 opposite:

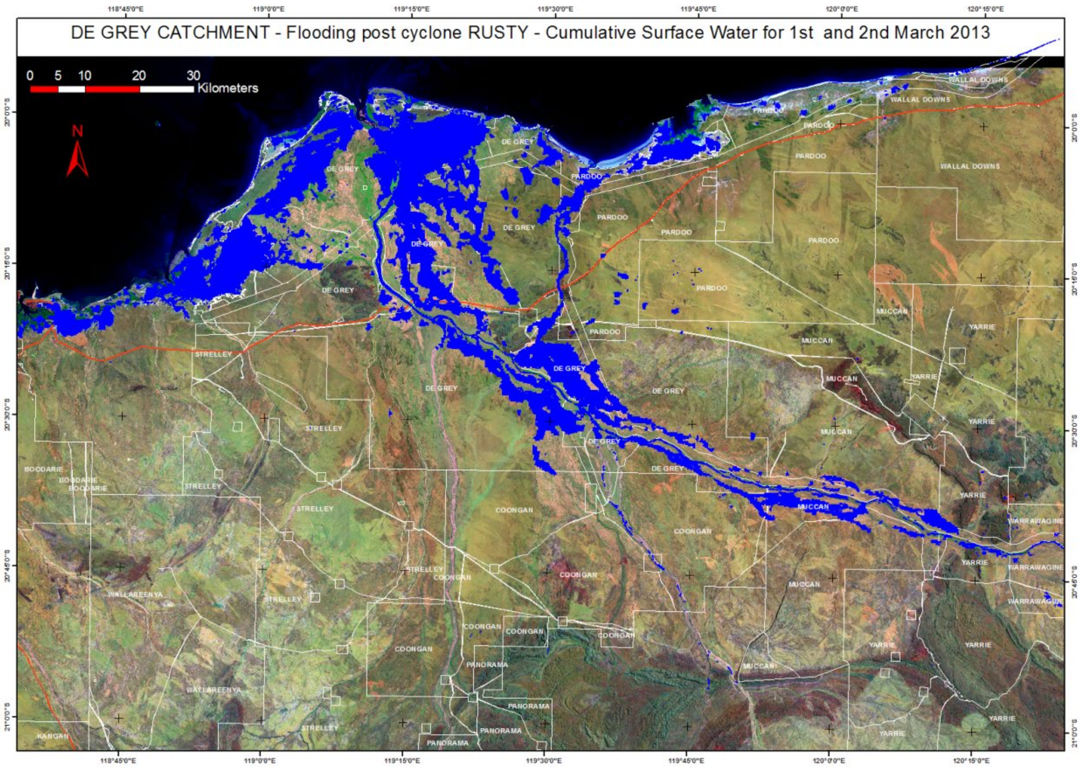



*Figure 13. Radar flood mapping combined with MODIS FloodMap data – flood in blue*

## Firewatch - time since last burn

**Carolyn McMillan**

Landgate maps fire burnt areas from NOAA/AVHRR Satellite imagery Australia wide every nine days. At the end of each month the data is aggregated and cleaned and added to an archive of Fire Burnt Areas. The ongoing processing of the most recent NOAA/AVHRR data and the back processing of historical data has extended the archive of fire burnt area data from January 1988 to December 2012.

A GIS analysis was undertaken on the fire burnt area archive to produce a time since last burn dataset. This dataset aggregates all the fire burnt area data from 1988 to 2012 (Figure 14) and calculates the number of years since fire has been mapped, Australia wide.

The dataset is updated at the end of each month as new data is added to the archive.The Time Since Last Burn dataset is an input into fire spread modeling and also could be considered in both fire planning and fire suppression activities.

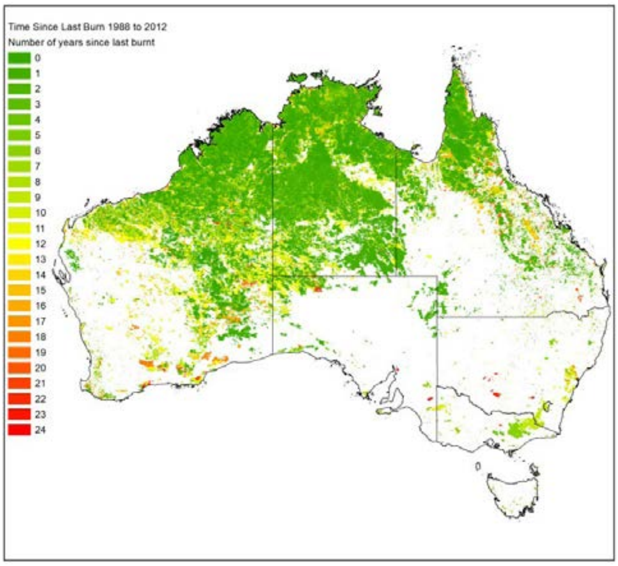



*Figure 14: Australia wide Time Since Last Burn from 1988 to 2012.*

## Modis vegetation growth indicators in WA for 2012

Norm Santich

The Normalised Difference Vegetation Index (NDVI) has been generated from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on a weekly basis using a maximum-value compositing scheme since 2003. NDVI is highly sensitive to chlorophyll, which provides a convenient way to image the amount of green vegetation cover over land at a 250 m resolution.

A year of interest can be put into context with other years in the MODIS archive by selecting an NDVI composite from the same time of year from all years, calculating the mean NDVI and the standard deviation. The difference of a pixel of interest from the mean value in terms of the number of standard deviations is known as the standardised anomaly. In statistics, the standardised anomaly is also known as the z–score, and is given mathematically as:

$$z = \frac{x - \mu}{\sigma}$$

where μ is the mean and σ is the standard deviation.

The standardised NDVI anomaly image for the week commencing 4 January 2012 shows generally greener than average conditions across much of Western Australia at that time of year, particularly in the Eucla. Much of the Wheat Belt was also showing higher than average NDVIs at that time of the year due to a much wetter than average spring and early summer in 2011. By examining the standardised NDVI anomaly images at quarterly intervals (Figures 15 – 18) it can be seen how this situation is largely reversed due to a dry winter in the Wheat Belt and fires in the Northern Interior. Wetter than average conditions in the north east Gascoyne during 2012 are also highlighted by positive anomalies in the NDVI.

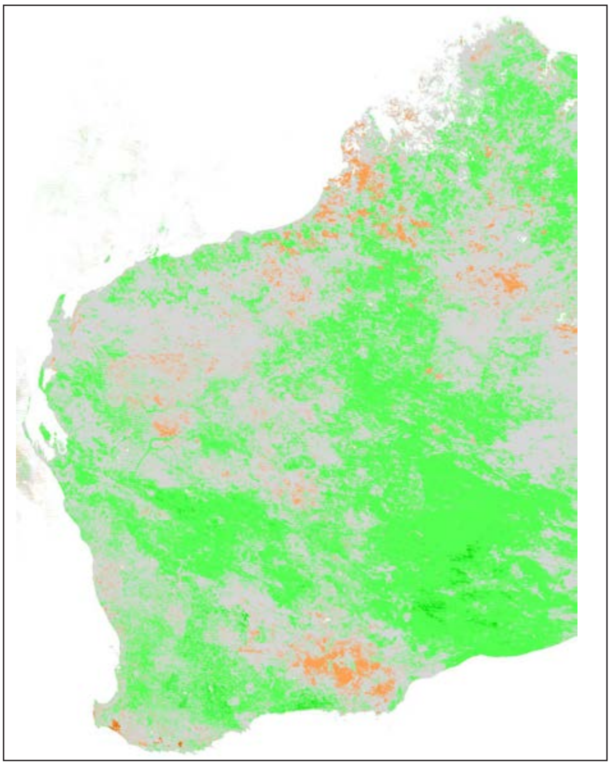


*Figure 15. A standardised NDVI anomaly image of WA for 4/1/2012*

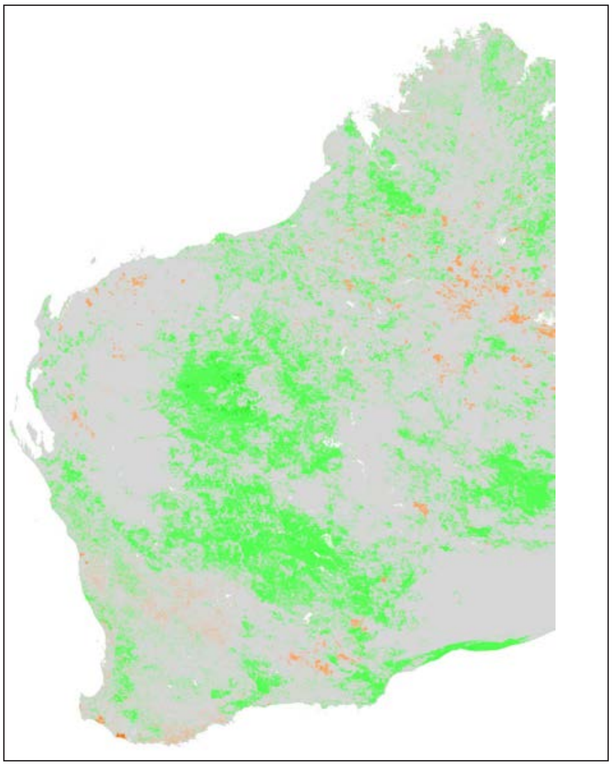


*Figure 16. A standardised NDVI anomaly image of WA for 4/4/2012*

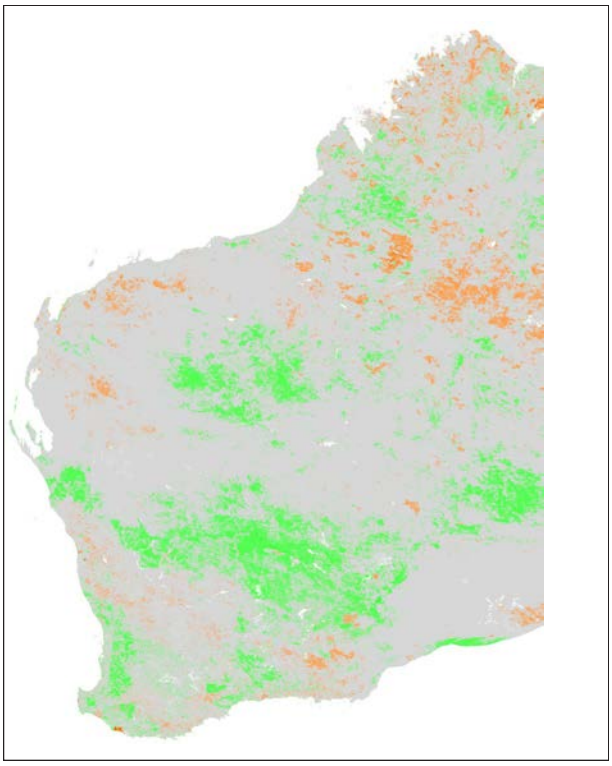


Figure 17. A standardised NDVI anomaly image of WA for 4/7/2012

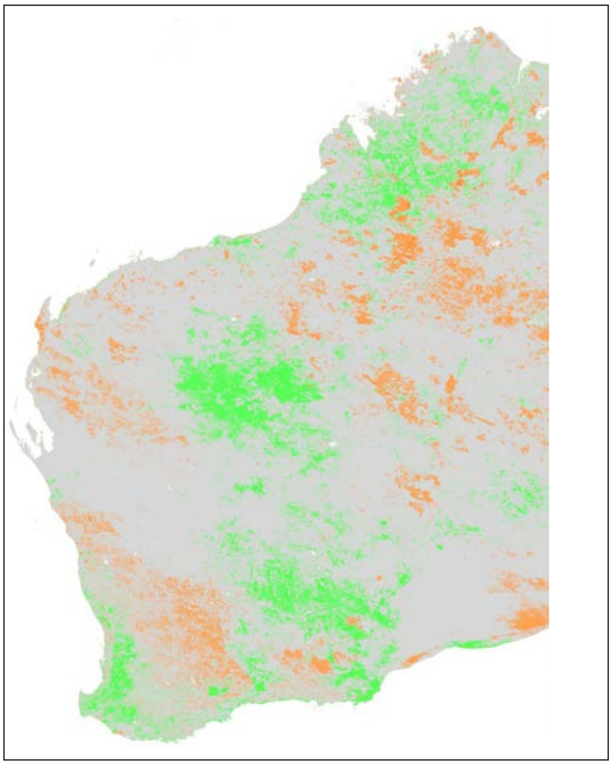


Figure 18. A standardised NDVI anomaly image of WA for 3/10/2012

## Pastures from space – a pasture biomass tool to aid farm management

Richard Stovold, Norm Santich, Sarfraz Khokhar

The Pastures From Space program continues to provide web based delivery of Pasture Growth Rate (PGR) and Feed on Offer (FOO) or biomass information, every week, to farmers in the south western agricultural zone of Western Australia and the southern agricultural regions of eastern Australia (Figure 19). The information is available as an annual subscription service and is distributed by our licensed consultant Fairport Technologies.

