Western Australian Satellite Technology and Applications Consortium

WASTAC

Annual Report 2013





www.wastac.wa.gov.au

WASTAC

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Front Cover : Landgate is exploring new uses for the Moderate resolution Imaging Spectroradiometer (MODIS) on board the Terra and Aqua satellites to support pasture utilisation in the rangelands of Australia through its RangeWatch program and improve user experience in the intensive sheep production in south western Western Australia through Pastures from Space.
Emphasis is now on developing web-based systems compatible with mobile tablets, making it an easily accessible and versatile application out in the field.

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

Contents

WASTAC Chairman's Report 2013

Following the release of Australia's Space Utilisation Policy at ANU's Stromlo Observatory on 9 April 2013, the first Australian Government Earth Observations from Space Working Group (AGEOSWG) was conducted on 21 May 2013. This Group's role is to draw together the key Government agencies involved in Earth Observations from Space, advise the Australian Government Space Coordination Committee on the status and future of the Australian EOS sector and provide required coordination across EOS activities within the Australian Government. AGEOSWG receives input from the Australian Earth Observation Community Coordination Group (AEOCCG), which is a wider consultation mechanism incorporating private industry, the research and education sector, all levels of government, and any other interested individuals in Earth Observations from Space. While the meetings and discussions of the AGEOSWG are not open to all, the meetings of the AEOCCG are, and I would encourage anyone with an interest in Earth Observations from Space (whether your interest be terrestrial, marine, or atmospheric) take the opportunity to participate in the AEOCCG. The AGEOWG doesn't know what it doesn't know and can't act on behalf of broader Australian interests without input from the broader community.

At a strategic level, the WASTAC Board has agreed to commission a report looking at the medium and long term options for its reception facilities in light of the Australian Space Utilisation Policy and the National Earth Observations from Space Infrastructure Plan. It is hoped this work will be commissioned in 2014 with a report submitted to the Board either in late 2014 or early 2015.

At an operational level the main development activities of WASTAC in 2013 were troubleshooting the reception of NPOESS Preparatory Project (NPP) data and issues associated with reception at the Murdoch station during the warmer months of the year. While neither problem was resolved in 2013, the issues have apparently been resolved in 2014 and will be reported in the 2014 Annual Report.

With the failure of NOAA-17 on 10 April 2013, and the issues with the X-band reception at Murdoch, the number of passes received dropped from 20,502 in 2012 to 19,181 in 2013. No new satellites were added to the capture list, although FY3c was launched in September 2013. It is hoped that software updates will allow for processing of FY3 data locally and FY3 may become a source for application development in 2014 or 2015.

WASTAC is also preparing for the Bureau of Meteorology's move from East Perth to West Perth to occur sometime in early to mid 2014 and bring along with it the challenge of reorienting communications to ensure the Bureau continues to receive uninterrupted data supply.

As the Operational Applications reports show, data sourced from WASTAC is contributing worldwide numerical weather forecasting, and tracking and monitoring cyclones in Australia, as well as tracking a changing climate (Willmott et al., BOM). Landgate is exploring new uses for MODIS to support pasture utilisation in the rangelands of Australia and improve user experience in the intensive sheep production in south western Western Australia through Pastures from Space (Stovold et al., Landgate). Landgate continues to map fire scars from the NOAA/AVHRR sensor (Kristina, Landgate) and explores additional uses for MODIS data in coastal inundation associated with cyclone activity (Ferri and Buchanan, Landgate).

Of special significance is Aurora, a development between the Department of Fire and Emergency Services, the University of Western Australia and Landgate with support from the Department of Communications, which utilises MODIS-derived fire hotspots to predict bushfire spread across all of Australia. At the time of writing, Aurora has won six state, national and international IT awards with possibilities for a further two in 2014, including a Western Australia Premier's Award.

On the research front, CSIRO is working on the calibration and validation of MODIS in the marine environment (Hardman-Mountford; King, CSIRO). Some of this work could be extended to other sensors in due course. Curtin University is researching the estimation of total suspended sediments based on algorithm development already done for MODIS (Broomhall and Fearns, Curtin University).

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
Chairman, WASTAC 2013

WASTAC BOARD FOR 2013

Dr Matthew Adams- Chairman	Landgate
Mr Richard Stovold - Secretary	Landgate
Prof. Merv Lynch	Curtin University
Prof. David Antoine	Curtin University
Dr Kimberley Clayfield	CSIRO
Dr Edward King	CSIRO
Dr Anthony Rea	Bureau of Meteorology
Mr Mike Bergin	Bureau of Meteorology
Dr Adam Lewis	Geoscience Australia
Prof. Tom Lyons	Murdoch University
Dr. Halina Kobryn	Murdoch University

WASTAC standing committee and proxy to the board

Dr Matthew Adams - Chairman	Landgate
Mr Richard Stovold - Secretary	Landgate
Prof. Merv Lynch	Curtin University
Prof. David Antoine	Curtin University
Mr Andrew Burton	Bureau of Meteorology
Mr Russell Steicke	Bureau of Meteorology
Prof. Tom Lyons	Murdoch University
Dr. Halina Kobryn	Murdoch University
Dr Tom Cudahy	CSIRO
Dr Medhavy Thankappan	Geoscience Australia
Mr Mike Pasfield	Geoscience Australia

WASTAC technical committee:

Mr Russell Steicke (Chairman)
Prof. Merv Lynch
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.

The Bureau of Meteorology (BoM) is proposing to relocate its office to West Perth in mid 2014. As the new location is unsuitable for direct microwave communications to Curtin University, a backup path via Murdoch University is being utilised until the microwave links can be re-established.

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 L band facility receives 500 to 600 passes per month from a range of satellites - NOAA-15, NOAA-16, NOAA-17,NOAA-18, and NOAA-19.

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.

During 2013, the X band facility received passes from the METOP A, METOP B, Terra, Aqua,FY3B and NPP satellites, as well as passes from other L band satellites where there were no scheduling conflicts.

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 data, fire scar mapping and agricultural applications in real time.

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 sections of this report.

A total of 19,181 passes were archived at Curtin and Murdoch in 2013.

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 and VIIRS quick-look data is also held on the Web. The archive of MODIS, NOAA,VIIRS 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

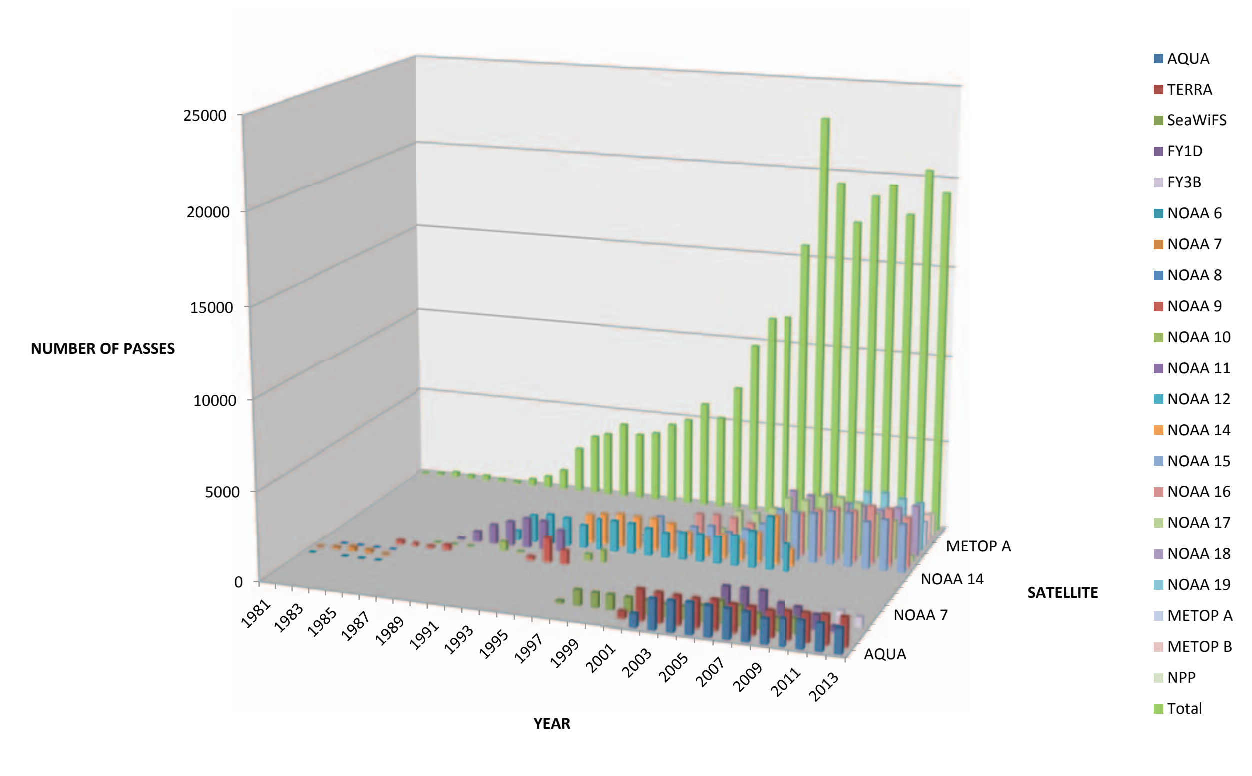
http://www.rss.dola.wa.gov.au/newsite/seawifsql/SeaWiFSql.html

http://www.rss.dola.wa.gov.au/newsite/viirsql/VIIRSql.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 CSIRO in Canberra.

TOTAL ARCHIVED PASSES 1981-2013

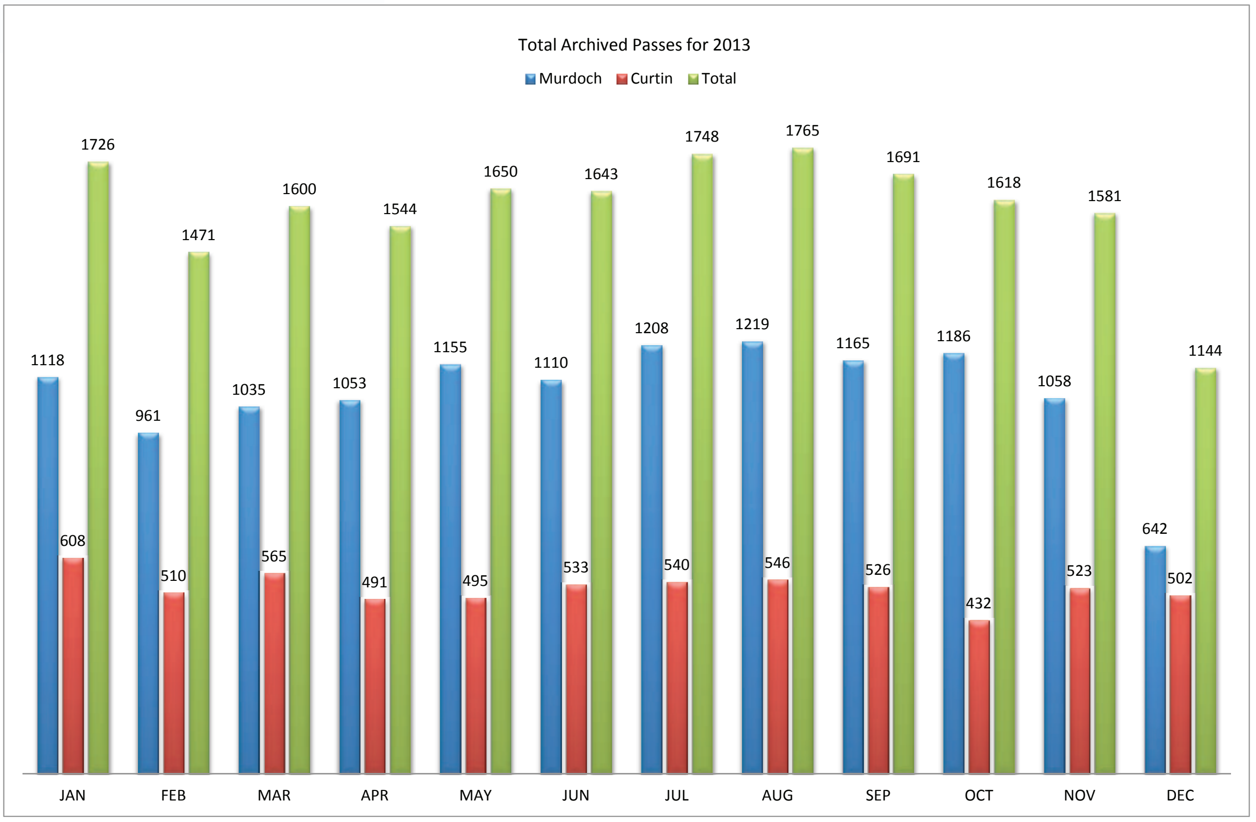


Total Archived Passes 1981 - 2013

	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
2013	1349	1569	557	1383	1503	1243											2781	2845	316	2883	2752	19181

TOTAL ARCHIVED PASSES 2013

		NOAA 15	NOAA 16	NOAA 17	NOAA 18	NOAA 19	FY3B	METOP A	METOP B	TERRA	AQUA	NPP	TOTAL
JAN	C	82	146	92	137	151							608
	M	141	96	0	123	107	57	133	113	138	105	105	1118
													1726
FEB	C	73	137	72	94	134							510
	M	126	92	0	123	79	15	103	128	135	95	65	961
													1471
MAR	C	105	141	116	56	147							565
	M	143	92	0	141	31	20	119	130	138	104	117	1035
													1600
APR	C	107	143	36	68	137							491
	M	144	107	0	124	58	30	110	134	129	102	115	1053
													1544
MAY	C	106	147	0	93	149							495
	M	141	105	0	146	102	8	125	143	136	125	124	1155
													1650
JUN	C	99	146	0	142	146							533
	M	139	93	0	116	87	39	126	130	130	121	129	1110
													1643
JUL	C	96	144	0	149	151							540
	M	155	94	0	126	91	85	134	142	133	121	127	1208
													1748
AUG	C	102	144	0	153	147							546
	M	155	106	0	132	91	80	134	137	134	127	123	1219
													1765
SEP	C	95	146	0	139	146							526
	M	131	102	0	137	113	69	115	137	121	127	113	1165
													1691
OCT	C	79	116	0	118	119							432
	M	157	127	0	148	124	56	119	133	125	114	83	1186
													1618
NOV	C	97	141	0	143	142							523
	M	147	90	0	126	114	45	121	126	121	98	70	1058
													1581
DEC	C	106	148	0	100	148							502
	M	55	42	0	49	38	53	44	50	129	110	72	642
													1144
		2781	2845	316	2883	2752	557	1383	1503	1569	1349	1243	19181
	Curtin	1147	1699	316	1392	1717							6271
	Murdoch	1634	1146	0	1491	1035	557	1383	1503	1569	1349	1243	12910