The consortium partners comprising Landgate, CSIRO and Department of Food and Agriculture WA continue their support of the program which has been used by the agricultural market for over 7 years.Farmers across Australia can subscribe to Pastures From Space as a weekly web-based delivery service through Fairport Technologies.

Recent studies and interaction with local farm producers and district agronomists have highlighted the value of this information for early season farm planning. Investigation to provide early season estimates of potential available feed biomass for stock has been identified as a key advance for the industry.This new innovation is being evaluated.

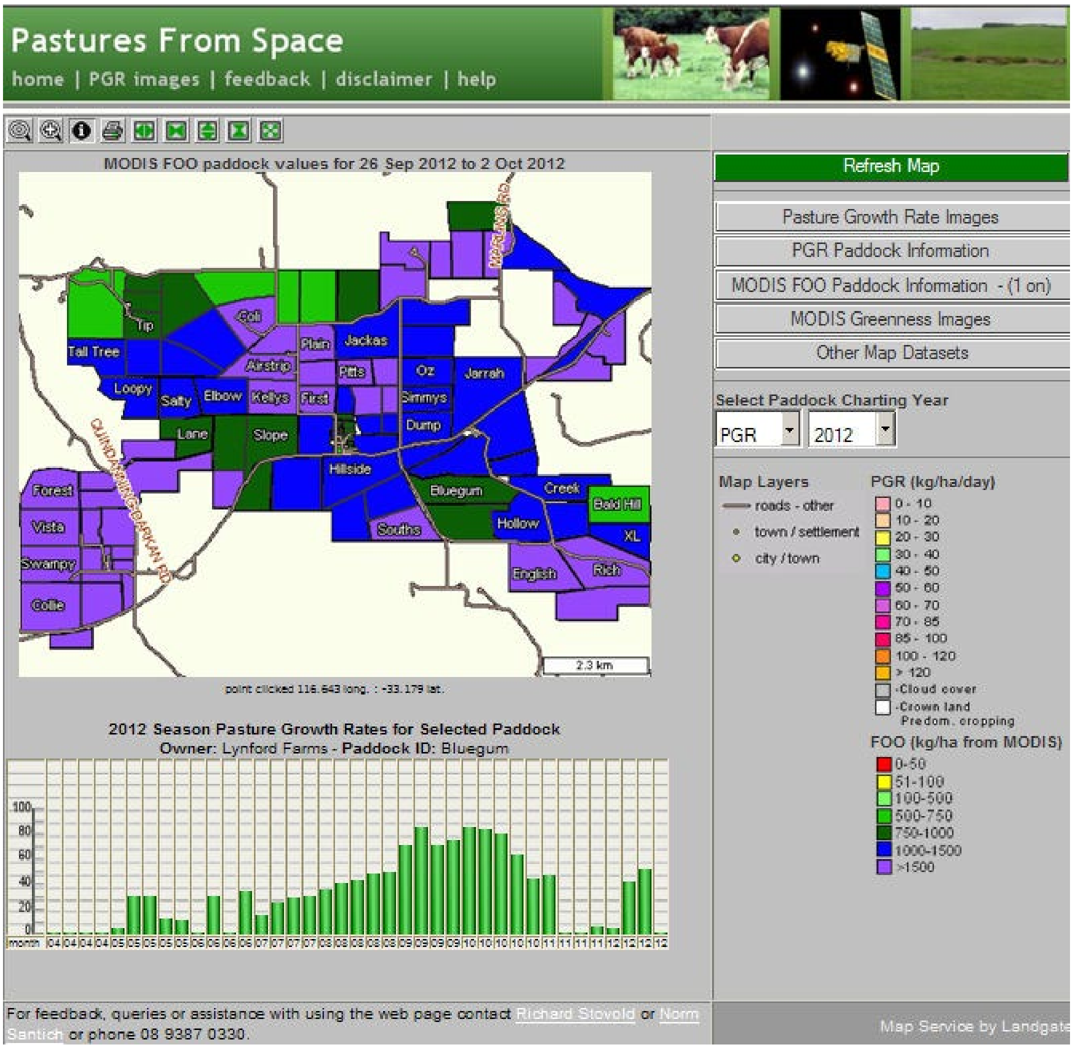



*Figure 19: Weekly Feed On Offer (FOO) information available online at paddock level covering a farming property in Williams Western Australia for the weekly period 26 September to 2nd October 2012.*

To view the Pastures From Space information visit http://www.pasturesfromspace.csiro.au .

To visit the Landgate website http://www.landgate.com.au (go to the Farm channel and select Pastures From Space) .

For information on the Fairport subscription service visit http://www.fairport.com.au/pasturewatch

## Plant vigour indicator index maps for regional agricultural season growth trends

Richard Stovold, Norm Santich

The Plant Vigour Indicator is being generated weekly from processed MODIS NDVI data providing a season update of plant growth in the South West wheatbelt of Western Australia. Landgate is providing farmers and land managers access to the data on the Agimage Landgate website under the farm channel. The information is published fortnightly in the Countryman newspaper.

The imagery (Figure 20) can assist farmers to determine the progress of the season and provides vital production information for their properties.

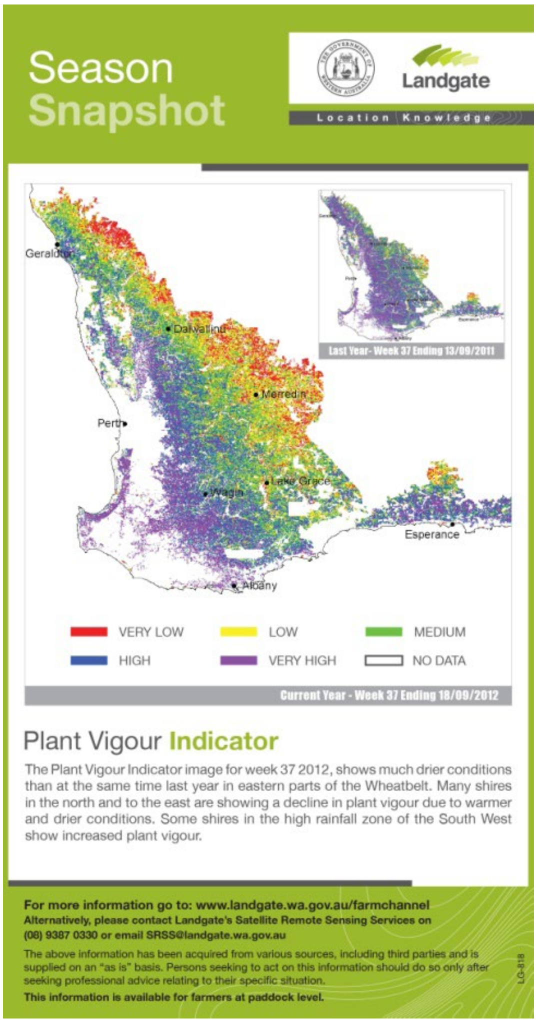



*Figure 20: Seasonal comparison of the Plant Vigour Indicator for September 2011 and 2012.*

## Frost mapping and Land Surface Temperature (LST)

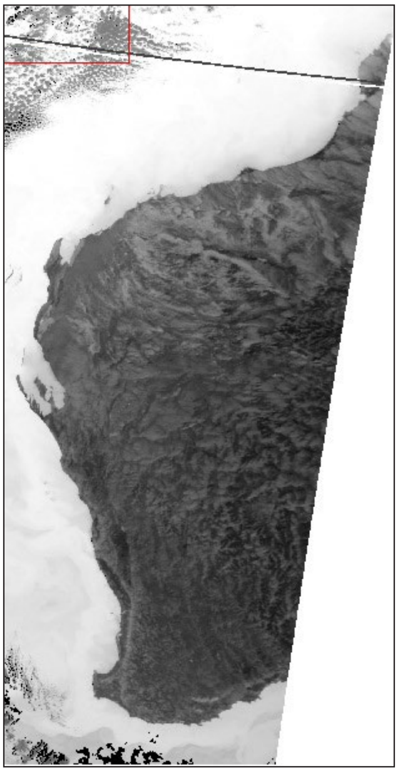
Andrew Buchanan, Mike Steber,
Mario Ferri, Norman Santich

Frost is a significant risk over much of Western Australia, particularly in spring when the crops are at their most susceptible stages of flowering and grain filling. The historical incidence of frost varies greatly across the agricultural regions of Western Australia, with greatest occurrence in the central, eastern and southern regions. The northern and coastal regions generally have a lower risk (DAFWA – www.agric.wa.gov.au/frost). During the colder, latter part of the night in the winter and early spring months the MODIS sensor on Aqua passes over Western Australia before 4am while the NOAA-AVHRR series have sensors that capture information between 4am and 7am. These are the times at which frost events are most likely to occur.

Soil and air temperature, wind speed/direction and soil moisture are recorded automatically at roughly one to three minute intervals from about 50 Department of Food and Agriculture (DAFWA) weather stations in the south west of Western Australia. Landgate has seen the value of this information and is now archiving it every three minutes directly from the DAFWA weather station web page. This has enabled an investigation into the relationship between the satellite derived land surface temperature and the soil and air temperatures.

The study used the Sobrino Land Surface Temperature algorithm (Sobrino et al., 2003) which calculates emissivity's using NDVI thresholds so that there is no ambiguity with respect to the land cover classification of the pixel.

Two cloud free satellite scenes were chosen to compare to coincident weather station data. The first was an Aqua MODIS pass captured at 1:59 am WST on the 4/7/2012 and the second was NOAA-15 AVHRR pass at 4:57am WST on the 4/7/2012 (Figure 21). Figures 22 and 23 show the relationships between the satellite LST's and the surface air temperatures.



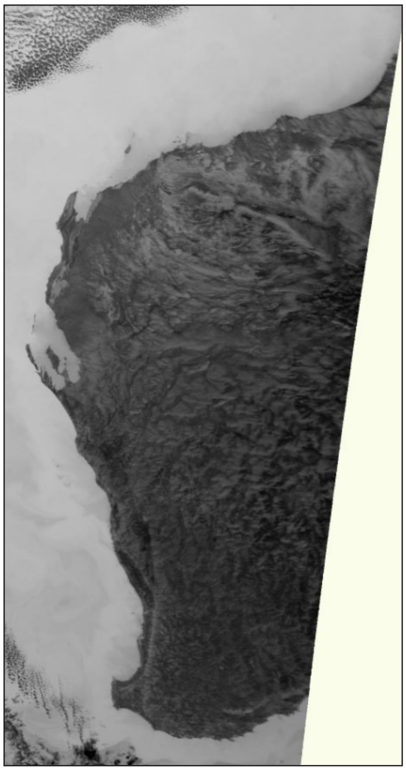


*Figure 21. Left – Cloud free Aqua MODIS pass at 1:59am WST 4/7/12*
*Right – Cloud free NOAA-15 AVHRR pass at 4:57am WST 4/7/12*

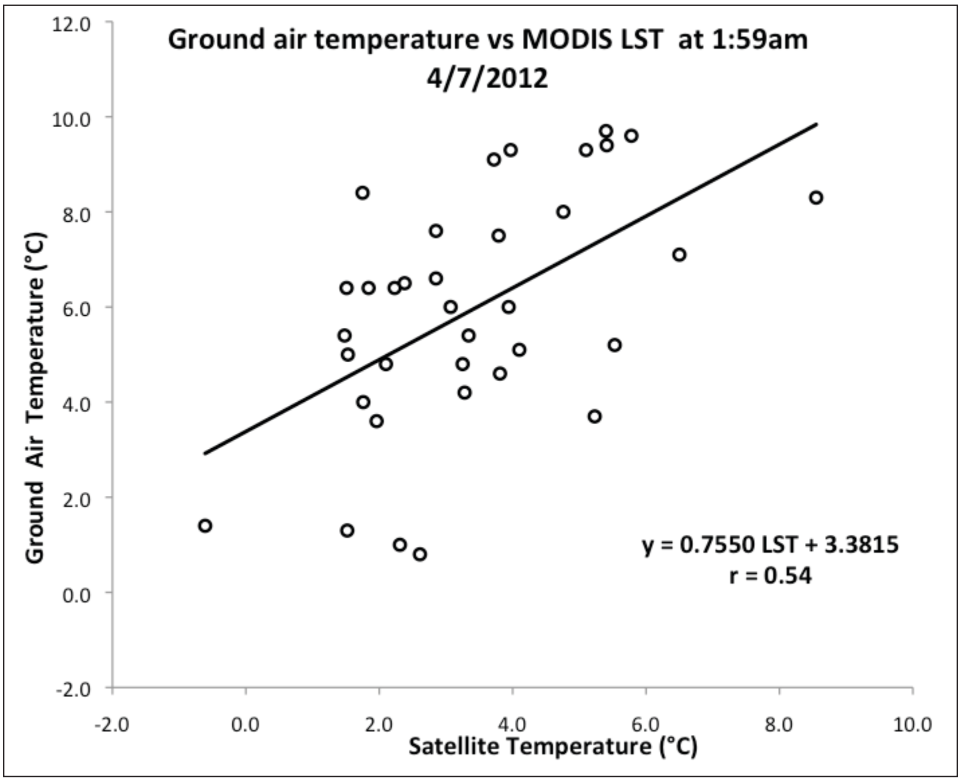



*Figure 22. Ground air temperature regressed against MODIS Aqua LST (Sobrino) at 1:59am 4/7/12*

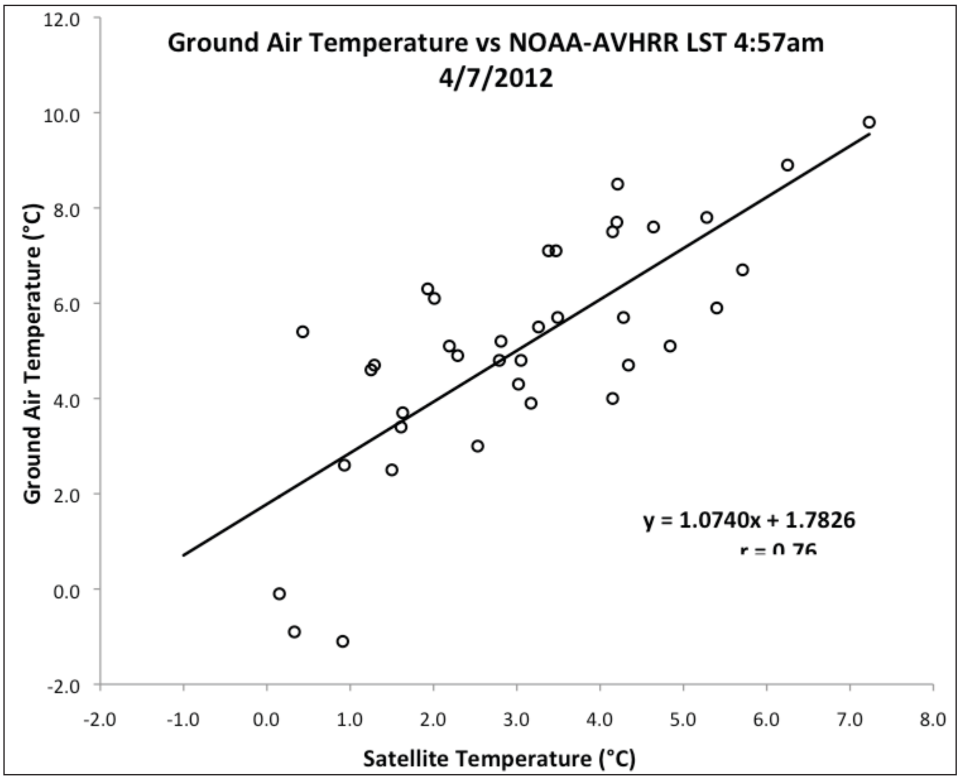



*Figure 23. Ground air temperature regressed against NOAA-AVHRR LST (Sobrino) at 4:57am 4/7/12*

It is important that any satellite derived environmental product be validated with ground truth information. The DAFWA weather stations provide an invaluable opportunity to match the satellite derived values with actual ground data. This investigation is an attempt to bring two related datasets together namely:

i) Satellite derived land surface temperature; and
ii) Ground soil and ground air temperature

The DAFWA weather stations' temperatures (soil and air) and the Sobrino satellite LST have low correlation coefficients. The satellite land surface temperatures record lower temperatures (on average 5 degrees Celsius cooler) than the ground station soil temperatures which are recorded at 4.5cm depth.

The satellite LSTs closest DAFWA ground station match are the air temperatures recorded at 1.25m height. Attempts could be made to adjust the satellites temperatures to the ground air temperatures to give a satellite adjusted air temperature product.

## Mapping Large Scale Aerosol Events Using MODIS Time Series of Surface Reflectance

**Ifra Khokhar, Brendon McAtee and Jackie Marsden**

As part of the Natural Disaster Resilience Program (NDRP) Extending FireWatch project to determine Aerosol Optical Depth (AOD) using the reflectance change-based methodology developed by Broomhall et al (2009), MODIS images were analysed to develop a reliable method of using satellite imagery for the detection of aerosols that is independent of land surface type.

In summary, following the methodology described by Broomhall et al (2009), daily surface reflectance values estimated from MODIS (Terra and Aqua), after being atmospherically corrected using the Simple Method of Atmospheric Correction (SMAC) process (Rahman and Dedieu, 1994) in which the AOD is fixed, are compared to the surface reflectance expected based on the Bi Directional Reflectance Distribution Function (BRDF) (Roujean et al, 1992) defined for the location on the Earth's surface being viewed by the satellite. Any difference between the estimated and expected surface reflectance is termed the 'reflectance change'. This reflectance change is assumed to be caused by aerosols in the atmosphere and is used to estimate AOD via a look up table produced through radiative transfer modelling of the atmosphere.

As an example of the utility of this method, Figure 24 compares the aerosol maps produced from the time series-based method of AOD estimation to the NASA MOD04 algorithm (Kaufman and Tanre, 1998) for an area in northern Australia on 13 October 2012. It can be seen that the time series-based method (Figure 25) delivers much better detail of bushfire smoke plumes compared to MOD04 because the spatial resolution of the product is 1.25km as compared to 10km for MOD04.

In the future, AOD features such as smoke plumes will be extracted and delivered as GIS-ready features and data layers to users of Landgate's FireWatch service (www.firewatch.landgate.wa.gov.au).

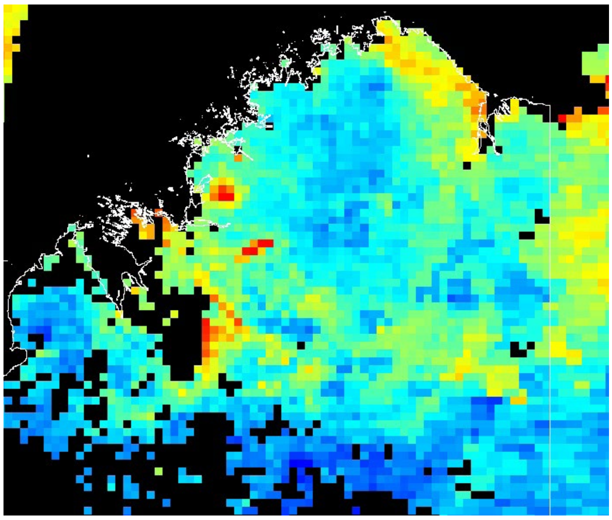


*Figure 24. Maps of bushfire smoke produced from MOD04 for 13 October 2012 in northern Australia.*

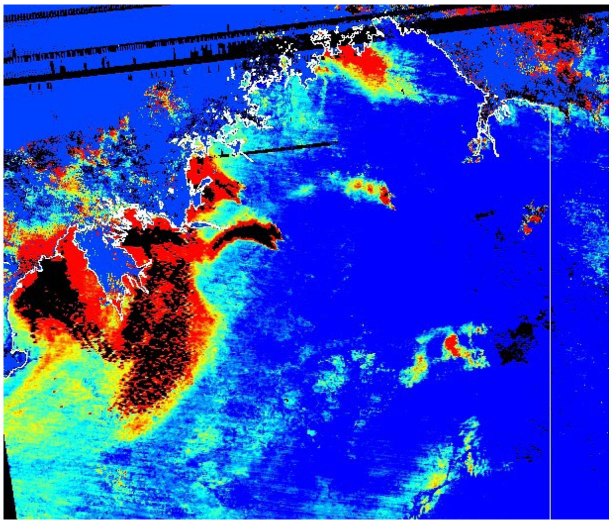


*Figure 25. Maps of bushfire smoke produced by the methodology of Broomhall et al (2009) for 13 October 2012 in northern Australia.*

*Smoke features are more clearly defined using the method of Broomhall et al (2009).*

## References.

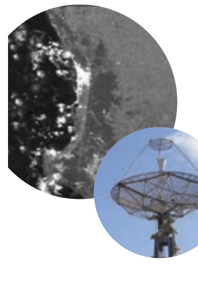

Broomhall, M., McAtee, B., & Maier,S., (2009)," An investigation into the remote sensing of aerosols based on MODIS data for Western Australia." In Springer Verlag series on Geoinformation and Cartography, Series Editors: Cartwright, W., Gartner, G., Meng, L., & Peterson, M. ISSN:1863-2246.,2009

Kaufman, Y. and D. Tanre (1998). Algorithm for remote sensing of troposhperic aerosols from MODIS. MODIS algorithm theoretical basis document: MOD04.

Rahman and Dedieu (1994), "SMAC: a simplified method for the atmospheric correction of satellite measurements in the solar spectrum. " International Journal of Remote Sensing 15, 123--143.

Roujean, J., M. Leroy, et al. (1992). "A bidirectional reflectance model of the Earth's surface for the correction of remote sensing data." Journal of Geophysical Research 97(D18): 20455-20468.

Sobrino JA, El-Kharraz J, Li L (2003) Surface temperature and water vapour retrieval from MODIS data. International Journal of Remote Sensing 24, 5161-5182.

# Geoscience Australia

## Historical Flood Mapping from Satellite Imagery for the National Flood Risk Information Project

On 17 November 2011 the Assistant Treasurer, Mr Bill Shorten announced the Government's response to the Natural Disaster Insurance Review. This response included the need to improve the provision to flood risk information which involves Geoscience Australia building, hosting and populating a single access point or shopfront to flood risk information. This also includes the development of national guidelines for flood modelling and collection, comparability and reporting. The purpose of the shopfront is to provide a single authoritative source of flood related information for use by all or any sector ranging from local government through to industry. The earth observation component will produce a time series of observed surface water over the continent of Australia as a spatial database. The time series will be derived from the historical satellite imagery available to Geoscience Australia, in particular the archive of Landsat-5 and Landsat-7 imagery, but with a view to also include historical data available from the MODIS archive. The spatial database will allow the time-series of observed water to be queried or combined to generate map products and web feature services.