Total Archived Passes for 2013
Murdoch
Curtin
Total
1118
608
1726
961
510
1471
1035
565
1600
1053
491
1544
1155
495
1650
1110
533
1643
1208
540
1748
1219
546
1765
1165
526
1691
1186
432
1618
1058
523
1581
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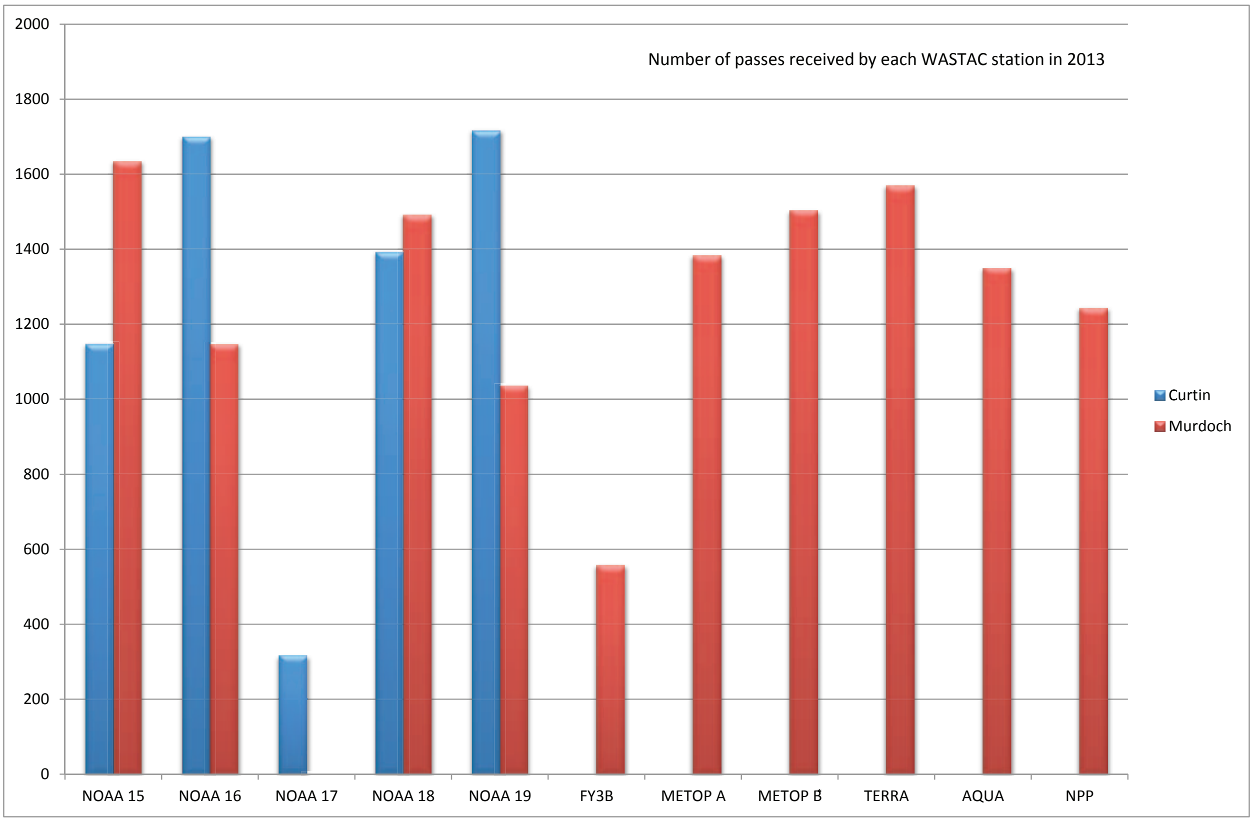
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


Number of passes received by each WASTAC station in 2013
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Curtin
Murdoch
NOAA 15
NOAA 16
NOAA 17
NOAA 18
NOAA 19
FY3B
METOP A
METOP B
TERRA
AQUA
NPP

Operational Applications 2013

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

Mike Willmott, Denis Margetic, Helen Beggs, Ian Grant and the Severe Weather Section of the Western Australian Regional Forecasting Centre.

Satellite Operations

The Bureau of Meteorology carries the responsibility for the operation and maintenance of the WASTAC L-band antenna located at Curtin University. While over a decade old, the L-band antenna continues to receive useful imagery and sounding data from NOAA-15, NOAA-16, NOAA-18 and NOAA-19. These satellites are no longer considered operational, but still contribute significantly to global weather observations.

However, the age of the equipment is beginning to show with a reduction in system performance (see figure 1). Some of the performance loss is due to the degradation of the radio-frequency (RF) components, though radio frequency interference (RFI) also has a contributing effect. The computing equipment is beyond its designed life expectancy and will be upgraded in 2014.

It should be noted that the current operational polar orbiting satellites, Metop and Suomi-NPP, are received using the dual-band antenna located at Murdoch University.

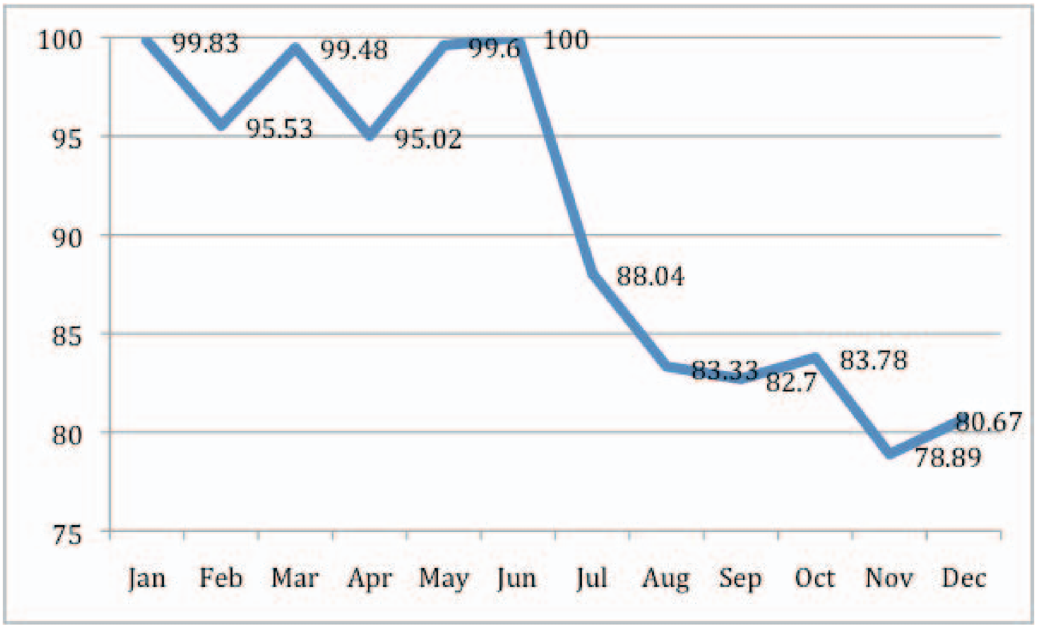


Figure 1: Curtin L-band antenna ingest performance during 2013

All Imagery received from the NOAA suite of satellites is processed and archived within the Bureau's Central Computing Facility. The processed data is made available in real time to operational analysts, forecasters, research and training departments within the Bureau and the archive data can be made available to clients both internally or externally.

The sounding data from the Advanced TIROS Operational Vertical Sounder (ATOVS) from the NOAA satellites provides input into numerical weather prediction (NWP) systems to assist in the vertical profiling of the atmosphere. 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 thirty 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 operational sounding data received by the WASTAC L-band antenna from the NOAA satellites consistently meets the 30-minute timeliness target.

New IMOS GHRSST satellite sea surface temperature products over the Australian region

As part of the Integrated Marine Observing System (IMOS), the Australian Bureau of Meteorology produces high-resolution satellite sea surface temperature (SST) products over the Australian region, designed to suit a range of operational and research applications. All these products follow the latest International Group for High Resolution Sea Surface Temperature (GHRSST) file formats, assisting international data exchange and collaboration.

The highest resolution (1.1 km) data from the Advanced Very High Resolution Radiometer (AVHRR) sensors on the National Oceanographic and Atmospheric Administration (NOAA) polar-orbiting meteorological satellites can only be obtained through receiving direct broadcast High Resolution Picture Transmission (HRPT) data from the satellite as this data is not stored on-board. In Australia, HRPT data is received by a consortium of agencies (Bureau of Meteorology, WASTAC, Australian Institute of Marine Science (AIMS) and Commonwealth Scientific and Industrial Research Organisation (CSIRO)) at ground-stations located in Darwin, Townsville, Melbourne, Hobart, Perth and Alice Springs and in Antarctica, at Casey and Davis. Figure 2 shows the approximate coverage of the data from these reception stations.

In collaboration with CSIRO's Marine and Atmospheric Research, the Bureau is "stitching" this raw data from multiple ground-stations and producing real-time, HRPT AVHRR Sea Surface Temperature (SST) data from operational NOAA polar-orbiting satellites in GHRSST (www.ghrsst.org) formats. The

Bureau of Meteorology, in collaboration with CSIRO Marine and Atmospheric Research, combines raw data from these ground-stations and produces real-time level 2 (geo-located, swath) and level 3 (gridded, composite) files containing either "skin" or "foundation" SSTs following the GHRSST formats (http://imos.org.au/sstproducts.html). The products are available in real-time from the Integrated Marine Observing System (IMOS) File Transfer Protocol (ftp) server at ftp://aodaac2-cbr.act.csiro.au/imos/GHRSST and the IMOS Ocean Portal (www.imos.org.au) and are currently being reprocessed back to 1992. The reprocessing is expected to be completed by July 2014.

The IMOS HRPT AVHRR SST data (including data from the WASTAC receiving station) are being ingested into the Bureau's Global Australian Multi-Sensor Sea Surface Temperature Analysis (GAMSSA) and Regional Australian Multi-Sensor Sea Surface Temperature Analysis (RAMSSA) systems and also the operational coral bleaching monitoring system, ReefTemp NextGen (http://www.bom.gov.au/environment/activities/reeftemp/reeftemp.shtml). Figure 3 shows an example of 14 Day Mosaic Sea Surface Temperature for the Great Barrier Reef from the ReefTemp NextGen system for 28 November 2013.

These data are also used in the GHRSST Tropical Warm Pool Diurnal Variability (TWP+) project (https://www.ghrsst.org/ghrsst/tags-and-wgs/dv-wg/twp/), in the real-time mapping of meso-scale ocean currents in the Australian region (http://oceancurrent.imos.org.au/) and in various marine research projects requiring ultra-high resolution SST data in the Australian region.

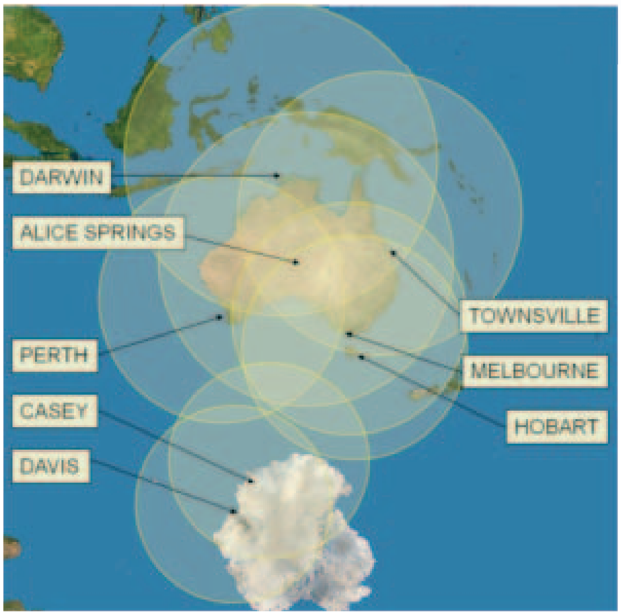


Figure 2: Approximate coverage of the Australian and Antarctic AVHRR receiving stations