The first proof-of-concept release of the National Flood Risk Information Project (NFRIP) was launched in November 2012, comprising a web-accessible database of flood studies for locations around Australia, and a flood mapping service (Figure 26 and 27) allowing the visualisation of flooding derived from Earth observation satellites. The flood mapping service concept comprises a national, MODIS-based product, and three Landsat study areas, demonstrating individual flood maps and flood summary information. The individual flood maps, available for the three study areas, demonstrate floods as observed by Landsat satellites for single dates. The flood

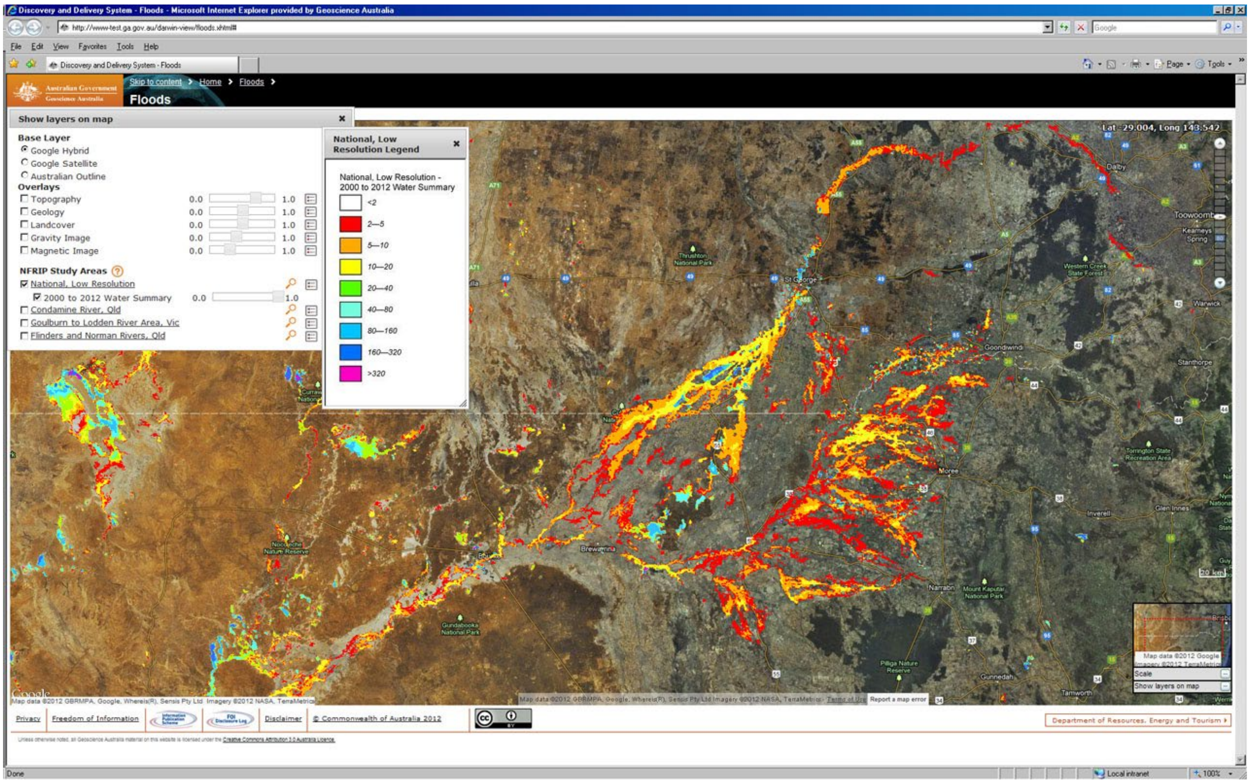



*Figure 26. A view of the online flood mapping service, showing an example of the national, MODIS-based flood summary product over the NSW-QLD border. The colouring of the observed water indicates how often water was seen at every point. Red areas are unusual events, including floods, while blue areas are usual conditions, such as dams and other permanent water bodies.*

summary product demonstrates long time series' of observations consolidated into single maps for MODIS nationally, and Landsat for each of the study areas, showing how often floods have been observed.

The project will release the flood summary product for priority areas across Australia by November 2013 (Figure 28), followed by the remainder of Australia by November 2014. In addition, a search-and-retrieve system will be made available online, allowing users to choose a location and retrieve individual flood maps where flooding was observed between 1987 and 2012.

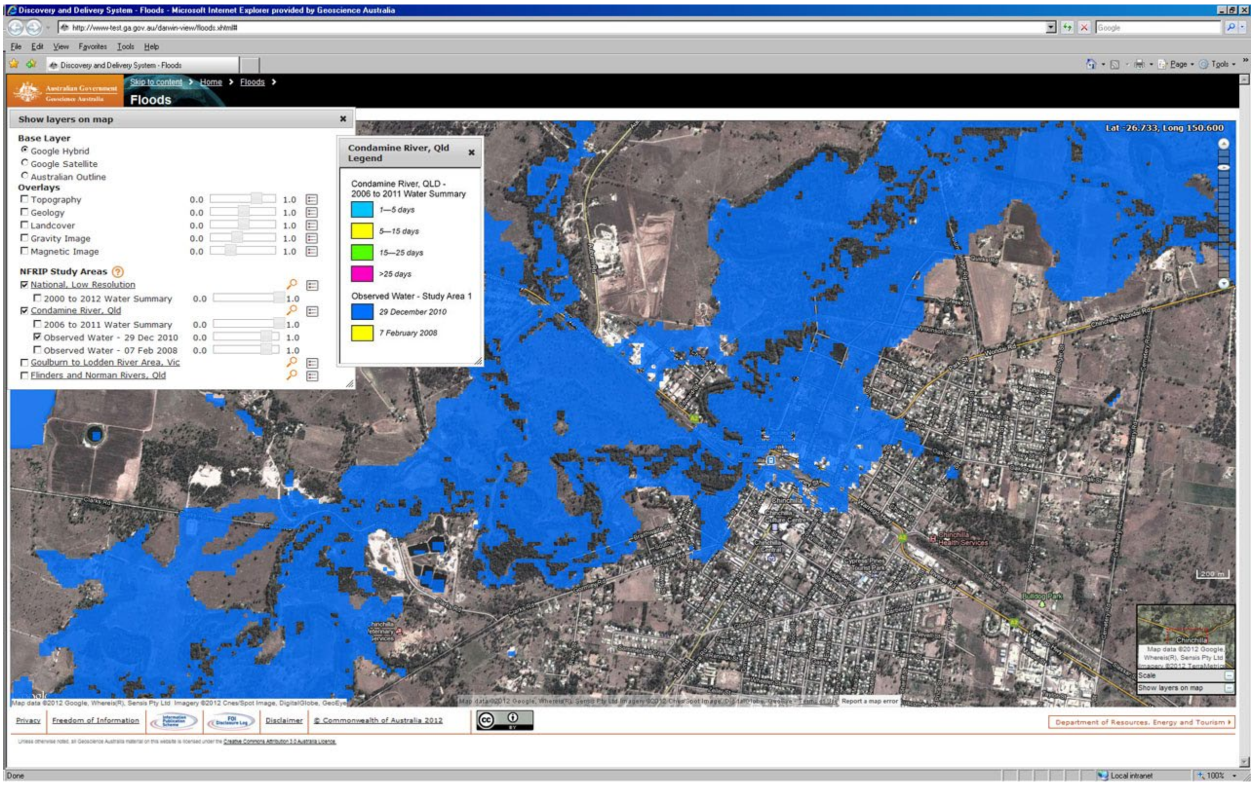



*Figure 27. Another view of the online flood mapping service, showing an example of a single observation of a flood by Landsat-5 on the 29th December 2010 over Chinchilla, QLD. The blue area indicates water as derived from the satellite image, and can be seen inundating parts of the township*

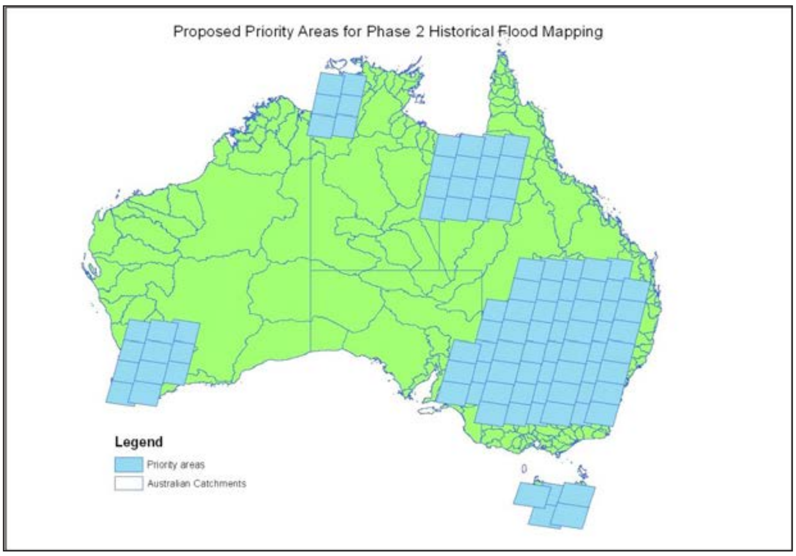



*Figure 28. Priority areas to be processed for the November 2013 release of NFRIP. Areas in blue indicate the Landsat scenes to be included in each priority area*

# Research Developments 2012



Investigations of new techniques for processing and applying satellite data continue at Curtin University, CSIRO and Landgate, and this section outlines some of the research being undertaken to underpin and improve the operational products described earlier.

## CSIRO

Edward King

### Earth Observation Informatics Platform

An important development for remote sensing activities in CSIRO in 2012 was the formation of an organisation-wide platform to leverage capability in Earth Observation Informatics (EOI TCP). Led by Dr Arnold Dekker, this platform will provide unifying support for EO technologies and techniques in CSIRO, with a focus on informatics. Other key areas of interest include sensor technologies, improved calibration and validation of remote sensing data sets, securing key time series for Australia, and development of application techniques such as model-data assimilation. The platform will also play an important part in enabling CSIRO to fulfill its role in the Commonwealth's National Earth Observations from Space Infrastructure Plan.

### Improving Regional Ocean Colour in IMOS

CSIRO operates the IMOS satellite remote sensing Ocean Colour sub-facility. One of the activities in this sub-facility is improving the applicability of global ocean colour algorithms in Australian waters through the compilation of in-situ reference data sets. These data are being contributed to NASA and ESA, as well as being used locally to match-up with the satellite ocean colour data sets also produced by IMOS. An important new source of these in-situ data, supported by IMOS, is the deployment of hyperspectral radiometers on research vessels in order to continuously characterise the light fields at the ocean surface under a wide variety of conditions.

The first of these radiometers, deployed on the Marine National Research Facility vessel the Southern Surveyor in late 2011, is a DALEC instrument manufactured by In-situ Marine Optics in Perth. The instrument contains three Zeiss UV-Vis enhanced spectroradiometers which are designed to measure spectral upwelling radiance ($L_u$), downwelling radiance ($L_{sky}$) and downwelling irradiance ($E_d$) in a near-simultaneous fashion, above water. A passive gymbal mount with adjustable damping stabilises the instrument during transit (Figure 1) allowing spectroradiometric measurements to be collected with consistent geometry whilst the ship is in motion. Pitch and roll sensors record data for quality control purposes. An embedded compass, GPS and motor control adjust the sun-relative azimuth angle ($\phi$) during data collection.


*Figure 1. (a) The DALEC instrument is mounted at the end of the boom extending from the foremast of the Southern Surveyor over the bow of the vessel (b) Close-up of the DALEC sensor head*

During 2012 the first 6 months of data from the first DALEC were analysed and lodged in the IMOS data repository (Figure 2 and 3). Since the DALEC is a new instrument, some effort has been invested in developing analysis methods, verifying correct operation and establishing QA/QC protocols for the data. Testing of matchups with MODIS imagery is building confidence in this new data stream.