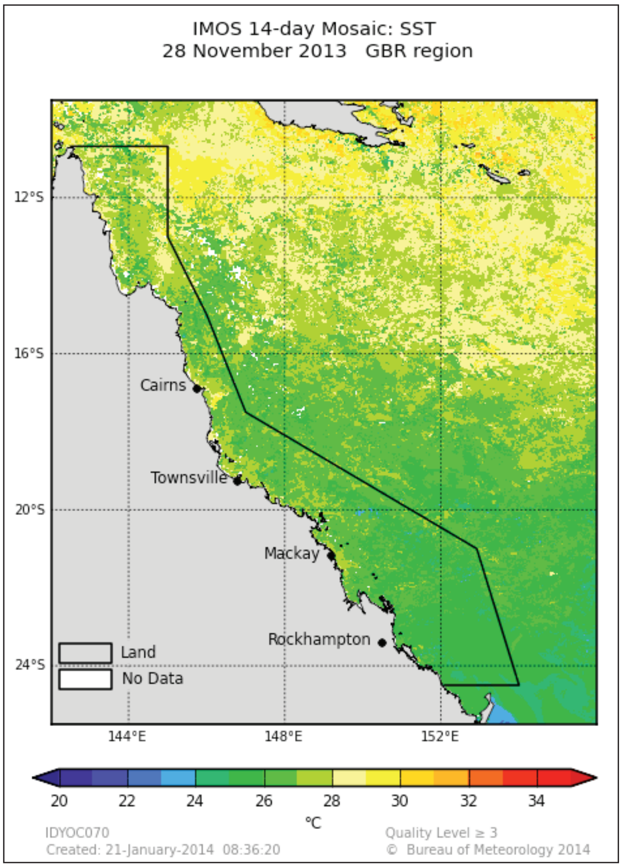


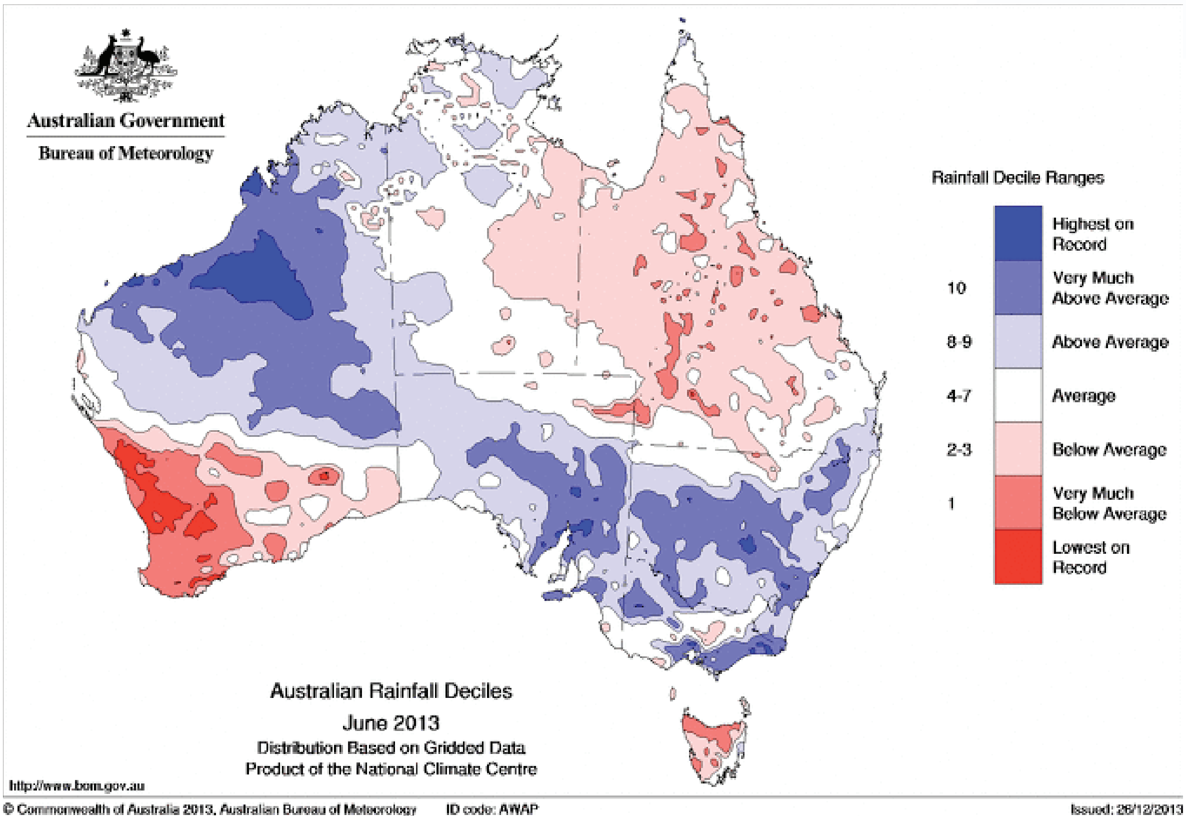
Figure 3: Example of output from the ReefTemp NextGen System

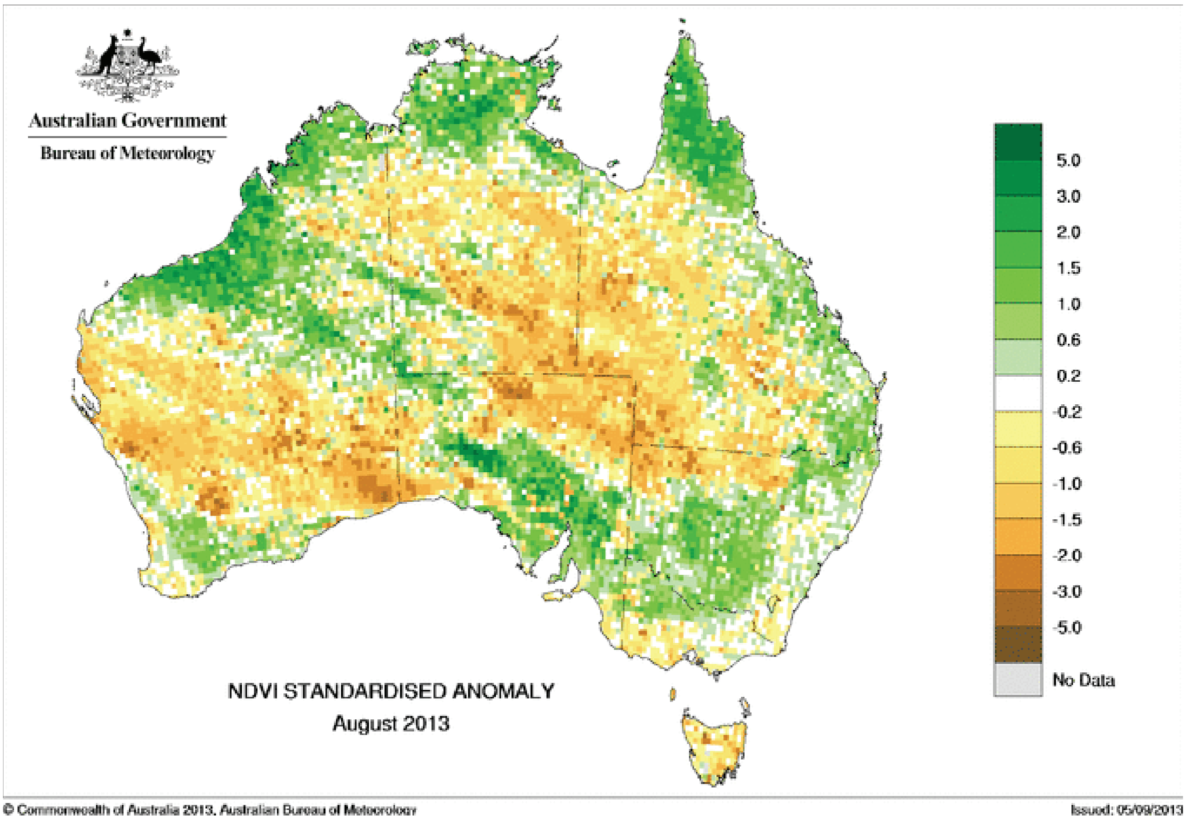
Normalised Difference Vegetation Index (NDVI)

The Normalised Difference Vegetation Index (NDVI) has a long history as the most commonly used remotely sensed measure of vegetation greenness at the regional scale. The Bureau generates NDVI data products monthly from AVHRR data acquired at NOAA receiving stations across Australia including the WASTAC station. The Bureau produces both NDVI itself and NDVI standardised anomaly, which expresses the departure of NDVI from the long-term mean for the month. The calculation of NDVI anomaly requires a long historical dataset, and most of the AVHRR record used for this has been collated by CSIRO. The Bureau provides national and state maps and data grids of monthly NDVI on its climate web pages. 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 is being developed by the Terrestrial Ecosystem Research Network.

The dynamics of NDVI tend to follow that of rainfall with a lag, as vegetation responds to the moisture availability. Figure 4 (top) shows the total rainfall for June 2013 across the country in terms of deciles. The decile is the rank of the rainfall amount relative to the amounts for that month for all years since 1900, in one of ten blocks of 10%. For a broad band running from the north-west to the south-east of the country the June 2013 rainfall amounts were in the top 30% (deciles 8–10) of June values, while in Queensland and southern Western Australia rainfall was in the bottom 30% (deciles 1–3). Figure 4 (bottom) shows the NDVI standardised anomaly for two months later, August 2013. The north-east to south-west band of strongly positive NDVI anomaly closely follows the extent of the June band of high rainfall, and indicates vegetation greenness that is significantly higher than usual for that time of year, which is expected as a response to the higher than normal rainfall.

Figure 4 (right)**:** The national map of monthly rainfall deciles for June 2013 (top) and the NDVI standardised anomaly maps for August 2013 (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.


Australian Government
Bureau of Meteorology
Rainfall Decile Ranges
Highest on Record
10
Very Much Above Average
8-9
Above Average
4-7
Average
2-3
Below Average
1
Very Much Below Average
Lowest on Record
Australian Rainfall Deciles
June 2013
Distribution Based on Gridded Data
Product of the National Climate Centre
http://www.bom.gov.au
© Commonwealth of Australia 2013, Australian Bureau of Meteorology
ID code: AWAP
Issued: 26/12/2013


Australian Government
Bureau of Meteorology
5.0
3.0
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1.5
1.0
0.6
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-0.2
-0.6
-1.0
-1.5
-2.0
-3.0
-5.0
No Data
NDVI STANDARDISED ANOMALY
August 2013
© Commonwealth of Australia 2013, Australian Bureau of Meteorology
Issued: 05/09/2013

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 other two are operated from the Northern Territory Regional Forecasting Centre in Darwin and the Queensland Regional Forecasting Centre in Brisbane. (See Figure 5)

Tropical cyclones (TC) are a major destructive force causing extensive wind damage, flooding from intense rainfall, storm surges and occasionally loss of life. It is extremely important, therefore, to be aware of the formation of these systems and to monitor them closely. Since the majority of these systems originate in conventional data sparse areas, the usual way of determining the origin of these systems is by 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 alone and hourly satellite imagery from MTSAT-2 (operated by the Japan Meteorological Agency), Feng Yun 2 East 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 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 is able to take refuge, prepare properties or make other arrangements with plenty of time to spare.

Since the WASTAC L-Band and X-Band provide 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.

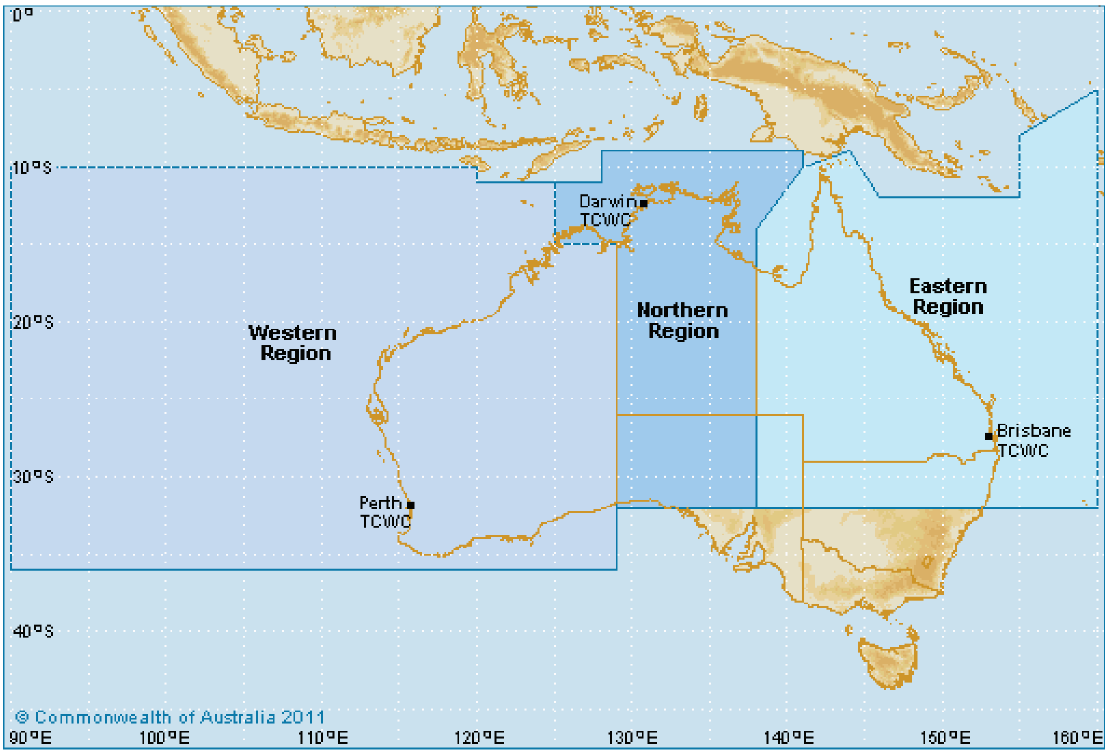

Figure 5: The three Tropical Cyclone Warning Centres and their areas of responsibility. To the west of the Western Region, the area of responsibility falls to La Reunion.

For the Period 1 January 2013 to 31 December 2013, there were seven tropical cyclones that entered or formed within Perth TCWC's area of responsibility (See Table 1). Of these, the most severe tropical cyclones that threatened the Australian coastline were Severe Tropical Cyclone Rusty and Severe Tropical Cyclone Christine.

Tropical Cyclone	Period (2013)	Max Intensity	Impact on Coast or Other Aus. Territory	Means of Detection
Narelle*	5 – 15 Jan 2013	Cat 4	Nil	Satellite
Peta	20 – 23 Jan 2013	Cat 1	Minimal	Satellite
Rusty*	21 Feb – 1 Mar 2013	Cat 4	Moderate	Satellite
Victoria*	7 – 12 Apr 2013	Cat 3	Nil	Satellite
Alessia	22 – 24 Nov 2013	Cat 1	Minimal	Satellite
Bruce*	16 – 24 Dec 2013	Cat 3	Nil	Satellite
Christine*	28 Dec 2013 – 1 Jan 2014	Cat 3	Moderate	Satellite

* Classified as Severe Tropical Cyclone

Table 1: List of Tropical Cyclones for the Period January 2013 to December 2013

Severe Tropical Cyclone RUSTY
(Figure 6 and 7)

(21 February to 1 March 2013)

A monsoon trough combined with an active phase of the Madden-Julian Oscillation (MJO) produced a broad but weak low near 13S 122E on the morning of 22 February. The low moved steadily to the southwest before becoming near stationary and gradually intensifying on 23 February. Overnight on 23 February the low began to take a southerly track while continuing to intensify. It was named Tropical Cyclone Rusty at 2 pm WST 24 February, about 360km north of Port Hedland.