The DALEC will be transferred from the Southern Surveyor to the RV Investigator once the latter is delivered in 2013. Based on the success with the first instrument, a second DALEC will be deployed on an AIMS vessel during 2013 to provide more coverage of tropical waters.

Further details of the DALEC deployment and data analysis are described in an extended abstract: "Autonomous Ship-Based Ocean Colour Observations on Australian Research Vessels", V.Brando, J.Lovell, E. King, R. Keen, P. Daniel, D. McKenzie, L. Woodward, R. Palmer, D. Mills, L. Besnard, M. Slivkoff and W. Klonowski, 2013, International Ocean Colour Science meeting, Darmstadt, Germany (http://iocs.ioccg.org/iocs-2013-meeting/abstracts/)

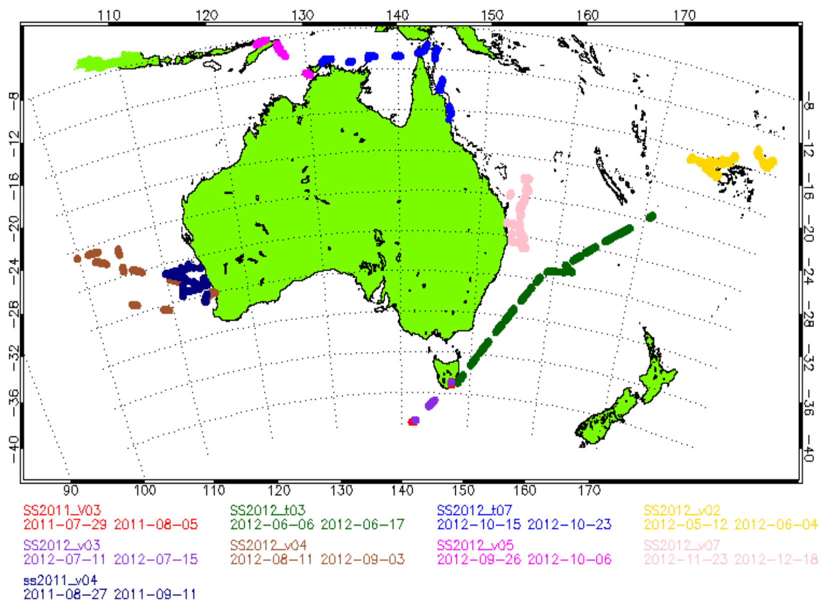



*Figure 2. Voyage tracks showing where the first 1.4 million DALEC spectra were collected in 2011 and early 2012.*

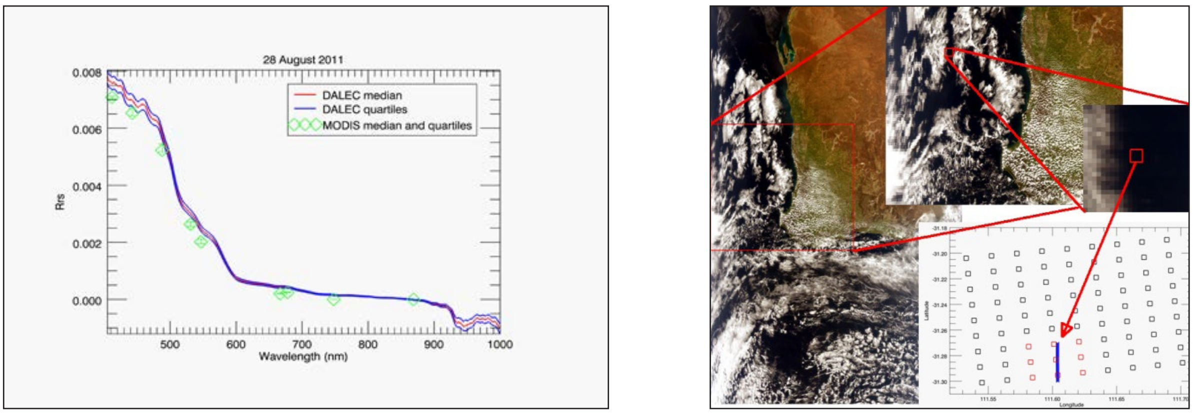



*Figure 3. Example comparison of DALEC reflectances (left) measured within half an hour of a MODIS Aqua overpass (right) during August/September 2011 off WA.*

# Curtin University of Technology

# Remote Sensing and Satellite Research Group (RSSRG)

## Shallow Water Products for the Hyperspectral Imager for the Coastal Ocean

Lachlan McKinna, Rodrigo Garcia and Peter Fearns

The Hyperspectral Imager for the Coastal Ocean (HICO™) is a prototype instrument that was installed on the International Space Station in September 2009. HICO is the first space-borne hyperspectral sensor designed with characteristics appropriate for coastal marine remote sensing. Present operational Earth observing sensors such as MODIS have a limited number of spectral bands (10 approx.) dedicated to ocean colour remote sensing with pixel resolutions of approximately 1 x 1 km. At these spectral and spatial resolutions MODIS often cannot resolve complex fine-scale features in coastal marine areas. To improve coastal marine remote sensing, the HICO sensor was developed with 87 contiguous bands from 400 – 900 nm, high signal-to-noise characteristics and a 90 x 90 m pixel resolution. Although HICO scenes are relatively small (42 x 192 km) compared to MODIS (1300 x 2000 km), the introduction of this sensor represents an important advance in remote sensing technology for coastal marine regions.

Throughout 2012, the RSSRG has been actively involved in the evaluation and research of HICO data. In particular, efforts have focused on the effectiveness of the TAFKAA atmospheric correction and development of shallow water algorithms for shallow aquatic ecosystems. Case studies using HICO data have focused on scenes captured over the Shark Bay World Heritage Area, Western Australia (see Figure 4). Shark Bay is a sensitive ecosystem, home to stromatolites and extensive seagrass meadows. Preliminary HICO-derived bathymetry and habitat maps are shown in Figure 5 and 6 respectively.

The RSSRG has been an active contributor to the HICO Data User's Group by sharing its experience with HICO data. Furthermore, the RSSRG have liaised with various institutes on the processing of HICO data including the US Office of Naval Research, Oregon State University and NASA.

Future planned HICO research includes specular surface (glint) corrections and characterisation of shallow water product uncertainties.

*Relevant Links:*
HICO Project: http://hico.coas.oregonstate.edu/

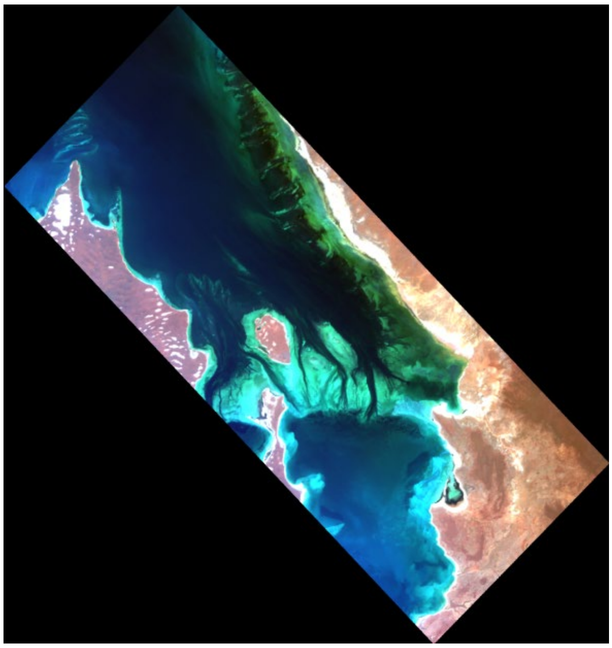


*Figure 4: A true colour HICO image of eastern Shark Bay, Western Australia*

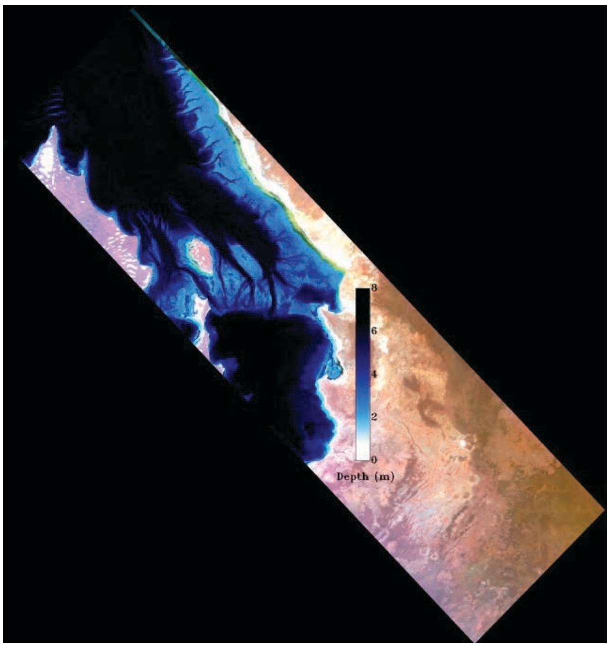



*Figure 5: HICO derived bathymetry product of eastern Shark Bay.*

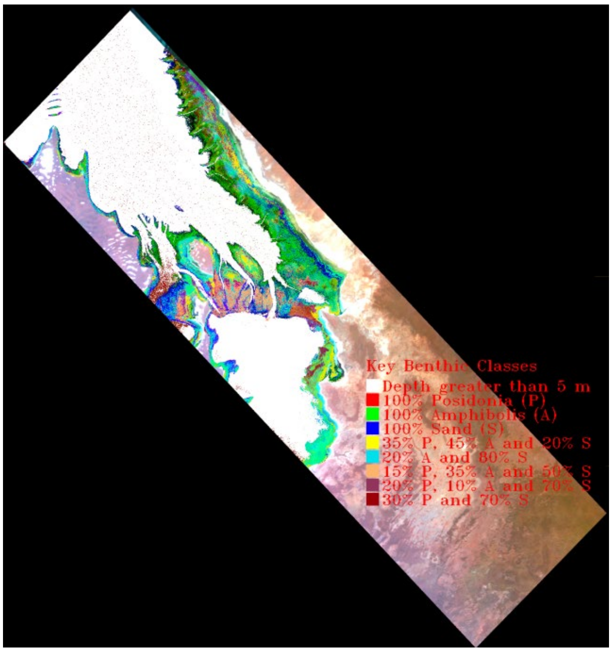



*Figure 6: HICO derived benthic classification product.*

## Development of an Australian Hyperion Data Archive

### Mark Broomhall

Curtin University, as Part of the Terrestrial Ecosystem Research Network (TERN) AusCover project, has procured 10 years of hyperspectral data collected over Australia by the Hyperion sensor on board a US Geological Survey satellite, and is making them available for land, vegetation and minerals research.

The current archive of 1276 data files has been processed and is being made available via the AusCover data portal (http://data.auscover.org.au/xwiki/bin/view/Product+pages/Hyperion+Hyperspectral+SurfRefl+Curtin). Hyperion is a polar-orbiting sensor on board the EO-1 (Earth Observing One). Hyperion was the first hyperspectral imager that NASA launched into space. It was launched on board EO-1 in late 2000 as a one-year demonstration mission, but has continued to operate under the direction of the US Geological Survey (USGS). Hyperion is still collecting data—which means it has outlived its projected lifespan by 1000%!

Hyperion provides hyperspectral data across 242 spectral bands, from 355 nm to 2500 nm, with a pixel size of 30 m by 30 m at nadir (i.e. directly beneath the sensor) and a swath width of 7 km. The current AusCover Hyperion archive includes data from 2001 to 2010 .The Hyperion archive is useful for collecting high spatial resolution reflectance data of terrestrial targets, which may then be aggregated to MODIS spatial resolution to aid in validation of MODIS terrestrial product algorithms (Figure 7).

The AusCover facility's partner, the Remote Sensing and Satellite Research Group (RSSRG) at Curtin University, has implemented a workflow for Hyperion data processing on the iVEC high-performance computing (HPC) system. This includes data pre-processing steps to fix errors such as missing lines, "bad" bands and compensation for spectral smile (a distortion in measuring wavelengths), which was adapted from code developed by CSIRO Office of Space Science and Applications (COSSA). The corrected data are processed to surface reflectance (a measure of the amount of solar radiation reflected from surfaces on Earth) using internationally accepted methods and developed in collaboration with researchers from CSIRO Minerals and Exploration. The developed code base is written in freely available languages and can be ported between operating systems. The code has been developed in a modular design to accommodate future upgrades or addition of processing steps, and to allow it to be adapted to support the next generation of hyperspectral sensors.

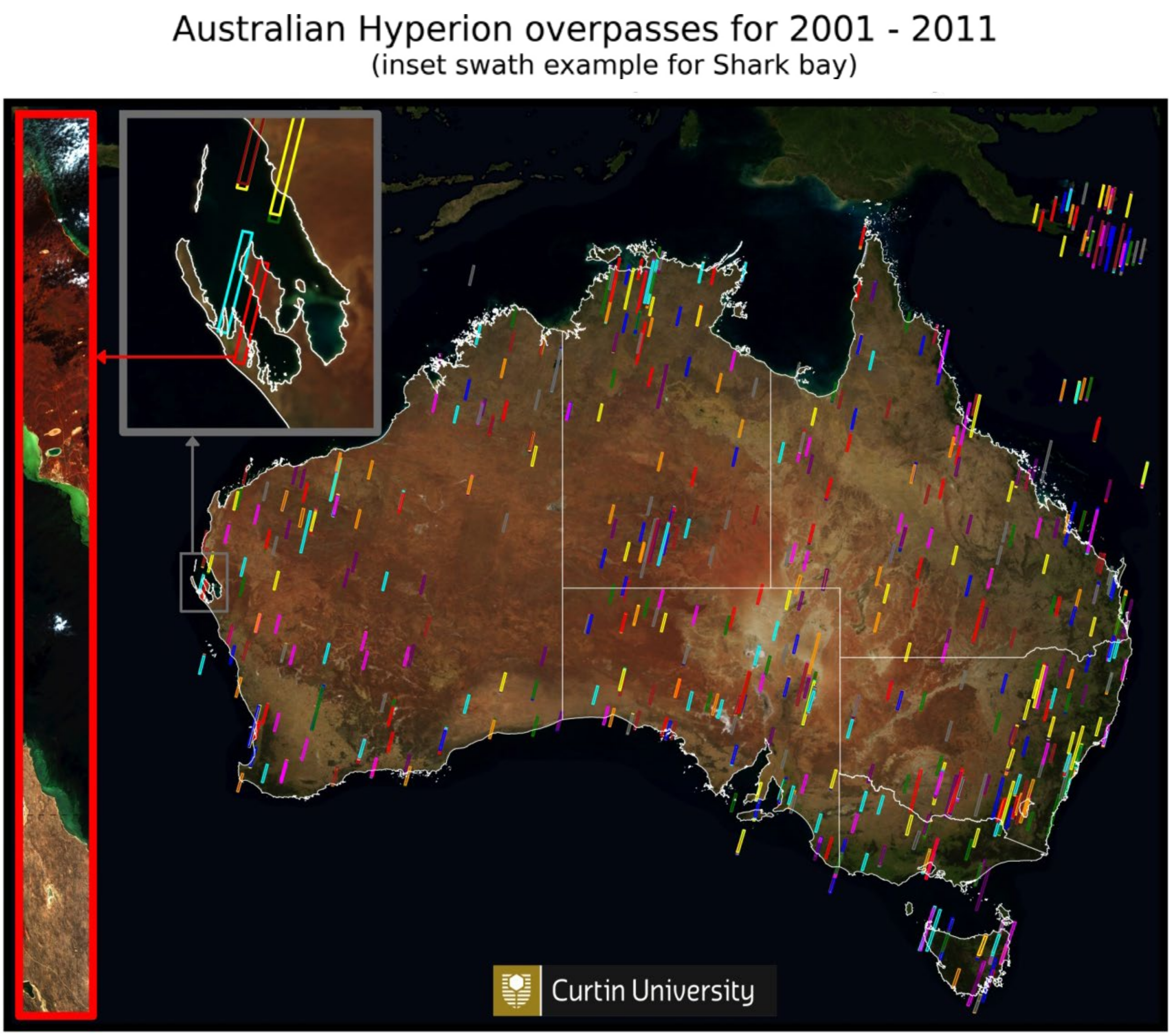



*Figure 7. Overpass locations for all Hyperion data captured between 2001 and 2011 for the Australian region. The grey-bordered inset of overpasses of Shark Bay shows the scale of the Hyperion swaths. The red-bordered inset is an RGB image of the swath captured on the 1 May 2003, which shows the Francois Peron National Park and the town of Denham.*

## Atmospherically corrected 19-band MODIS product

Helen Chedzey[1], Mark Broomhall[1],
Dr Brendon McAtee[2], Mark Gray[1],
Dr Peter Fearns[1], Professor Mervyn Lynch[1]

[1] Curtin University Remote Sensing and Satellite Research Group , [2] Landgate

Reflectance observations from bands 1 to 7 of MODIS have been used extensively in Australian research in near real-time terrestrial observation systems. These observations are used to generate surface, vegetation and atmospheric products. The Simple Method for Atmospheric Correction (SMAC) has been implemented in the AusCover processing system for use with MODIS reflective band observations to generate SMAC-derived Bottom of the Atmosphere Reflectance (BOAR) values for bands 1 to 19 and 26. These reflectances are made freely available to the Australian research community for evaluation. Individual granules are available along with daily gridded files that contain all the granules available for that day.

SMAC-corrected MODIS reflectances have led to the implementation of several novel applications for land surface and atmospheric observations such as the use of MODIS band 8 product in aerosol optical depth estimation (Figure 8). Further, these 19-band MODIS reflectances can be used in reflectance change observations to derive enhanced smoke and airborne dust observations. The full spectral coverage available in reflectance observations results in improved observations of the Australian land surface and vegetation characteristics, highlighting cases where the use of these non-standard MODIS products benefit operational observation of Australia's bioregions.

This work is facilitated by AusCover, the remote sensing component of the Terrestrial Ecosystem Research Network (TERN), a national program building a new generation of infrastructure for ecological study of the Australian landscape.

**Relevant Link:**

http://data.auscover.org.au/xwiki/bin/view/Product+pages/SurfRefl+19Band+MODIS+CU

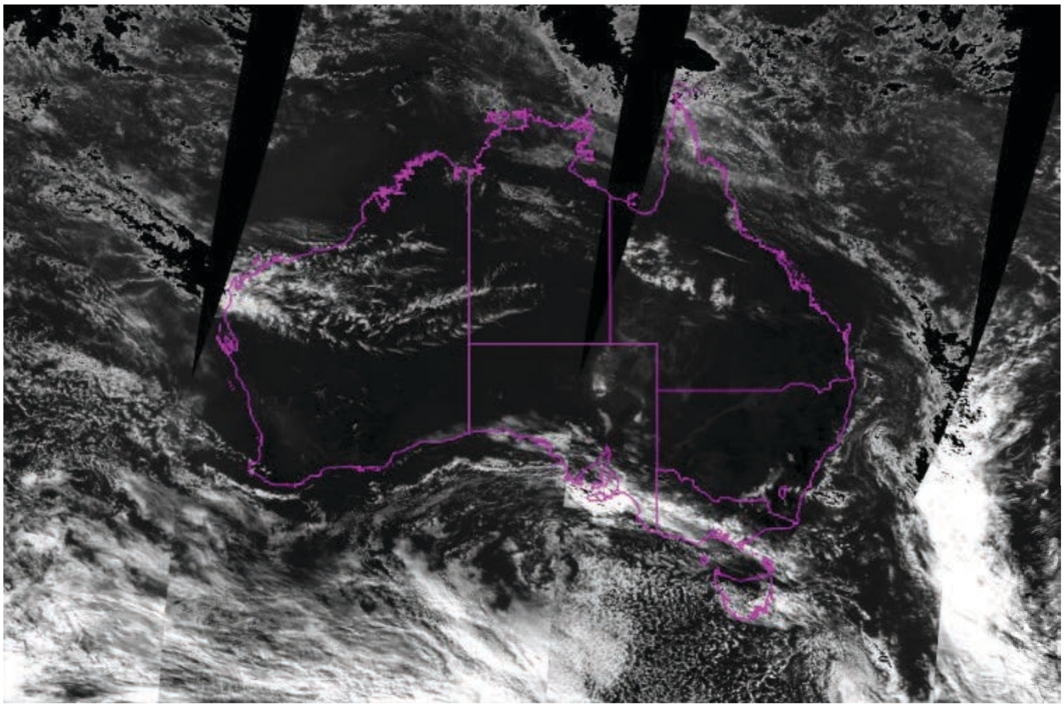


*Figure 8. Atmospherically corrected reflectances over Australia at 412nm (Band 8 MODIS Terra) on 30 April 2003. The continental outline highlights the low band 8 reflectance values present over land that are useful in aerosol detection.*

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## INDEPENDENT AUDITORS' REPORT

***To The Members of the Board***

## WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATION CONSORTIUM - L BAND

We have audited the accompanying financial report of the Western Australian Satellite Technology and Application Consortium – L Band which comprises the balance sheet as at 31 December 2012, income statement and cash flow statement for the period ended 31 December 2012 and notes comprising a summary of significant accounting policies and other explanatory information.

### Officer's Responsibility for the Financial Report

The Board of the Western Australian Satellite Technology and Application Consortium – L Band is responsible for the preparation of the financial report information and has determined that the basis of preparation of this information described in Note 1, is appropriate to meet the reporting requirements of the Western Australian Satellite Technology and Application Consortium – L Band as per the existing joint venture agreement. The Board's responsibility also includes the establishment of internal control as the Board determines is necessary to enable the preparation of a financial report that is free from material misstatement, whether due to fraud or error.

### Auditor's Responsibility

Our responsibility is to express an opinion on the financial report based on our audit. We have conducted our audit in accordance with Australian Auditing Standards. Those standards require that we comply with relevant ethical requirements relating to audit engagements and plan and perform the audit to obtain reasonable assurance whether the financial report is free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial report. The procedures selected depend on the auditor's judgement, including the assessment of the risks of material misstatement of the financial report, whether due to fraud or error. In making those risk assessments, the auditor considers internal control relevant to Western Australian Satellite Technology and Application Consortium – L Band's preparation of the financial report, in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the entity's internal control.

An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of accounting estimates made, as well as evaluating the overall presentation of the financial report.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

**Electronic publication of the audited financial report**

It is our understanding that the Western Australian Satellite Technology and Application Consortium intends to electronically present the audited financial report and auditor's report on its internet website. Responsibility for the electronic presentation of the financial report on the Western Australian Satellite Technology and Application Consortium website is that of those charged with governance of the Western Australian Satellite Technology and Application Consortium. The security and controls over information on the website should be addressed by the Western Australian Satellite Technology and Application Consortium to maintain the integrity of the data presented. The examination of the controls over the electronic presentation of audited financial report on the Western Australian Satellite Technology and Application Consortium website is beyond the scope of the audit of the financial report.

**Opinion**

In our opinion, the financial report presents fairly, in all material respects, the financial position of Western Australian Satellite Technology and Application Consortium – L Band as at 31 December 2012 and its financial performance for the period then ended.

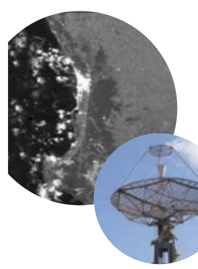
**Basis of Accounting**

Without modifying our opinion, we draw attention to Note 1 to the financial report, which describes the basis of accounting. The financial report has been prepared to assist the Board and the joint venture participants of the Western Australian Satellite Technology and Application Consortium – L Band to meet the reporting requirements. As a result, the financial report may not be suitable for another purpose.