Rusty continued to steadily intensify as it moved in a south to southeasterly direction towards the coast; reaching category 3 intensity around 8 pm WST 25 February. During this period Rusty had a very large radius of gale force winds surrounding the centre, with Port Hedland Airport recording sustained gales from midnight WST 25 February, at which time the centre of Rusty was still 210km to the NNE.

Severe Tropical Cyclone Rusty became near stationary during 26 February, with the radius to gale force winds surrounding the centre contracting as the system gradually intensified. Rusty reached category 4 intensity for a brief period on the morning of 27 February before weakening to a category 3 system and resuming its movement to the south southeast towards the coast, crossing the coast that afternoon at 5 pm WST 27 February, 10km east of Pardoo Station, with wind gusts reaching 200km/h. Rusty rapidly weakened once it crossed the coast and was downgraded to below cyclone strength around 2 pm WST 28 February, around 70km SE of Nullagine.

Water and structural damage to buildings was reported from both Pardoo Station and Pardoo Roadhouse, with many trees down and significant flooding. Pardoo Station also reported cattle loss as a result of hypothermia. Only minor damage was reported in Port Hedland. Due to the very slow movement of the system (average speed of 5.5km/h from the morning of 23 February to crossing) there was a significant disruption to shipping and offshore industries, with Port Hedland Port closed for 86 hours, as well as onshore mining operations near the path of Rusty.

Port Hedland Airport recorded sustained gales for 39 hours from midnight WST 25 February which is unprecedented in the wind record that goes back to 1942. Major flooding occurred in the De Grey River catchment as a result of the prolonged heavy rainfall.

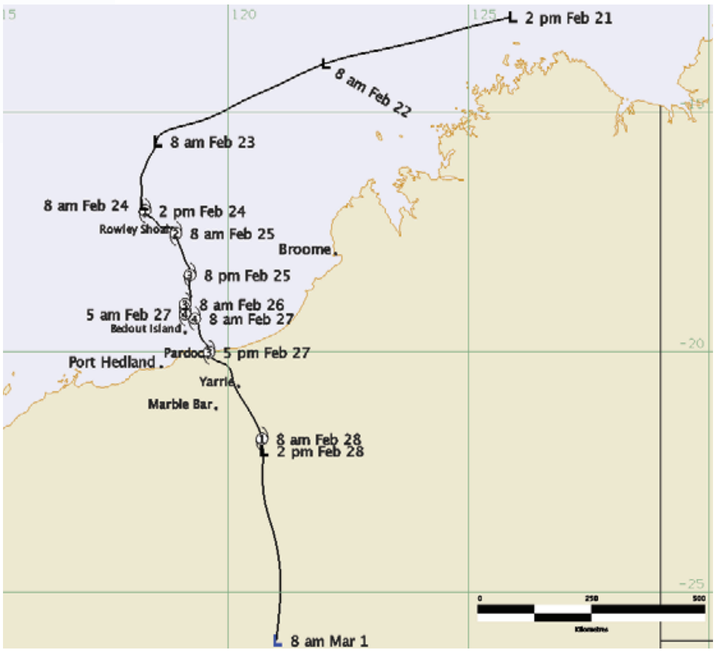

Figure 6: The operational track of Severe Tropical Cyclone Rusty.

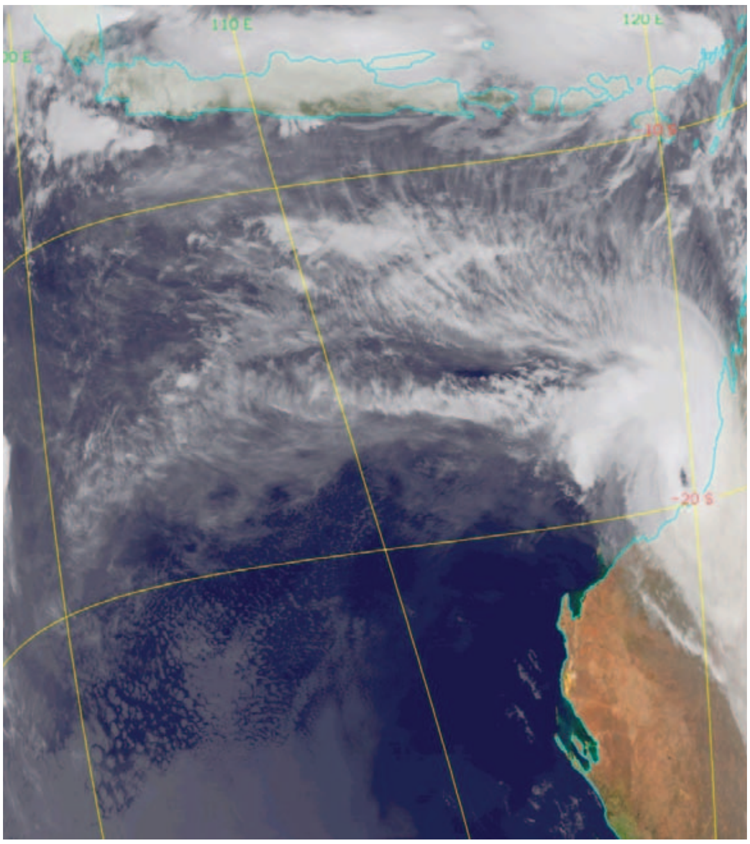

Figure 7: Severe Tropical Cyclone Rusty at time of maximum intensity. Image taken from NOAA-19 at 17:59 UTC on 26 February 2013.

Severe Tropical Cyclone CHRISTINE
(Figure 8 and 9)

(28 December 2013 to 1 January 2014)

An active monsoon trough north of the State spawned a number of transient low pressure systems in the lead up to Christmas. One of these formed in the Joseph Bonaparte Gulf and was the subject of a tropical cyclone warning for the far northern Kimberley on the 24th and 25th December. This low did not develop and moved west to be absorbed by a broader monsoon circulation. A discrete centre within this broad circulation was analysed from Christmas Day. This low began moving towards the south southwest.

The large nature of the system contributed to slow intensification. It was not until 5pm WST on 28 December that it was named Tropical Cyclone Christine at which time it was located off the west Kimberley about 280km north northwest of Broome. Christine steadily intensified while continuing on a south to southwest track, reaching category 3 intensity around 11pm on 29 December.

A feature of the system was its large size, with gale force winds and heavy rainfall well away from the centre. Severe Tropical Cyclone Christine crossed the Pilbara coast as a category 3 system between Roebourne and Whim Creek around midnight on Monday night. As Christine crossed the coast very destructive winds were experienced, with a gust of 172km/hr recorded at Roebourne Airport. Other notable wind speeds were 133 km/hr at Karratha and 130 km/hr at Port Hedland.

Christine gradually weakened once it crossed the coast and began to accelerate to the southeast. The system maintained its cyclonic structure further inland than most tropical cyclones and was finally downgraded to below cyclone strength at 2 am WST 01 January 2014 when it was around 50km northwest of Wiluna. Heavy rainfall was recorded in the vicinity of the cyclone path, with the heaviest 24 hour fall being 168mm at Abydos North, a rain gauge to the southeast of Port Hedland. Other notable 24 hour falls were 134mm at Roebourne airport, 123mm at Port Hedland and 113mm at Karratha. There was minor to moderate flooding in catchments of the De Grey River and Pilbara Coastal Rivers. After weakening below TC intensity, the system moved quickly across south eastern WA, producing damaging winds and moderate to heavy rainfall.

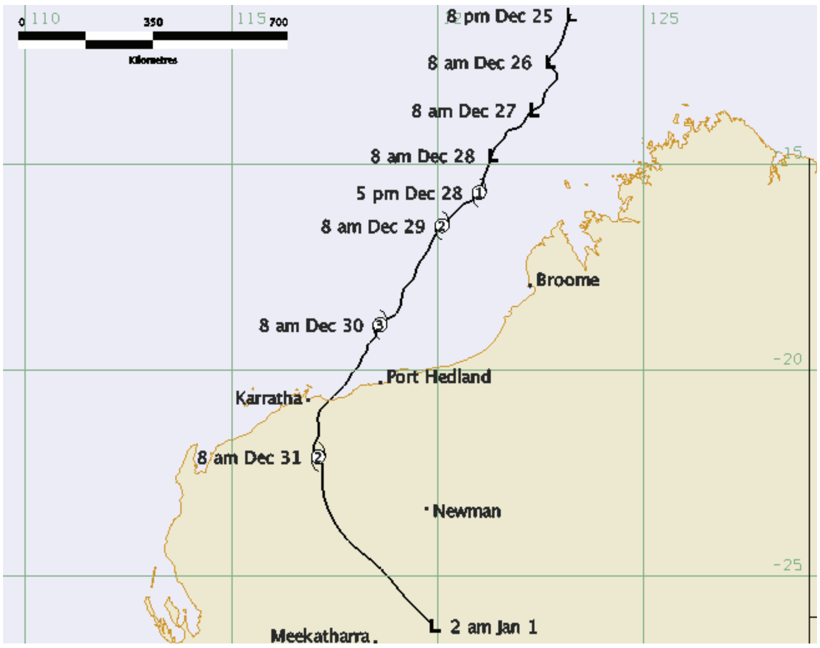

Figure 8: The operational track of Severe Tropical Cyclone Christine.

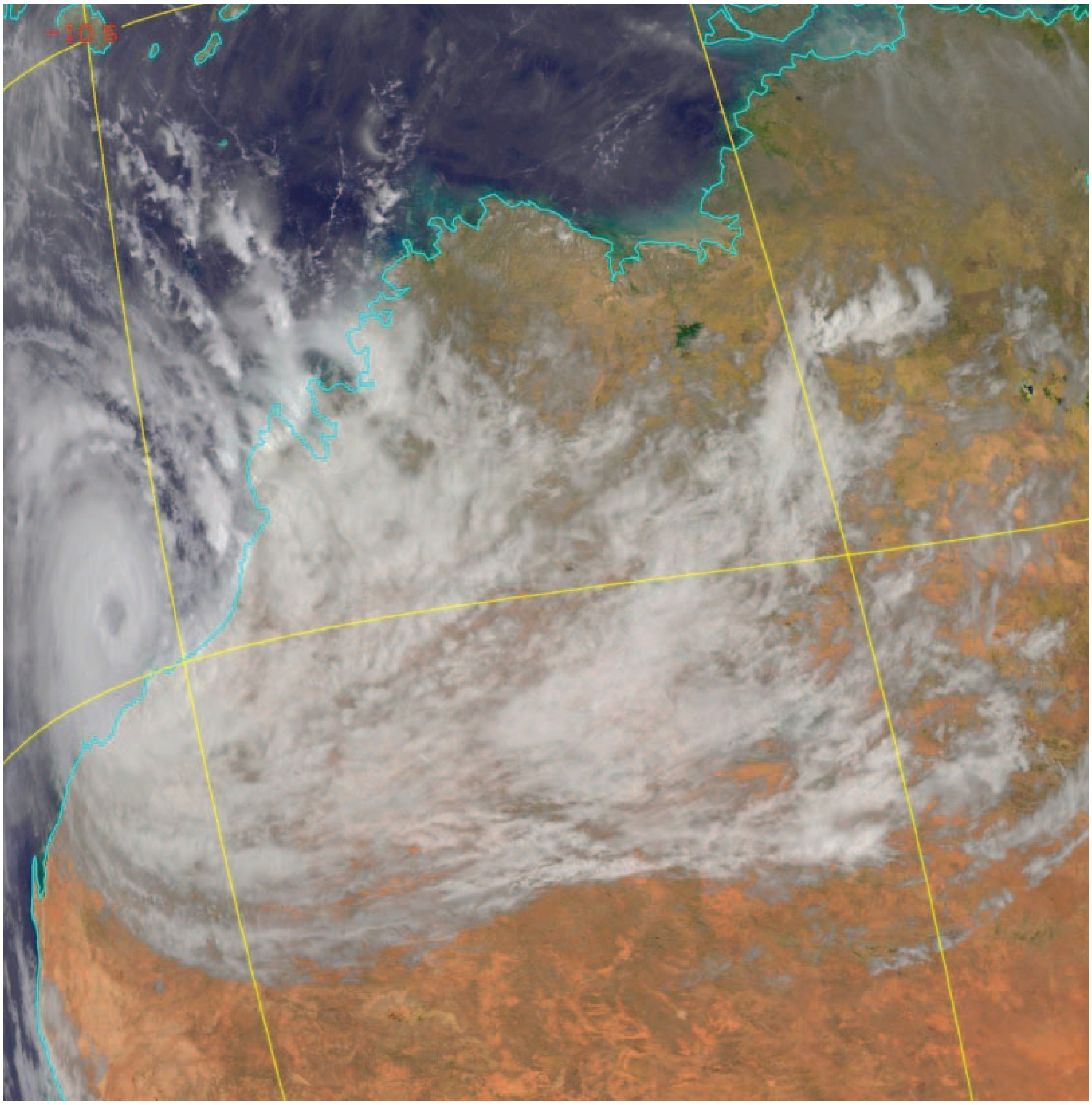

Figure 9: Severe Tropical Cyclone Christine at maximum intensity nearing the Pilbara Coast. Image taken from NOAA-16 at 00:33 UTC 30 December 2013.

Landgate, Satellite Remote Sensing Services, Floreat

RangeWatch - CRC-SI Biomass Business Project

Richard Stovold, Bruce Hearder

Biomass Business is a 3 year federally funded Cooperative Research Centre for Spatial Information (CRC-SI) project run at Liveringa Station in the Kimberley region of WA to develop improved uses of the Moderate resolution Imaging Spectroradiometer (MODIS) data from the Terra and Aqua satellites to support pasture utilisation in the rangelands of Australia for pastoralist.