Santo Casilli CPA

Date: 21 MAY 2013

Perth



## WASTAC L - Band BUDGET 2012

### Estimated expenditure for the year January 2012 – December 2012

| | $ 2011 | $ 2012 |
|---|---|---|
| 1. Data Tapes | 0 | 0 |
| 2. System maintenance/repairs | 5000 | 5000 |
| 3. Telecommunications license of facility | 5000 | 5000 |
| 4. Consultants | 5000 | 5000 |
| 5. Sundry consumables | 1500 | 1500 |
| 6. Traveling – Airfares | 3000 | 3000 |
| 7. Provision for major equipment | 12000 | 12000 |
| 8. Annual Report | 8000 | 6000 |
| **TOTAL:** | **$39,500** | **$37,500** |

### Estimated income/revenue for the year January 2012– December 2012

| | | |
|---|---|---|
| 1. Contributions received ($10,000 each) | 40000 | 40000 |
| 2. Interest | 6000 | 10000 |
| **TOTAL INCOME:** | **$46,000** | **$50,000** |

### Extra-ordinary expenditure January 2013– December 2013

1. To be funded from Capital Reserve:

   X Band upgrade for 2013 estimated at around $300,000 (Subject to Board approval)

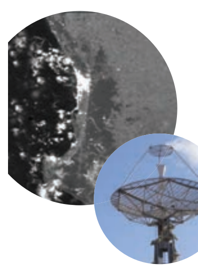
# WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATION CONSORTIUM
# L - BAND
# INCOME STATEMENT FOR THE YEAR ENDED 31 DECEMBER 2012

| | **2012** | **2011** |
|---|---|---|
| | **$** | **$** |
| **REVENUE** | | |
| Contributions Received | 40,000 | 40,000 |
| Interest Received | 13,404 | 14,865 |
| **Total Revenue** | **53,404** | **54,865** |
| **EXPENDITURE** | | |
| Depreciation Expenses | 7,805 | 17,486 |
| Equipment maintenance | 2,500 | 10,953 |
| Hospitality | 163 | 104 |
| Microwave License | 2,334 | 1,232 |
| Other operating expenditure | 10,828 | 5,942 |
| **Total Expenditure** | **23,630** | **35,717** |
| **Net Operating Result for the Year** | **29,775** | **19,148** |

15/05/2013

Linda Zhai
Senior Accountant - Client Service
Curtin University

Date



# WESTERN AUSTRALIAN SATELLITE TECHNOLOGY and APPLICATION CONSORTIUM
## L - BAND
## BALANCE SHEET AS AT 31 DECEMBER 2012

| | NOTE | 2012 | 2011 |
|---|---|---|---|
| | | $ | $ |
| **CURRENT ASSETS** | | | |
| Cash at Bank | | 346,576 | 322,796 |
| Prepayments | | 3,800 | |
| Accrued Revenue | | 10,000 | |
| **TOTAL CURRENT ASSETS** | | **360,376** | **322,796** |
| **NON - CURRENT ASSETS** | | | |
| Property, plant and equipment | 2 | 22,741 | 30,545 |
| **TOTAL NON - CURRENT ASSETS** | | 22,741 | 30,545 |
| **TOTAL ASSETS** | | **383,116** | **353,341** |
| **TOTAL LIABILITIES** | | - | - |
| **NET ASSETS** | | **383,116** | **353,341** |
| **EQUITY** | | | |
| Retained Funds | 4 | 383,116 | 353,341 |
| **TOTAL EQUITY** | | **383,116** | **353,341** |

15/05/2013

Linda Zhai
Senior Accountant - Client Service
Curtin University

Date

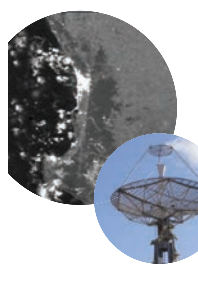
# WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATION CONSORTIUM
## L - BAND
## CASH FLOW STATEMENT FOR THE YEAR ENDED 31 DECEMBER 2012

| | NOTE | 2012 | 2011 |
|---|---|---|---|
| **CASH FLOWS FROM OPERATING ACTIVITIES** | | **$** | **$** |
| **Receipts** | | | |
| Contributions Received: | | | |
| Department of Land Information | | 10,000 | 10,000 |
| CSIRO | | 10,000 | 10,000 |
| Bureau of Meteorology | | 10,000 | 10,000 |
| Curtin University of Technology | | - | 10,000 |
| Interest Received | | 13,404 | 14,865 |
| **Total Receipts** | | **43,404** | **54,865** |
| **Payments** | | | |
| Payments to suppliers | | (19,625) | (14,691) |
| **Total Payments** | | (19,625) | (14,691) |
| **Net cash provided by operating activities** | 3 | **23,780** | **40,174** |
| **CASH FLOWS FROM INVESTING ACTIVITIES** | | | |
| Payments for property, plant and equipment | | - | - |
| **Net cash used in investing activities** | | - | - |
| **Net increase/(decrease) in cash** | | **23,780** | **40,174** |
| Cash at the beginning of the year | | 322,796 | 282,622 |
| **Cash at the end of the year** | | **346,576** | **322,796** |

15/05/2013

Linda Zhai
Senior Accountant - Client Service
Curtin University

Date



## WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATION CONSORTIUM
## L BAND
## NOTES TO THE FINANCIAL STATEMENTS
## FOR THE YEAR ENDED 31DECEMBER 2012

### 1 Summary of Significant Accounting Policies

The principal accounting policies adopted in the preparation of the financial report are set out below. These policies have been consistently applied unless otherwise stated.

**Basis of Preparation**

The Western Australian Satellite Technology and Application Consortium (WASTAC) L Band financial report is a special purpose financial report has been prepared in accordance with Australian Accounting Standards including Australian Accounting Interpretations, other authoritative pronouncements of the Australian Accounting Standards Board and Urgent Issues Group Consensus Views.

**Compliance with AIFRS**

Compliance with Australian Accounting standards ensures that the financial statements and notes comply with International Financial Reporting Standards.

**Historical cost convention**

These financial statements have been prepared on the accrual basis of accounting using the historical cost convention.

**(a) Valuation of Property, Plant and Equipment**

All property, plant and equipment is shown at cost, less subsequent depreciation and impairment losses. Cost includes expenditure that is directly attributable to the acquisition of the items. Subsequent costs are included in the asset carrying amount or recognised as a separate asset, as appropriate, only when it is probable that future economic benefits associated with the item will flow to the entity and the cost of the item can be measured reliably.

Any gains and losses on disposals are determined by comparing the disposal proceeds with the carrying amount and are included in the Income Statement.

**(b) Depreciation of non-current assets**

All property, plant and equipment having a limited useful life are depreciated over their estimated useful lives, in a manner which reflects the consumption of their future economic benefits.

Depreciation is calculated on a straight-line basis from the time the asset becomes available for use. Estimated useful lives are as follows:

- Computing equipment 3 years
- Other equipment 8 years

Assets' residual values and useful lives are reviewed, and adjusted if appropriate, at each balance sheet date.

A class of asset's carrying amount is written down immediately to its recoverable amount if the class of asset's carrying amount is greater than its estimated recoverable amount (see note 1(c)).

**(c) Impairment of property, plant and equipment**

At each reporting date, WASTAC reviews the carrying amounts of each class of asset within property, plant and equipment to determine whether there is any indication that those asset classes have suffered an impairment loss. If any such indication exists, the recoverable amount of the class of asset is estimated in order to determine the extent of the impairment loss. Where the asset does not generate cash flows that are independent from other assets, WASTAC estimates the recoverable amount of the cash-generating unit to which the asset belongs.

Recoverable amount is the higher of fair value less costs to sell and value in use. In assessing value in use, the depreciated replacement cost is used where the future economic benefits of WASTAC's assets are not primarily dependent on the assets' ability to generate net cash inflows.

If the recoverable amount of a class of asset is estimated to be less than its carrying amount, the carrying amount is reduced to recoverable amount. An impairment loss is recognised as an expense to the Income Statement immediately.

**(d) Income Tax**

The Board considers that its operations are exempt from income tax under the provisions of section

50-25 of the Income Tax Assessment Act (1997) as amended.

**(e) Goods and Services Tax (GST)**

Revenues, expenses and assets are recognised net of the amount of GST, except where the amount of

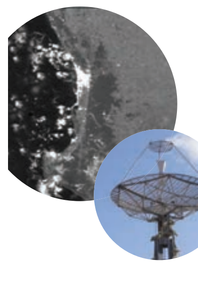
GST is not recoverable from the Australian Taxation Office. In these circumstances the GST is recognised

as part of the cost of acquisition of the asset or as part of an item of the expense.

**(f) Income Recognition**

The Board recognises income as it is received. All income is stated net of the amount of goods and services tax (GST).

Interest is recognised on the effective interest rate method.



## 2 Property, Plant and Equipment

| | 2012 | 2011 |
|---|---|---|
| **Computer Equipment** | | |
| At cost | 151,468 | 151,468 |
| Accumulated depreciation | (151,468) | (151,468) |
| | - | - |
| **Other Equipment** | | |
| At cost | 222,806 | 222,806 |
| Accumulated depreciation | (200,065) | (192,260) |
| | 22,741 | 30,546 |
| Total Property, Plant and Equipment | **22,741** | **30,546** |

**Reconciliations**

Reconciliations of the carrying amounts of property, plant and equipment at the beginning and end of the current financial year are set out below:

| | Computer Equipment | Other Equipment | Total |
|---|---|---|---|
| **Carrying amount at start of year** | - | 30,546 | 30,546 |
| Additions | - | - | - |
| Depreciation expense | - | (7,805) | (7,805) |
| **Carrying amount at end of year** | **-** | **22,741** | **22,741** |

## 3 Notes to the Cash Flow Statement

**Reconciliation of operating result from ordinary activities to net cash inflow from operating activities**

| | 2012 | 2011 |
|---|---|---|
| Net operating result | 29,775 | 19,148 |
| Depreciation expense | 7,805 | 17,486 |
| Movement in Current Assets | (13,800) | 3,540 |
| **Net cash provided by operating activities** | **23,780** | **40,174** |

## 4 Retained Earnings

| | 2012 | 2011 |
|---|---|---|
| Balance at beginning of the year | 353,341 | 334,193 |
| Operating surplus/(deficit) for the year | 29,775 | 19,148 |
| **Balance at end of the year** | **383,116** | **353,341** |

CPA

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PO Box 617 Subiaco WA 6904

**Mobile**: 0409 104 929 - **Phone**: 9388 3678 **Fax**: (08) 9388 3860
**Email**: scasilli@westnet.com.au

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## INDEPENDENT AUDITORS' REPORT

***To The Members of the Board***

## WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATION CONSORTIUM - X BAND

We have audited the accompanying financial report of the Western Australian Satellite Technology and Application Consortium – X Band which comprises the balance sheet as at 31 December 2012, income statement and cash flow statement for the period ended 31 December 2012 and notes comprising a summary of significant accounting policies and other explanatory information.

### Officer's Responsibility for the Financial Report

The Board of the Western Australian Satellite Technology and Application Consortium – X Band is responsible for the preparation of the financial report information and has determined that the basis of preparation of this information described in Note 1, is appropriate to meet the reporting requirements of the Western Australian Satellite Technology and Application Consortium – X Band as per the existing joint venture agreement. The Board's responsibility also includes the establishment of internal control as the Board determines is necessary to enable the preparation of a financial report that is free from material misstatement, whether due to fraud or error.

### Auditor's Responsibility

Our responsibility is to express an opinion on the financial report based on our audit. We have conducted our audit in accordance with Australian Auditing Standards. Those standards require that we comply with relevant ethical requirements relating to audit engagements and plan and perform the audit to obtain reasonable assurance whether the financial report is free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial report. The procedures selected depend on the auditor's judgement, including the assessment of the risks of material misstatement of the financial report, whether due to fraud or error. In making those risk assessments, the auditor considers internal control relevant to Western Australian Satellite Technology and Application Consortium – X Band's preparation of the financial report, in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the entity's internal control.