This Landgate R&D project RangeWatch, to model pasture growth in the pastoral rangelands, is being undertaken in conjunction with project partners from the Precision Agriculture Research Group from the University of New England NSW, CSIRO Centre for Environment and Life Sciences, Curtin University and industry partner the Milne Agrigroup who own Liveringa Station

The aims of the Project are:-

1. Utilising MODIS satellite imagery and climate data, derive a pasture biomass model to estimate available stock feed at critical times in the pasture growing season.
2. Provide a web enabled delivery tool for the pastoralist to view seasonal biomass and pasture growth rate estimates

The expected longer term outcomes of the project will be the development of a simple web tool to allow pastoralists to access their weekly derived biomass and pasture growth measurements of their pastures in every paddock. The RangeWatch (Figure 11) web tool and pasture growth model will assist producers to calculate the viable number of stock from the dry to wet season each year for sustainable land management. A new APP called FATstock (Figure 10) has also been developed which will give free and easy use of a stocking rate calculator compatible with Apple and Android mobile devices and tables.

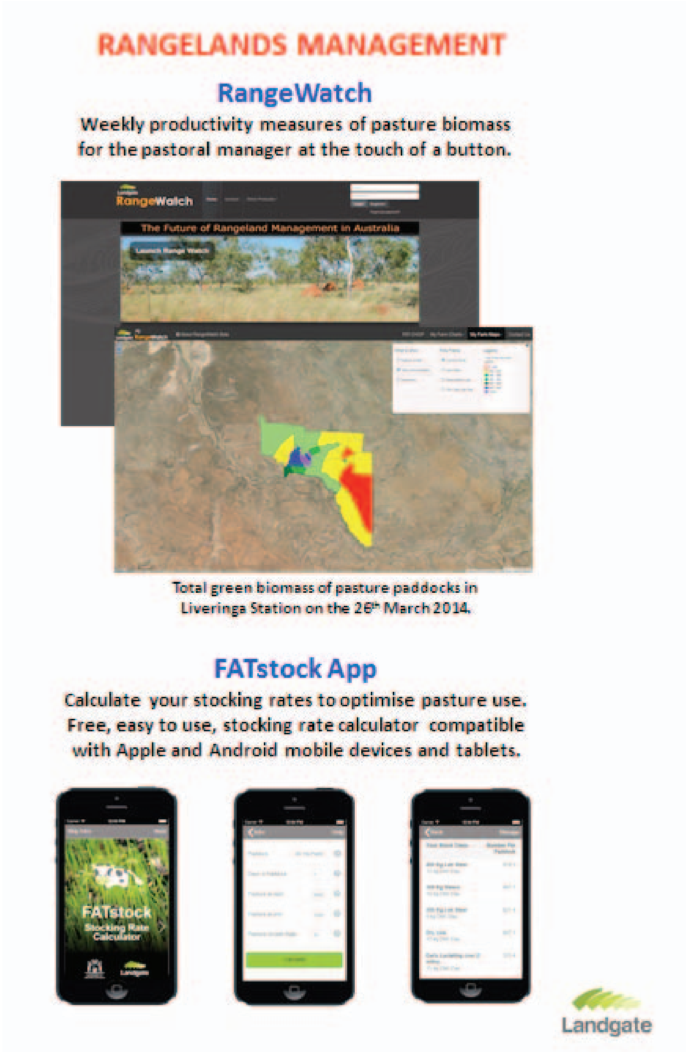

Figure 10: The web tool and derived pasture growth model RangeWatch shows weekly biomass and pasture growth measurements of pastures in every paddock. FATstock is the stocking rate calculator APP compatible with Apple and Android mobile devices and tables.

The expected benefits to the agricultural industry are the establishment of more efficient, sustainable and profitable pastoral enterprises leading to improved supply of meat and livestock for local and overseas markets.

It is envisaged that with further validation this model could be extended to the Kimberly and Pilbara regions of WA and other northern rangelands regions in other states of Australia.

Figure 11: RangeWatch: a web enabled etool for pastoralists to view their property weekly biomass and pasture growth information.

New and improved Pastures from Space

Richard Stovold, Norm Santich, Sarfraz Khokhar

The new and improved 'Pastures from Space' (PfS) is a state-of-art and innovative agricultural analysis product. It combines satellite imagery and climate data to help farmers estimate the amount of feed in their paddocks and how quickly their pastures are growing. Pastures From Space was initially developed by CSIRO in collaboration with the Department of Food and Agriculture (DAFWA) and Landgate.

This new version developed by Landgate is a web-based system compatible with most browsers and with mobile tablets, making it an easily accessible and versatile application out in the field.

The new version:

- helps calculate optimal stocking rates and feed budgeting;
- assists with rotational grazing;
- maximises pasture usage efficiency;
- forecasts total dry matter production;
- optimises fertiliser application at paddock level; and
- improves pasture water use efficiency.

PfS enables farmers to understand seasonal variability and the individual farming system's ability to manage stock grazing pressure and assist with decisions to ensure feed supply matches that pressure. The analysis provided by PfS indicates whether the farm system has the capacity to increase pasture production, allowing the farm manager to make significant tactical decisions.

Once farmers have a sound understanding of the use of the technology, they can analyse the information for themselves as the season unfolds and use it to make informed decisions about their agricultural business.

The PfS data includes pasture growth rates (PGR), feed on offer (FOO) Figure 12, total dry matter (TDM) and Greenness Imagery (NDVI).

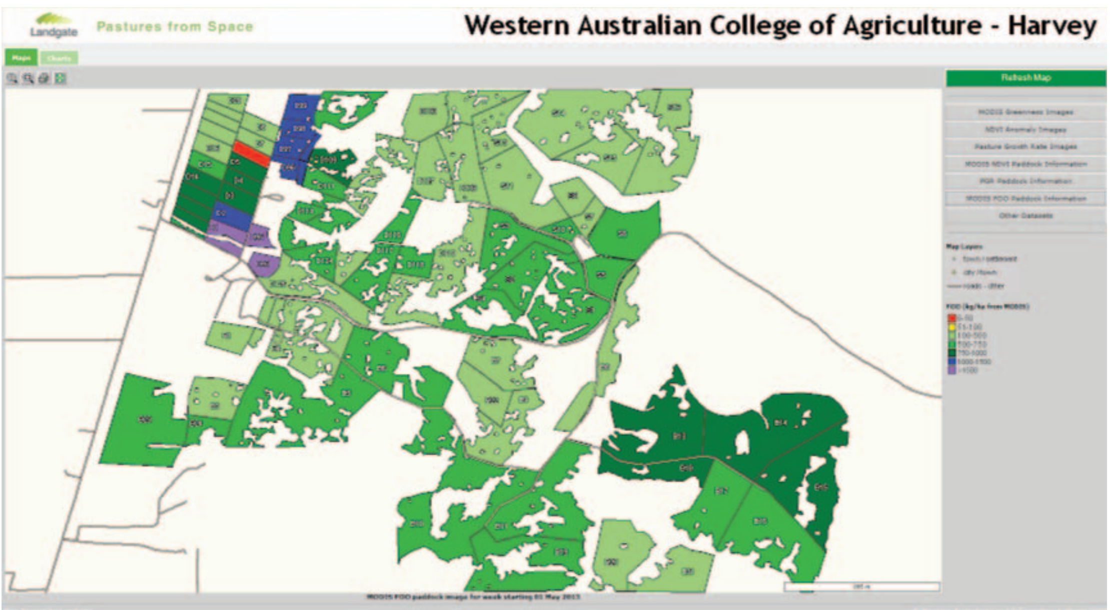

Figure 12: Weekly Feed On Offer (FOO) information available online at paddock level covering the WA College of Agriculture in Harvey Western Australia for the weekly period 1 May 2013 to 7th May 2013.

Producers are now using the Total Dry Matter (TDM) Production (kg/ha) trend graphs to assist them to estimate their seasonal production and animal stocking levels. With 10 years of TDM information as shown in Figure 13, they are able to make earlier and more accurate stocking decisions on their property.

The current seasonal TDM values can be viewed weekly on the Pastures From Space website for any paddock within a property allowing producers to predict the likely progress of the seasons pasture growth when compared to other years.

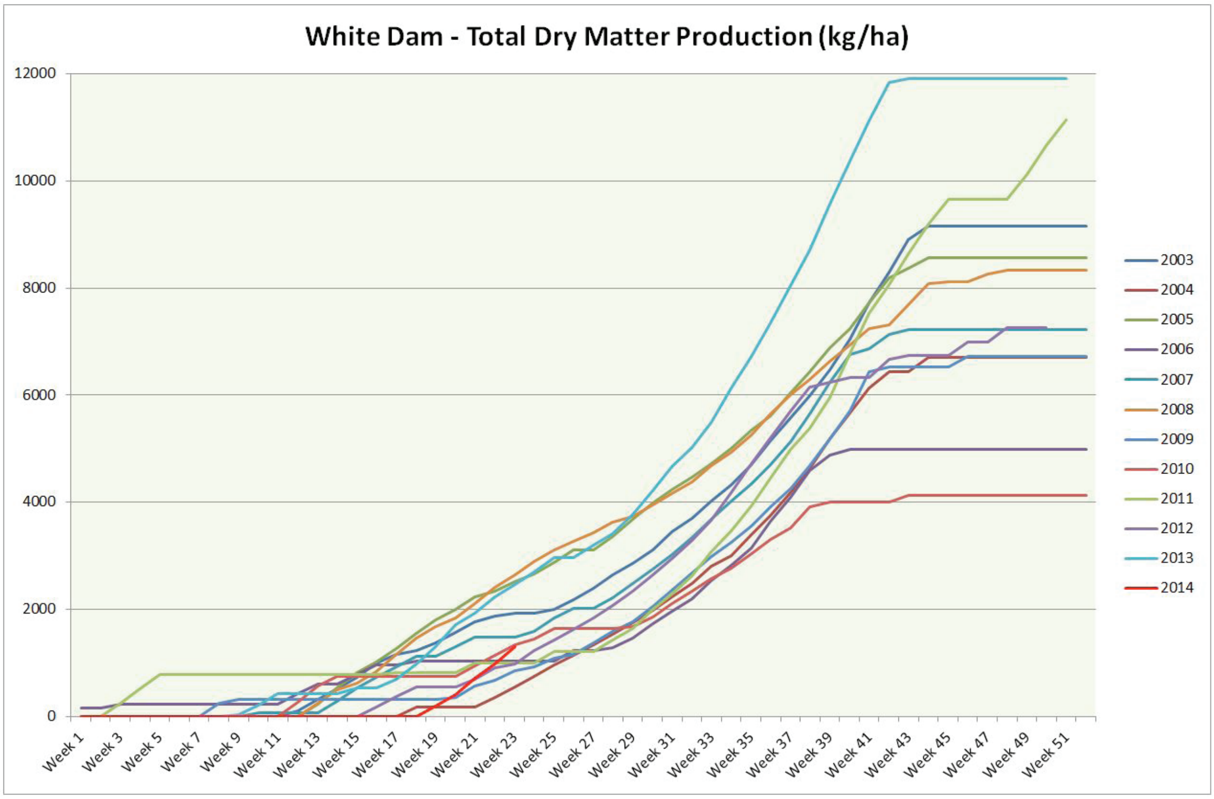

Figure 13: Historical Total Dry Matter Production (kg/ha) for a paddock called White Dam graphed from 2013 to the present time.

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).

Hamersley Agricultural Project

Norm Santich

In October 2012, Rio Tinto commissioned the Hamersley Agricultural Project with the aim of using surplus water from the Marandoo Mine to produce 30,000 tonnes of hay per year. By late April 2013, 2,000 tonnes of hay had been produced. The Moderate resolution Imaging Spectroradiometer (MODIS) on board the Terra and Aqua satellites has been monitoring the Hamersley Agricultural Project since its inception in 2012 and has shown the growth of the project over 2013. The images below are from the weekly MODIS NDVI composites and show the location of Hamersley Station. The irrigated pivots are located at the south east corner of the station. The NDVI images Figures 14 and 15 also show the transition from the dry season into the wet season and back into the dry season.

The higher resolution Landsat 8 image in Figure 16 dated 29th August 2014 indicates the growth variability of each of the pivots.

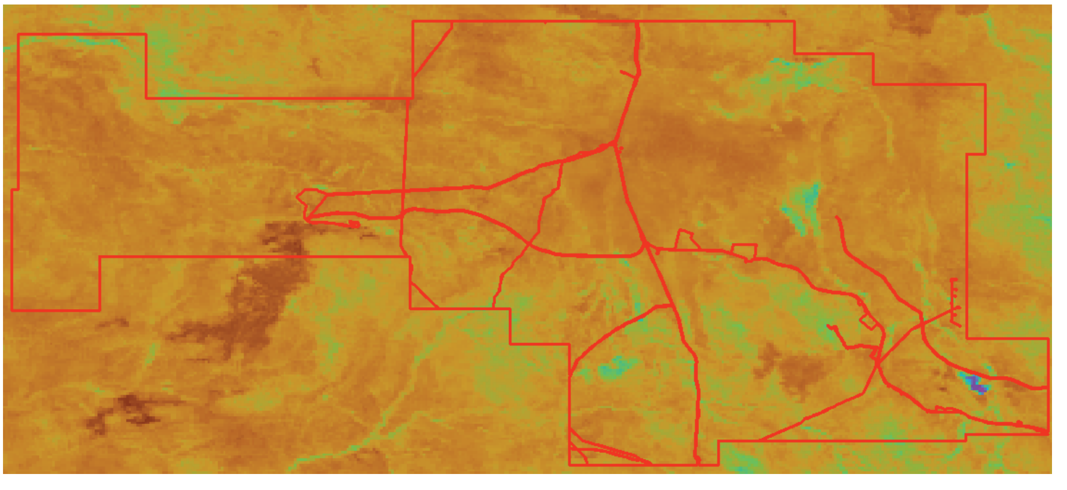

Figure 14: Maximum value NDVI composite, week commencing 2/1/2013.
The irrigated pivots have appeared as blue pixels in the south east corner of the property.

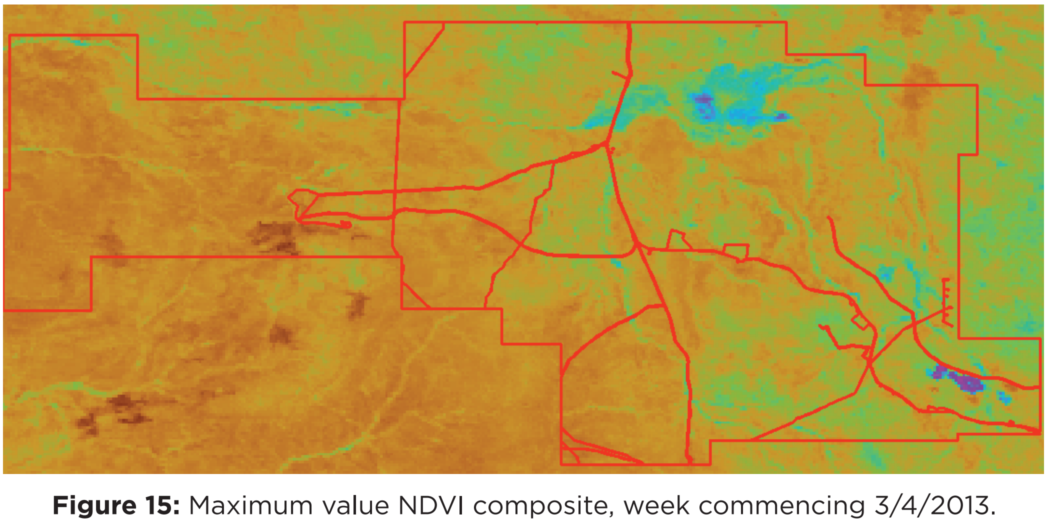

Figure 15: Maximum value NDVI composite, week commencing 3/4/2013.
Approximately 2,000 tonnes of hay had been produced in its first quarter.

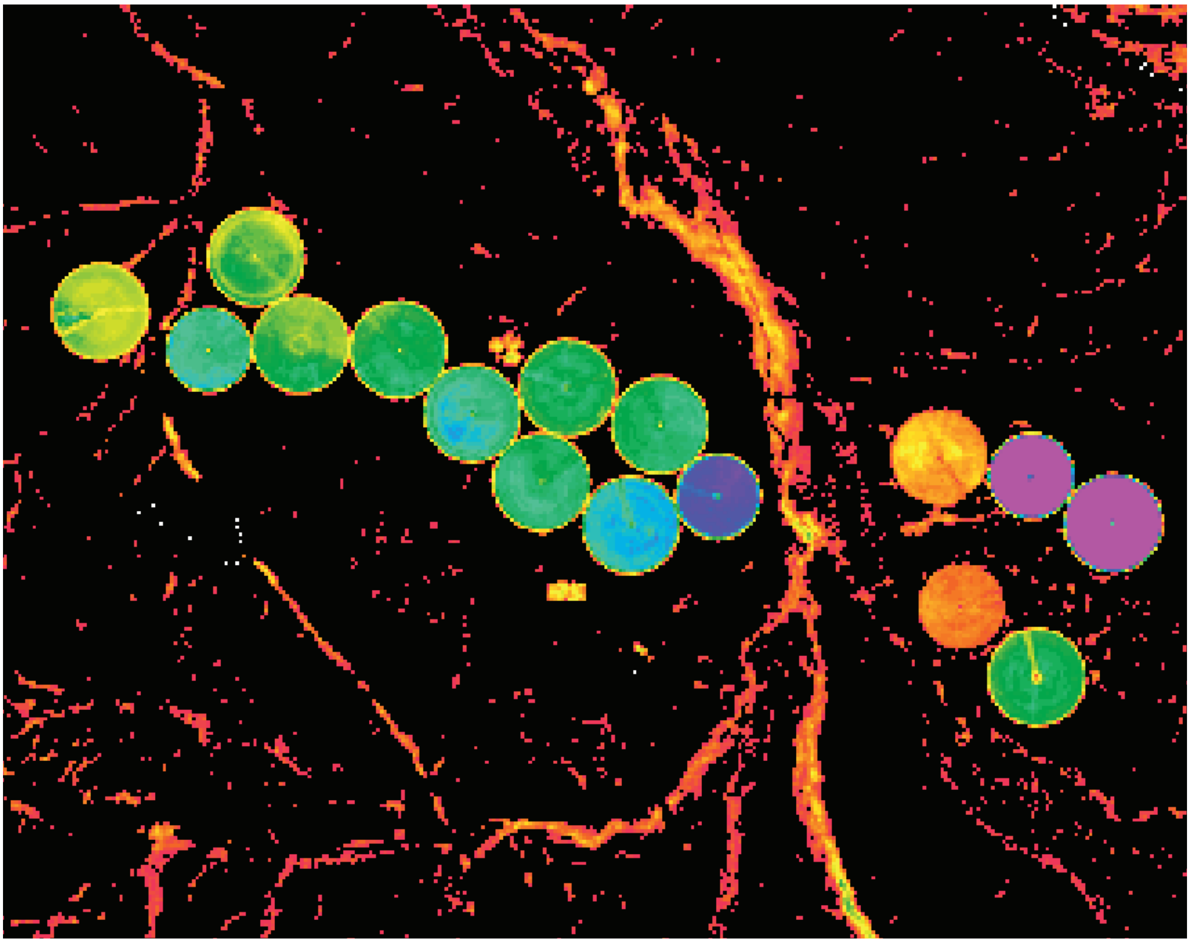

Figure 16: Landsat 8 satellite NDVI image dated 29th August 2014 depicting the growth variability of the irrigated pasture central pivot plots from high growth in purple,medium in green and low in orange.

Aurora Bushfire Simulation System

Gerrit van Burgel

Aurora provides emergency services in regional and remote areas with an early warning tool to better manage prescribed bushfire burning and wildfires. It uses fire hotspots detected from the MODIS sensor on board the Terra and Aqua satellites as ignition points that are passed to the University of Western Australia's (UWA) *Australis* bushfire spread simulator, which predicts bushfire spread within seconds.

Aurora is a partnership between Landgate, UWA and the Department of Fire and Emergency Services (DFES), and partly funded by the Commonwealth Department of Broadband, Communications and the Digital Economy. It will improve bushfire risk management, and the response to fire events throughout Western Australia.

Emergency services teams are able to run simulations through Aurora using a combination of their own information and pre-existing data. This allows the testing of various ignition points and weather conditions to determine the best days for carrying out prescribed burns or to run a series of fire scenarios quickly(Figure 17).

Fuel load data comes from a combination of Landgate's Satellite Remote Sensing Services (SRSS) fire burnt area mapping together with the Department of Parks and Wildlife (DPAW) and DFES fuel age datasets. The fire burnt area maps are digitised from NOAA-AVHRR satellite imagery.

Aurora has won a number of awards including the 2013 National iAwards (Winner in the Society Domain in the Regional Category), the 2013 Asia Pacific ICT awards (Winner in the Sustainability and Environment Technology Category) and the 2013 Western Australian Spatial Excellence Awards (WASEA).

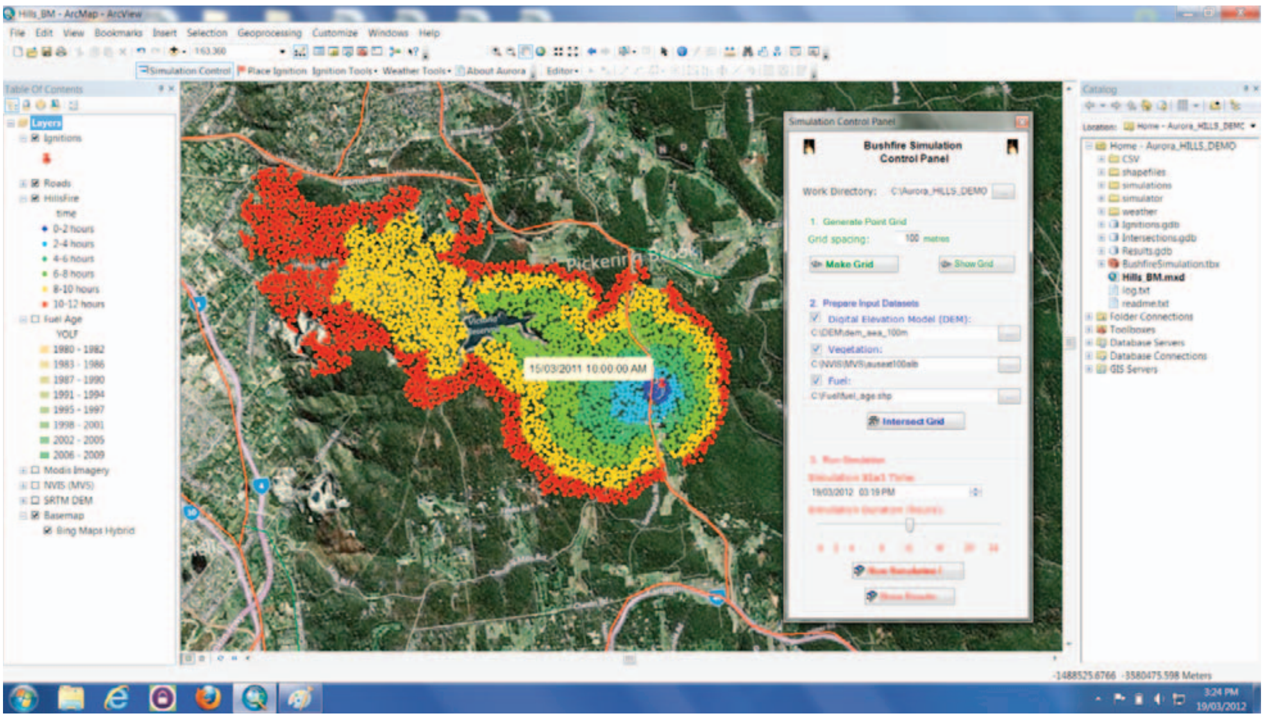

Figure 17: Aurora Desktop interface and prediction tool.

Historical fire data for the last three years, 2011, 2012 and 2013

Agnes Kristina

Landgate, Satellite Remote Sensing Services, has been mapping Australia fire burnt areas from satellite since 1988. Fire burnt areas are mapped from NOAA AVHRR satellite imagery with 1km ground resolution. Due to the pixel size we do not map any burnt areas smaller than 4 km square. To increase the accuracy in manual mapping of fire burnt areas, layers such as water bodies, known static hot spots (e.g. flares), fire hotspots, previous fire burnt areas, previous NOAA AVHRR images and MODIS images are used.

Mapped fire burnt areas are used by fire agencies to assist in managing active fire and prescribed burns. Extensive fire historical data are critical for the understanding of fire behaviour. Figure 18 shows the total area burnt mapped from the NOAA AVHRR data in square kilometres for Australia over the last 14 years.

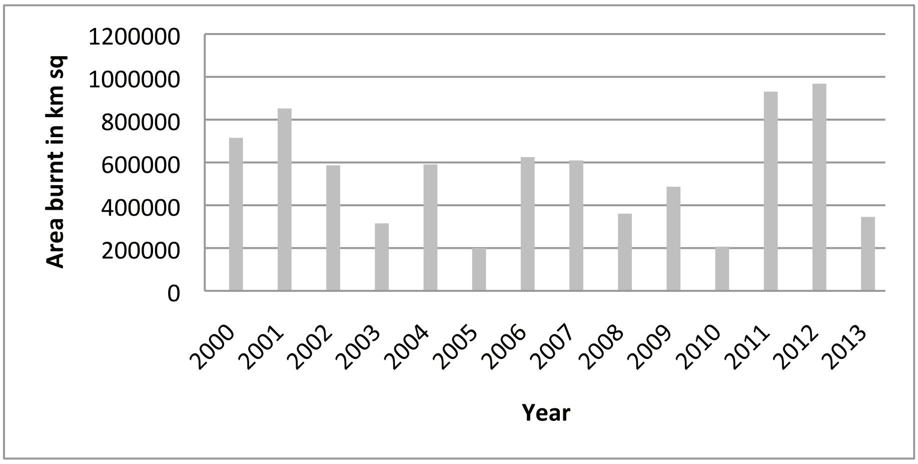

Figure 18: Total fire burnt areas in square kilometres from 2000 to 2013. (Derived from manual NOAA AVHRR fire burnt areas mapping.)

It can be seen in Figure 19 that on an annual basis landscape fires occur throughout Western Australia, Northern Territory and Queensland, with the possibility of repeat fires during these three years in the high rainfall regions of Northern Australia. Total area burnt of 930,900 square kilometres was recorded in 2011, 968,200 square kilometres in 2012 and 345,700 square kilometres in 2013.

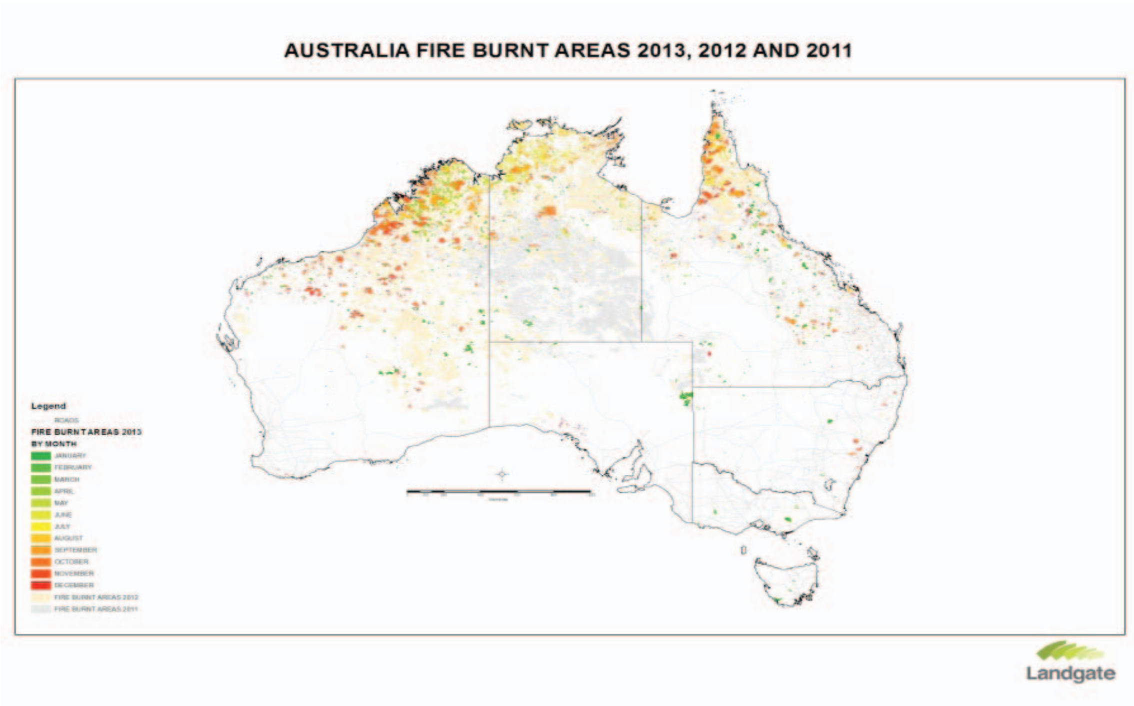

Figure 19: Australia fire burnt areas for years 2011, 2012 and 2013.