An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of accounting estimates made, as well as evaluating the overall presentation of the financial report.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

**Electronic publication of the audited financial report**

It is our understanding that the Western Australian Satellite Technology and Application Consortium intends to electronically present the audited financial report and auditor's report on its internet website. Responsibility for the electronic presentation of the financial report on the Western Australian Satellite Technology and Application Consortium website is that of those charged with governance of the Western Australian Satellite Technology and Application Consortium. The security and controls over information on the website should be addressed by the Western Australian Satellite Technology and Application Consortium to maintain the integrity of the data presented. The examination of the controls over the electronic presentation of audited financial report on the Western Australian Satellite Technology and Application Consortium website is beyond the scope of the audit of the financial report.

**Opinion**

In our opinion, the financial report presents fairly, in all material respects, the financial position of Western Australian Satellite Technology and Application Consortium – X Band as at 31 December 2012 and its financial performance for the period then ended.

**Basis of Accounting**

Without modifying our opinion, we draw attention to Note 1 to the financial report, which describes the basis of accounting. The financial report has been prepared to assist the Board and the joint venture participants of the Western Australian Satellite Technology and Application Consortium – X Band to meet the reporting requirements. As a result, the financial report may not be suitable for another purpose.

Santo Casilli CPA

Date: 21 MAY 2013

Perth

# WASTAC X- Band BUDGET 2012

## Estimated expenditure for the year January 2012 – December 2012

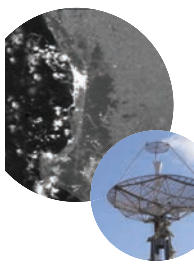
| | $ 2011 | $ 2012 |
|---|---|---|
| 1. Data Tapes | 3,000 | 2,000 |
| 2. System maintenance | 23,000 | 23,000 |
| 3. System repairs | 4,000 | 4,000 |
| 4. Consultants, product development | 20,000 | 20,000 |
| 5. Sundry consumables | 2,000 | 2,000 |
| 6. Travelling – Airfares | 4,000 | 4,000 |
| 7. Provision for major equipment | 125,000 | 25,000 |
| **TOTAL:** | **$181,000** | **$80,000** |

**Estimated income/revenue for the year January 2012 – December 2012**

| | $ 2011 | $ 2012 |
|---|---|---|
| 1. Annual Contributions $20,000 each | 80,000 | 80,000 |
| 2. Interest | 7,000 | 25,000 |
| **TOTAL INCOME:** | **$87,000** | **$105,000** |

**Additional committed expenditure (carry over) January 2012– December 2012**

| | $ 2011 | $ 2012 |
|---|---|---|
| 1. Microwave Murdoch to BoM | 85,000 | 0 |
| **TOTAL:** | **$85,000** | **$0** |



## WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATION CONSORTIUM
## X - BAND
## INCOME STATEMENT FOR THE YEAR ENDED 31 DECEMBER 2012

| | 2012<br>$ | 2011<br>$ |
|---|---|---|
| **REVENUE** | | |
| Contributions Received | 80,000 | 80,000 |
| Interest Received | 22,893 | 31,081 |
| **TOTAL REVENUE** | 102,893 | 111,081 |
| **EXPENDITURE** | | |
| Outsourced Work | - | 4,846 |
| Equipment < $5000 | - | 2,674 |
| Other Software & Licence <$5,000 | 9,325 | 6,897 |
| Maintenance | 6,176 | 1,200 |
| Depreciation | 22,911 | 18,372 |
| **TOTAL EXPENDITURE** | 38,412 | 33,989 |
| **NET OPERATING RESULT FOR THE YEAR** | **64,481** | **77,092** |

15/05/2013

Linda Zhai
Senior Accountant - Client Service
Curtin University

Date

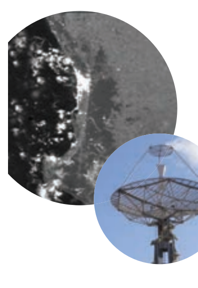
# WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATION CONSORTIUM
# X - BAND
# BALANCE SHEET AS AT 31 DECEMBER 2012

| | NOTE | 2012 | 2011 |
|---|---|---|---|
| **CURRENT ASSETS** | | **$** | **$** |
| Cash at bank | | 520,815 | 440,321 |
| **TOTAL CURRENT ASSETS** | | 520,815 | 440,321 |
| **NON-CURRENT ASSETS** | | | |
| Property, plant and equipment | 2 | 94,039 | 116,949 |
| **TOTAL NON-CURRENT ASSETS** | | 94,039 | 116,949 |
| **TOTAL ASSETS** | | **614,854** | **557,270** |
| **TOTAL LIABILITIES** | | - | 6,897 |
| **NET ASSETS** | | **614,854** | **550,373** |
| **EQUITY** | | | |
| Retained Funds | 4 | 614,854 | 550,373 |
| **TOTAL EQUITY** | | **614,854** | **550,373** |

15/05/2013

Linda Zhai
Senior Accountant - Client Service
Curtin University

Date



# WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATION CONSORTIUM X - BAND CASH FLOW STATEMENT FOR THE YEAR ENDED 31 DECEMBER 2012

| | NOTE | 2012 | 2011 |
|---|---|---|---|
| | | $ | $ |
| **Receipts** | | | |
| Contributions Received: | | | |
| Landgate | | 20,000 | 20,000 |
| CSIRO | | 20,000 | 20,000 |
| Bureau of Meteorology | | 20,000 | 20,000 |
| Geoscience Australia | | 20,000 | 20,000 |
| Interest Received | | 22,893 | 31,081 |
| **Total Receipts** | | 102,893 | 111,081 |
| **Payments** | | | |
| Payments to suppliers | | (22,399) | (8,720) |
| **Total Payments** | | (22,399) | (8,720) |
| **Net cash provided/(Used) by operating activities** | 3 | **80,494** | **102,361** |
| **CASH FLOWS FROM INVESTING ACTIVITIES** | | | |
| Payments for property, plant and equipment | | - | (96,086) |
| **Net cash used in investing activities** | | **-** | **(96,086)** |
| **Net increase/(decrease) in cash** | | **80,494** | **6,276** |
| Cash at the beginning of the year | | 440,321 | 434,045 |
| **Cash at the end of the year** | | **520,815** | **440,321** |

15/05/2013

Linda Zhai
Senior Accountant - Client Service
Curtin University

Date

# WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATION CONSORTIUM X BAND
# NOTES TO THE FINANCIAL STATEMENTS
# FOR THE YEAR ENDED 31 DECEMBER 2012

## 1 Summary of Significant Accounting Policies

The principal accounting policies adopted in the preparation of the financial report are set out below. These policies have been consistently applied unless otherwise stated.

**Basis of Preparation**
The Western Australian Satellite Technology and Application Consortium (WASTAC) X Band financial report is a special purpose financial report has been prepared in accordance with Australian Accounting Standards including Australian Accounting Interpretations, other authoritative pronouncements of the Australian Accounting Standards Board and Urgent Issues Group Consensus Views.

**Compliance with AIFRS**
Compliance with Australian Accounting standards ensures that the financial statements and notes comply with International Financial Reporting Standards.

**Historical cost convention**

These financial statements have been prepared on the accrual basis of accounting using the historical cost convention.

### (a) Valuation of Property, Plant and Equipment

All property, plant and equipment is shown at cost, less subsequent depreciation and impairment losses. Cost includes expenditure that is directly attributable to the acquisition of the items. Subsequent costs are included in the asset carrying amount or recognised as a separate asset, as appropriate, only when it is probable that future economic benefits associated with the item will flow to the entity and the cost of the item can be measured reliably.

Any gains and losses on disposals are determined by comparing the disposal proceeds with the carrying amount and are included in the Income Statement.

### ( b) Depreciation of non-current assets

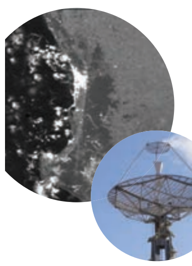
All property, plant and equipment having a limited useful life are depreciated over their estimated useful lives, in a manner which reflects the consumption of their future economic benefits.

Depreciation is calculated on a straight-line basis from the time the asset becomes available for use. Estimated useful lives are as follows:

- Computing equipment 3 years
- Other equipment 8 years

Assets' residual values and useful lives are reviewed, and adjusted if appropriate, at each balance sheet date.

A class of asset's carrying amount is written down immediately to its recoverable amount if the class of asset's carrying amount is greater than its estimated recoverable amount (see note 1(c)).



**(c) Impairment of property, plant and equipment**

At each reporting date, WASTAC reviews the carrying amounts of each class of asset within property, plant and equipment to determine whether there is any indication that those asset classes have suffered an impairment loss. If any such indication exists, the recoverable amount of the class of asset is estimated in order to determine the extent of the impairment loss. Where the asset does not generate cash flows that are independent from other assets, WASTAC estimates the recoverable amount of the cash-generating unit to which the asset belongs.

Recoverable amount is the higher of fair value less costs to sell and value in use. In assessing value in use, the depreciated replacement cost is used where the future economic benefits of WASTAC's assets are not primarily dependent on the assets ability to generate net cash inflows.

If the recoverable amount of a class of asset is estimated to be less than its carrying amount, the carrying amount is reduced to recoverable amount. An impairment loss is recognised as an expense to the Income Statement immediately.

**(d) Income Tax**

The Board considers that its operations are exempt from income tax under the provisions of section 50-25 of the Income Tax Assessment Act (1997) as amended.

**(e) Goods and Services Tax (GST)**

Revenues, expenses and assets are recognised net of the amount of GST, except where the amount of GST is not recoverable from the Australian Taxation Office. In these circumstances the GST is recognised as part of the cost of acquisition of the asset or as part of an item of the expense.

**(f) Income Recognition**

The Board recognises income as it is received. All income is stated net of the amount of goods and services tax (GST).

Interest is recognised on the effective interest rate method.

## 2 Property, Plant and Equipment

| | 2012 | 2011 |
|---|---|---|
| **Computer Equipment** | | |
| At cost | 33,428 | 33,428 |
| Accumulated depreciation | (25,716) | (19,376) |
| | 7,712 | 14,052 |
| **Other Equipment** | | |
| Equipment | | |
| At cost | 866,833 | 866,833 |
| Accumulated depreciation | (780,505) | (763,935) |
| | 86,327 | 102,898 |
| Total Property, Plant and Equipment | **94,039** | **116,949** |

**Reconciliations**

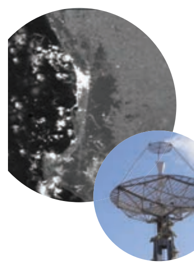
Reconciliations of the carrying amounts of property, plant and equipment at the beginning and end of the current financial year are set out below:

| | Computer Equipment | Other Equipment | Total |
|---|---|---|---|
| **Carrying amount at start of year** | 14,052 | 102,898 | 116,950 |
| Additions/(Disposals) | - | | - |
| Depreciation expense | (6,340) | (16,571) | (22,911) |
| **Carrying amount at end of year** | **7,712** | **86,327** | **94,039** |

## 3 Notes to the Cash Flow Statement

**Reconciliation of operating result from ordinary activities to net cash inflow from operating activities**

| | 2012 | 2011 |
|---|---|---|
| Net operating result | 64,481 | 77,092 |
| Depreciation expense | 22,911 | 18,372 |
| Movement in Current Assets & Liability | (7,385) | 6,897 |
| **Net cash provided/(used) by operating activities** | **80,007** | **102,361** |



## 4 Retained Earnings

| | | |
|---|---|---|
| Balance at beginning of the year | 550,373 | 473,281 |
| Operating surplus/(deficit) for the year | 64,481 | 77,092 |
| **Balance at end of the year** | **614,854** | **550,373** |