For more fire information, contact Ronald Craig (ron.craig@landgate.wa.gov.au) or visit Landgate's firewatch website (firewatch.landgate.wa.gov.au) or our new firewatch-Beta (firewatch-beta.landgate.wa.gov.au).

Validating A Rapid Response Coastal Inundation Model with Modis Imagery

Mario Ferri and Andrew Buchanan

Landgate has developed a rapid response coastal inundation modelling tool that can provide inundation scenarios for both cyclone and storm tide. This modelling tool distinguishes itself from other similar models by its user-friendly operation and its rapid solutions to inundation scenarios. As with all other models, the reliability of the output is dependent upon the accuracy of the inputs which includes oceanographic data, digital elevation model and meteorological information.

Satellite surface water observations are ideally suited for collecting inundation evidence as storm surge extent is difficult to obtain both historically and for post-cyclone events. The only limitation to optical satellite capture is the cloud cover associated with cyclone events. In spite of this limitation satellite captured surface water observations can be used to validate inundation due to storm surge.

As an example Figure 20 shows the result of comparing the predicted inundation from Landgate's rapid response storm surge model for TC cyclone Christine (30 December 2013) against surface water captured from MODIS within the Landgate Floodmap project.

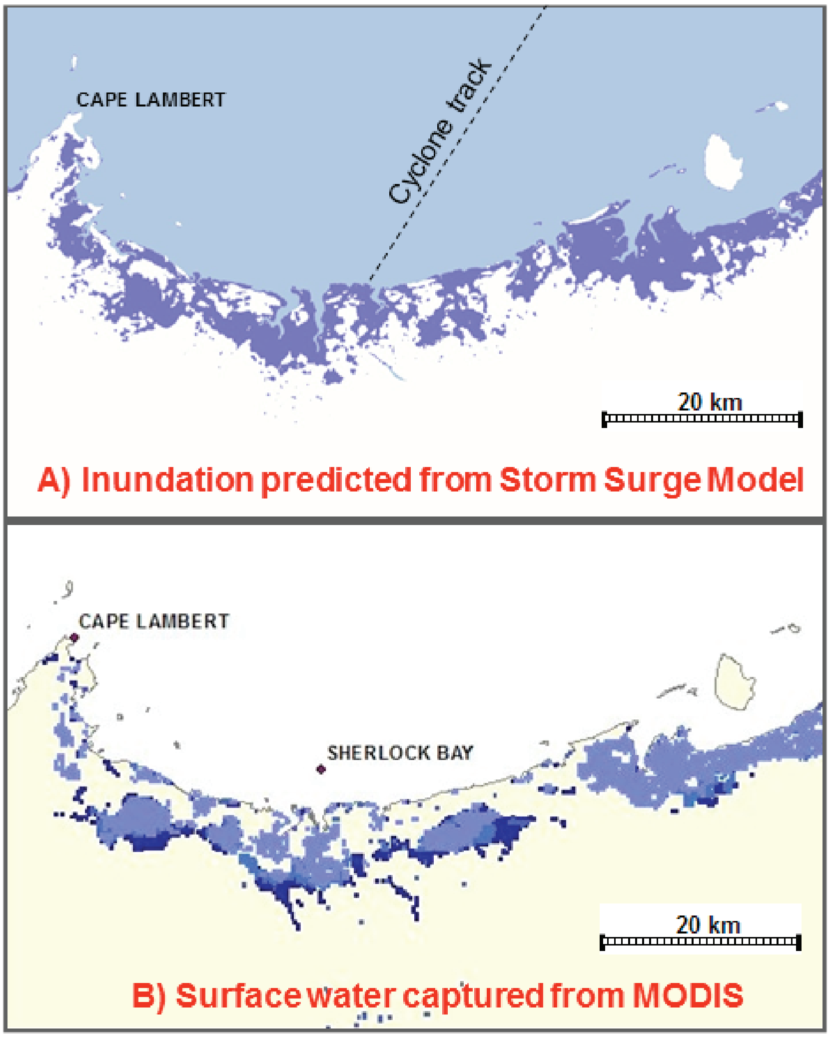

Figure 20: Cyclone Christine (30/12/2013) – A) Predicted inundation (dark blue) from model compared with B) Surface water captured from satellite (shades of blue). Discrepancies may arise due to the time lag between the cyclone landfall and the first cloud free satellite surface observation.

Research Developments 2013

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

CSIRO bio-robots make a splash in the Indian Ocean

Nick Hardman-Mountford

Robotic floats (Figure 1) armed with revolutionary new biosensors will be launched in the Indian Ocean, as part of a new India-Australia research partnership to try and find out what makes the world's third largest ocean tick – and how both nations can benefit from it. CSIRO have joined forces with India's National Institute of Oceanography (CSIR-NIO) and the Indian National Centre for Ocean Information Services (INCOIS) to deploy sensors that measure chlorophyll, coloured dissolved organic matter (CDOM), particle size distribution, dissolved oxygen and nitrate mounted on robotic profiling floats. These floats are similar to those used for the international Argo oceanographic network of more than 3000 floats that has successfully measured ocean temperature and salinity for a decade. The floats can repeatedly dive and ascend throughout the upper 2km of the ocean taking measurements as they go, then send their data back via communications satellites. The data collected, when combined with satellite ocean colour data from sensors such as MODIS, will enable a 3D picture of ocean phytoplankton and their role in carbon cycling to be constructed, informing research into climate variability and marine fisheries. Through CSIRO's Earth Observation and Informatics Future Science Platform, additional floats are being tested with sensors that measure light penetration into the ocean (upwelling radiance and downwelling irradiance) to test their use in calibration and validation of ocean colour satellites.

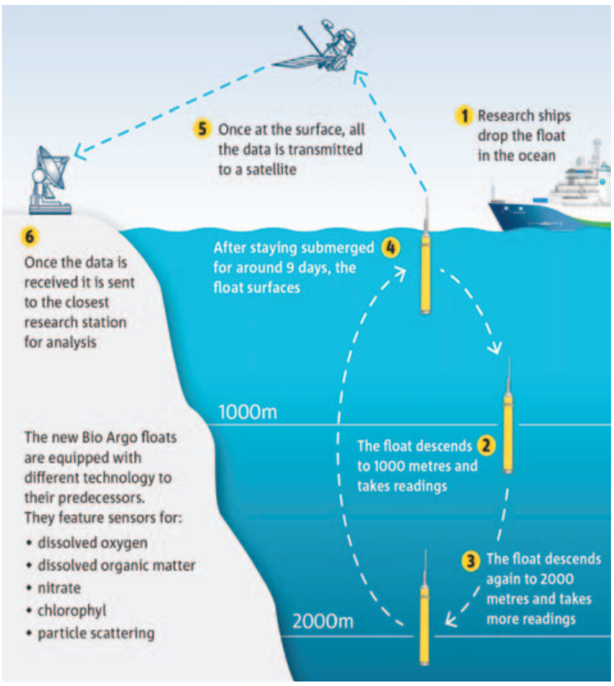

Figure 1: Principal scientist Nick Hardman-Mountford testing communications on one of the new Bio-Argo floats (left) and schematic diagram of the Bio Argo floats in operational use (right).

Validation of MODIS Ocean Colour Chl-a for the Australasian Region

Edward King

The Integrated Marine Observing System (IMOS) Satellite Remote Sensing Facility has compiled a database of bio-optical in situ sample analysis results for Australia, spanning over a decade of observations. In parallel IMOS has supported the production of a comprehensive data set of the MODIS/ Aqua standard ocean colour products at the National Computational Infrastructure (in Canberra) which are now available via the IMOS data portal. The standard NASA algorithms for Chlorophyll-a (Chl-a) are developed mostly using the NOMAD database of in situ observations (Werdell and Bailey, 2005). That database is based mostly on northern hemisphere data, contains no data from Australian waters at all, and indeed has a different distribution of Chlorophyll-a values than are found around Australia. Nevertheless, in the absence of ocean colour algorithms that have been specially tuned for Australian conditions, the NASA products are a valuable resource for researchers. A CSIRO team, led by Dr Jenny Lovell, is using the bio-optical database to undertake an evaluation of the performance of the global satellite Chlorophyll-a product in Australasian waters to develop an understanding of where it is applicable and with what uncertainty. Figure 2 illustrates the substantial volume of data available for satellite matchups provided by the IMOS database.

Analyses have been undertaken for four Chlorophyll-a algorithms supported by the SeaDAS processing package, including two empirical products (OC3 and Clark) and two semi-analytic products (GSM and Carder). Although none of the algorithms give good matchups for all the data points (eg Figure 3), it was found that the least scatter was evident in the open ocean (blue water) areas, although there remains significant bias. The full results will be published in the peer-review literature during 2014.

Not only does the IMOS bio-optical database enable this evaluation, indicating the caution required when using global products locally within Australia, but it can also support the development of tuned local algorithms. It is a publicly released dataset, available via the IMOS data portal and is also being provided to NASA and ESA for incorporation into their in situ data sets to improve future global algorithm development efforts. Researchers are encouraged to utilise the database, and to contribute their own measurements via the IMOS Satellite Ocean Colour sub-facility, to help make this a progressively more valuable piece of research infrastructure over time.

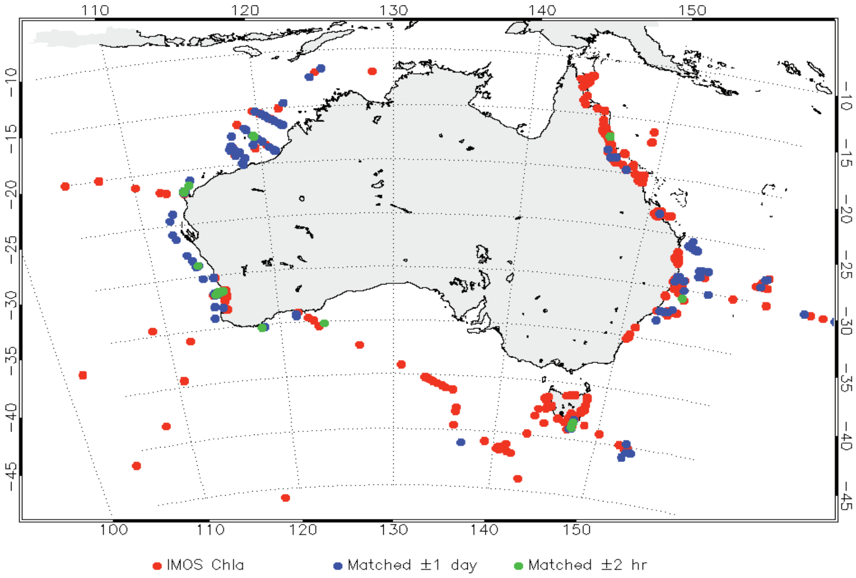

Figure 2: Satellite – in situ matchup points using the new IMOS bio-optical database.

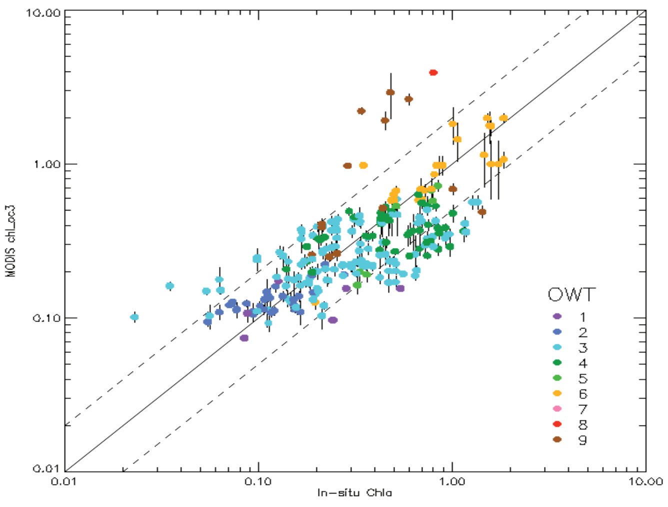

Figure 3: Comparison of MODIS satellite Chlorophyll with matched up in situ data. The colours denote optical water types (OWT), a classification scheme based on observed reflectance spectra (Moore et al, 2009).

References

Moore, T.S., Campbell, J.W., and Dowell, M.D., *A class-based approach to characterizing and mapping the uncertainty of the MODIS ocean chlorophyll product*, Remote Sensing of Environment, 113 (2009) 2424-2430.

Werdell, P.J. and Bailey, S.W., *An improved in situ bio optical data set for ocean color algorithm development and satellite data product validation*, Remote sensing of Environment, 98 (2005) 122-140

Curtin University Of Technology

Remote Sensing and Satellite Research Group (RSSRG)

MODIS and Landsat-8 monitoring of dredging plumes

Mark Broomhall and Peter Fearns, Curtin University

Coastal dredging projects are inevitable as more of the resource-rich North of Australia is utilised. Dredge projects are required to undergo strict environmental approvals outlining the impact of the program on the environment. Part of the approval process involves outlining a monitoring program while dredge operations are underway.

Satellite remote sensing provides a cheap and efficient way to not only monitor the spread of re-suspended sediments but also to estimate the concentration and effects of the dredging by-products.

The Remote Sensing and Satellite Research Group (RSSRG) at Curtin University in conjunction with CSIRO Marine and Atmospheric Research (CMAR) are undertaking research into dredge monitoring and characteristics as part of the Western Australian Marine Science Institute (WAMSI) dredge science node.

RSSRG has developed techniques to produce atmospherically corrected panchromatically sharpened Landsat 8 true colour images for the coastal ocean as displayed in Figure 4.

Figure 4: 15 m resolution true colour images for the coastal ocean over the Wheatstone dredging project.

These techniques have been extended to produce Landsat 8 reflectance products. These products can then be used to provide an estimate of the total suspended sediment (TSS) using algorithms similar to those already utilised with MODIS reflectance products. The results of these algorithms is shown in Figure 5 for Landsat 8 and Figure 6 for MODIS.

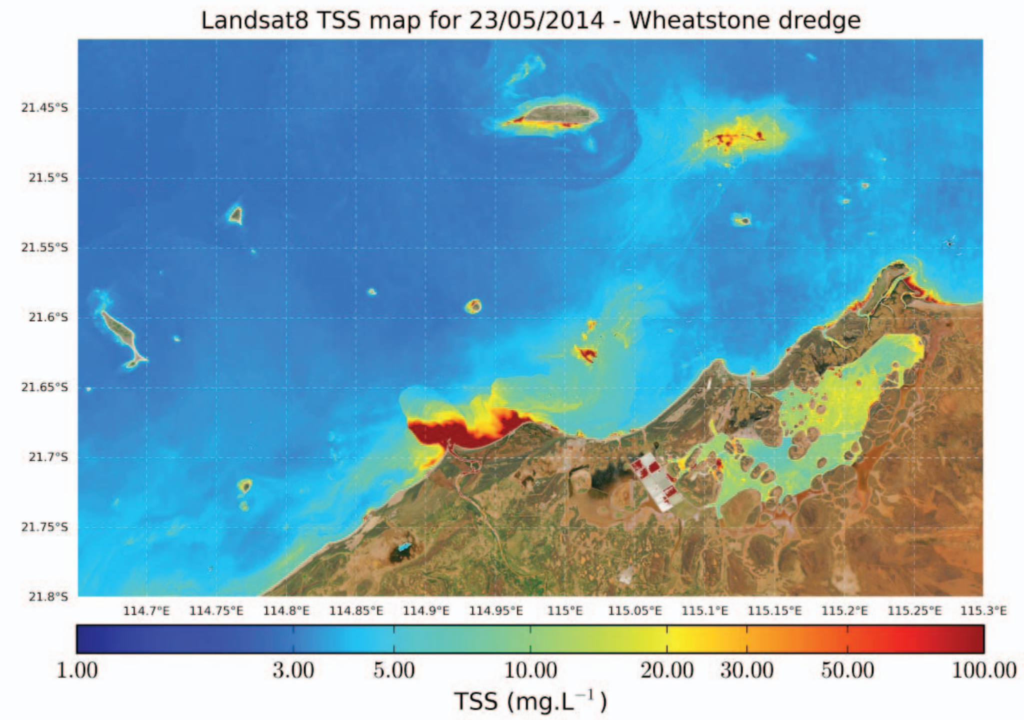

Figure 5: TSS estimate from Landsat 8.

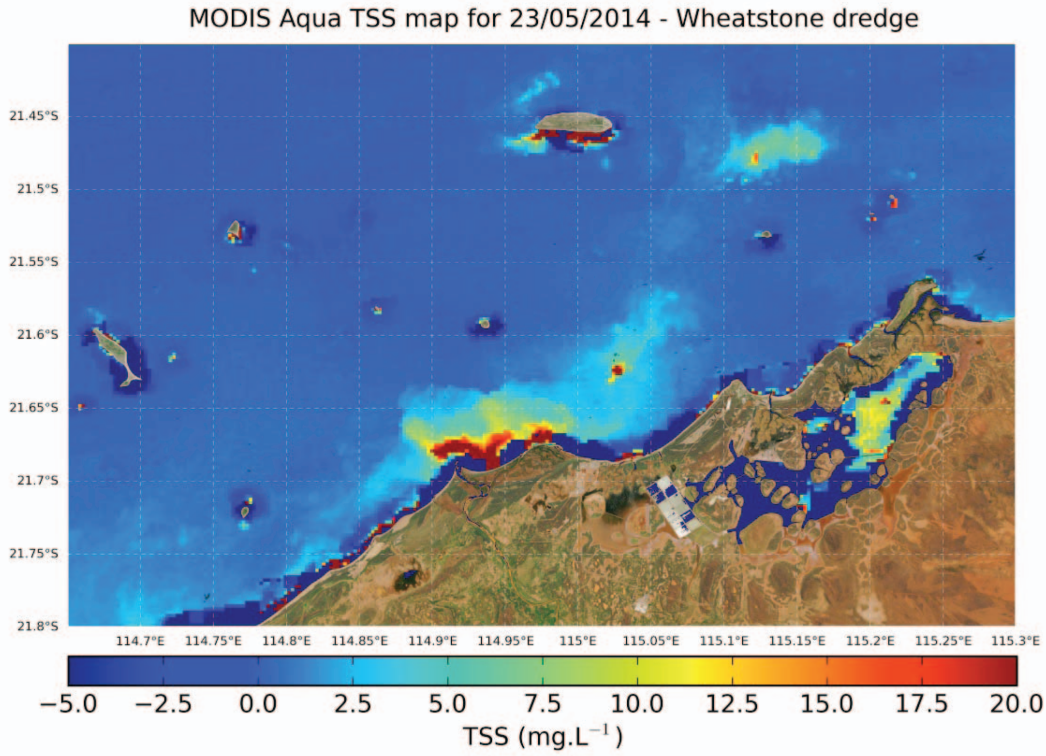

Figure 6: TSS estimate from MODIS Aqua. Dark blue regions show where the algorithm has failed to retrieve valid data.

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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 special purpose financial report of the Western Australian Satellite Technology and Application Consortium – L Band which comprises the balance sheet as at 31 December 2013, income statement and cash flow statement for the period ended 31 December 2013 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.

Auditor Independence

In conducting our audit, we have complied with the independence requirements of the Australian professional accounting bodies.

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 2013 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: 5 JUNE 2014

Perth

WASTAC L- Band BUDGET 2013

Estimated expenditure for the year January 2013 – December 2013

		2012 $	2013 $
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	6000	6000
	TOTAL:	**$37,500**	**$37,500**

Estimated income/revenue for the year January 2013– December 2013

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

Extra-ordinary expenditure carried over to January 2014– December 2014 financial year

1. To be funded from Capital Reserve:

   X Band upgrade for 2014 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 2013

	2013 $	2012 $
REVENUE		
Contributions Received	40,000	40,000
Interest Received	14,259	13,404
Total Revenue	**54,259**	**53,404**
EXPENDITURE		
Depreciation Expenses	7,805	7,805
Equipment maintenance	7,153	2,500
Hospitality	-	163
Microwave License	2,630	2,334
Other operating expenditure	4,191	10,828
Total Expenditure	**21,779**	**23,630**
Net Operating Result for the Year	**32,480**	**29,775**

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY and APPLICATION CONSORTIUM
L - BAND
BALANCE SHEET AS AT 31 DECEMBER 2013

	NOTE	2013 $	2012 $
CURRENT ASSETS			
Cash at Bank		414,661	346,576
Prepayments		-	3,800
Accrued Revenue		-	10,000
TOTAL CURRENT ASSETS		414,661	360,376
NON - CURRENT ASSETS			
Property, plant and equipment	2	14,936	22,741
TOTAL NON - CURRENT ASSETS		14,936	22,741
TOTAL ASSETS		**429,597**	**383,116**
CURRENT LIABILITIES			
Income received in advance		10,000	-
Accrued Expenses		4,000	
TOTAL CURRENT LIABILITIES		14,000.00	-
TOTAL LIABILITIES		**14,000.00**	**-**
NET ASSETS		**415,596**	**383,116**
EQUITY			
Retained Funds	4	415,596	383,116
TOTAL EQUITY		**415,596**	**383,116**

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATION CONSORTIUM
L - BAND
CASH FLOW STATEMENT FOR THE YEAR ENDED 31 DECEMBER 2013

	Note	2013	2012
CASH FLOWS FROM OPERATING ACTIVITIES		**$**	**$**
Receipts			
Contributions Received:			
Department of Land Information		10,000	10,000
CSIRO		20,000	10,000
Bureau of Meteorology		10,000	10,000
Curtin University of Technology		20,000	-
Interest Received		14,259	13,404
Other Receipt		3,800	
Total Receipts		78,059	43,404
Payments			
Payments to suppliers		(9,974)	(19,625)
Total Payments		(9,974)	(19,625)
Net cash provided by operating activities	3	**68,085**	**23,780**
CASH FLOWS FROM INVESTING ACTIVITIES			
Payments for property, plant and equipment		-	-
Net cash used in investing activities		**-**	**-**
Net increase/(decrease) in cash		**68,085**	**23,780**
Cash at the beginning of the year		346,576	322,796
Cash at the end of the year		**414,661**	**346,576**

Notes:

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

	2013	2012
Computer Equipment		
At cost	35,196	151,468
Accumulated depreciation	(35,196)	(151,468)
	-	-
Other Equipment		
At cost	202,441	222,806
Accumulated depreciation	(187,505)	(200,065)
	14,936	22,741
Total Property, Plant and Equipment	**14,936**	**22,741**

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	-	22,741	22,741
Additions	-	-	-
Depreciation expense	-	(7,805)	(7,805)
Carrying amount at end of year	**-**	**14,936**	**14,936**

3 Notes to the Cash Flow Statement

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

	2013	2012
Net operating result	32,480	29,775
Depreciation expense	7,805	7,805
Movement in Current Assets & Liabilities	27,800	(13,800)
Net cash provided by operating activities	**68,085**	**23,780**

4 Retained Earnings

	2013	2012
Balance at beginning of the year	383,116	353,341
Operating surplus/(deficit) for the year	32,480	29,775
Balance at end of the year	**415,596**	**383,116**

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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 special purpose financial report of the Western Australian Satellite Technology and Application Consortium – X Band which comprises the balance sheet as at 31 December 2013, income statement and cash flow statement for the period ended 31 December 2013 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.

Auditor Independence

In conducting our audit, we have complied with the independence requirements of the Australian professional accounting bodies.

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 2013 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: 5 JUNE 2014

Perth

WASTAC X- Band BUDGET 2013

Estimated expenditure for the year January 2013 – December 2013

		2012 $	2013 $
1.	Data Tapes	2,000	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	25,000	25,000
	TOTAL:	**$80,000**	**$80,000**

Estimated income/revenue for the year January 2013 – December 2013

1.	Annual Contributions $20,000 each	80,000	80,000
2.	Interest	25,000	25,000
	TOTAL INCOME:	**$105,000**	**$105,000**

WESTERN AUSTRALIAN SATELLITE
TECHNOLOGY and APPLICATION CONSORTIUM
X - BAND
INCOME STATEMENT FOR THE YEAR ENDED 31 DECEMBER 2013

	2013 $	2012 $
REVENUE		
Contributions Received	80,000	80,000
Interest Received	21,529	22,893
TOTAL REVENUE	101,529	102,893
EXPENDITURE		
Freight Expenses	113	-
Equipment < $5000	-	-
Other Software & Licence <$5,000	9,707	9,325
Maintenance	-	6,176
Depreciation	22,911	22,911
TOTAL EXPENDITURE	32,731	38,412
NET OPERATING RESULT FOR THE YEAR	**68,798**	**64,481**

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATION CONSORTIUM X - BAND BALANCE SHEET AS AT 31 DECEMBER 2013

	NOTE	2013 $	2012 $
CURRENT ASSETS			
Cash at bank		632,524	520,815
TOTAL CURRENT ASSETS		632,524	520,815
NON-CURRENT ASSETS			
Property, plant and equipment	2	71,128	94,039
TOTAL NON-CURRENT ASSETS		71,128	94,039
TOTAL ASSETS		**703,652**	**614,854**
CURRENT LIABILITIES			
Income received in advance		20,000	-
TOTAL CURRENT LIABILITIES		20,000	-
TOTAL LIABILITIES		**20,000**	**-**
NET ASSETS		**683,652**	**614,854**
EQUITY			
Retained Funds	4	683,652	614,854
TOTAL EQUITY		**683,652**	**614,854**

WESTERN AUSTRALIAN SATELLITE TECHNOLOGY AND APPLICATION CONSORTIUM X - BAND CASH FLOW STATEMENT FOR THE YEAR ENDED 31 DECEMBER 2013

	Note	2013 $	2012 $
Receipts			
Contributions Received:			
Landgate		20,000	20,000
CSIRO		40,000	20,000
Bureau of Meteorology		20,000	20,000
Geoscience Australia		20,000	20,000
Interest Received		21,529	22,893
Total Receipts		121,529	102,893
Payments			
Payments to suppliers		(9,820)	(22,399)
Total Payments		(9,820)	(22,399)
Net cash provided/(Used) by operating activities	3	**111,709**	**80,494**
CASH FLOWS FROM INVESTING ACTIVITIES			
Payments for property, plant and equipment		-	-
Net cash used in investing activities		**-**	**-**
Net increase/(decrease) in cash		**111,709**	**80,494**
Cash at the beginning of the year		520,815	440,321
Cash at the end of the year		**632,524**	**520,815**

Notes:

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 1c).

(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 ServicesTax (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

	2013	2012
Computer Equipment		
At cost	26,224	33,428
Accumulated depreciation	(24,852)	(25,716)
	1,372	7,712
Other Equipment		
At cost	866,833	866,833
Accumulated depreciation	(797,076)	(780,505)
	69,757	86,327
Total Property, Plant and Equipment	71,128	94,039

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	**7,712**	86,327	94,039
Additions/(Disposals)	-		-
Depreciation expense	(6,340)	(16,571)	(22,911)
Carrying amount at end of year	**1,372**	**69,756**	**71,128**

3 Notes to the Cash Flow Statement

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

	2013	2012
Net operating result	**68,798**	**64,481**
Depreciation expense	22,911	22,911
Movement in Current Assets & Liability	20,000	(7,385)
Net cash provided/(used) by operating activities	**111,709**	**80,007**

4 Retained Earnings

Balance at beginning of the yea	614,854	550,373
Operating surplus/(deficit) for the year	68,798	64,481
Balance at end of the year	**683,652**	**614,854**

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