WASTAC

Western Australian Satellite Technology and Applications Consortium

2018 Annual Report

Australian Government
Bureau of Meteorology

Landgate

Murdoch University

Australian Government
Geoscience Australia

CSIRO

Curtin University

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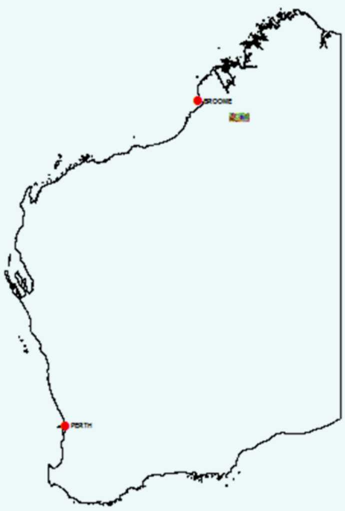
The website has been decommissioned.

A snapshot taken on 24 September 2019 can be found here: https://web.archive.org/web/20190924131022/http://www.wastac.wa.gov.au/

Front Cover: The first NOAA receiving dish at Curtin University, c.1982.

Editors: M Adams and M Steber - Landgate



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Chairman's Report

What a year 2018 turned out to be for WASTAC! It was intense, but rewarding. Unfortunately, it took until August 2019 to get our financial statements finalised and audited. This coincided with the death of my mother in the United States, the summer of bushfires from September 2019 to January 2020, and then the COVID Pandemic from there. It's only now, in January 2024, that I've been able to take the time to reflect on the year that was for WASTAC in 2018.

In late 2017 the X-band Deed members elected to and signed an Agreement to extend the WASTAC X-band Consortium until 31 December 2018 to facilitate the windup of the X-band Consortium. Members from the L-band Consortium also agreed to wind up the L-band Consortium on 31 December 2018. Consequently, there was a flurry of activity behind the scenes through 2018 to formally wind up both Deeds that made up WASTAC.

It is important to note that while WASTAC has wound down, its core function - the acquisition of satellite data via ground station capability in Western Australia - continues. WASTAC funded the cost of a new Orbital Systems reception capability located at Learmonth, which is operated by the Bureau of Meteorology with guidance and advice on reception requirements being provided by the Australian Ground Segment Technical Team (ANGSTT).

The Murdoch facility was transferred to Landgate at the termination of WASTAC. The Murdoch facility continues to contribute to the acquisition of public good satellite data in Western Australia and supports the national needs more broadly through ANGSTT.

In the day-to-day business of WASTAC, the total number of passes received in 2018 was 9,486. This is consistent with expectations with the satellites we chose to receive. While no additional satellites were officially added to the reception list in 2018, WASTAC was able to conduct some trial downloads of JPSS-1 during 2018 and JPSS-1 became operational on the Murdoch facility early in 2019. As of January 2024, Landgate is exploring options to receive FY-3F, particularly the MERSI-3 instrument as a risk mitigation satellite for the aging sensors on Terra.

In addition to funding the physical dish component of the new reception capability at Learmonth, the Board funded two key operational capabilities that are still functioning in 2024. One is the integration of 375m fire hotspot data from VIIRS into the Aurora Bushfire Simulation System, which simulates fire spread for 24 hours from fire hotspots over Australia within minutes of each VIIRS overpass being processed (see Small Research Grants section). The other capability was a website and workflow that allows for the publication of reception schedules from all government operated earth observation satellite receiving stations (generally 2.4m dishes for polar orbiting satellites) which can be found at https://s3-ap-southeast-2.amazonaws.com/web.angstt.gov.au/web/ui/index.html, and the stitching of data received by all Tier 3 stations into a whole of swath/orbit product.

And while WASTAC ceased on 31 December 2018, the Board created a Research and Education Entity Framework (REEF) to build capacity in the earth observation community in Western Australia through support of research and education opportunities. Two projects were funded from REEF and results are presented in this Annual Report in the Small Research Grants section.

The WASTAC partners contributed generously to the efficient running of WASTAC in its final year. Jackie Marsden, Joe Cudmore, and Mike Steber (Landgate), along with Kelly Desker (BOM), kept the stations and processing systems operating in 2018. Ed King (CSIRO) made available state vectors for geolocation of AVHRR imagery, as well as providing technical capability for the stitching project mentioned earlier. Our secretary, Dr. Wendy Thompson, was an invaluable resource to keep myself and the various processes moving that were required to keep WASTAC operating in the direction it had chosen to go until 31 December 2018.

As Chairman, and despite that I know that WASTAC was no more from 1 January 2019, I take pride in the major contributions WASTAC has made and whose legacy continues to make to support the advancement of our understanding of land, ocean and atmospheric processes across Australia.

Digital Signature

Dr Matthew Adams
Chairman, WASTAC 2018

WASTAC Board Members

WASTAC Board for 2018

Dr Matthew Adams – Chairman
Landgate

Dr Wendy Thompson – Secretary
Landgate

Adjunct Prof. Merv Lynch
Curtin University (School of Science – Physics)

Prof. David Antoine
Curtin University (School of Science – Physics)

Dr Edward King
CSIRO

Dr Alex Held
CSIRO

Ms Agnes Lane
Bureau of Meteorology

Mr Mike Bergin
Bureau of Meteorology

Dr Simon Oliver
Geoscience Australia

Dr Jatin Kala
Murdoch University

Dr Halina Kobryn
Murdoch University

Dr Margaret Andrew
Murdoch University

WASTAC Standing Committee and proxy to the Board

Dr Matthew Adams – Chairman
Landgate

Dr Wendy Thompson – Secretary
Landgate

Adjunct Prof. Merv Lynch
Curtin University (School of Science – Physics)

Prof. David Antoine
Curtin University (School of Science – Physics)

Mr Mike Ridout
Curtin University (WA School of Mines – Spatial Sciences)

Ms Kelly Desker
Bureau of Meteorology

Dr Jatin Kala
Murdoch University

Dr Halina Kobryn
Murdoch University

Dr Margaret Andrew
Murdoch University

Dr Peter Caccetta
CSIRO

Dr Edward King
CSIRO

Mr Vincent Rooke
Geoscience Australia

ANGSTT – Australian National Ground Segment Technical Team*

Dr David Hudson – Chair
Geoscience Australia

Mr Vincent Rooke
Geoscience Australia

Dr Wenjun Wu
Geoscience Australia

Dr Jackie Marsden
Landgate

Mr Mike Steber
Landgate

Ms Kelly Desker
Bureau of Meteorology

Dr Edward King
CSIRO

*Replaced WASTAC Technical Committee January 2017

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, National Oceanic and Atmospheric Administration (NOAA), Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) and FengYun-1D (FY-1D) 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 existing reception and processing capabilities and upgrade Meteorological Operational (MetOp) geolocation processing to utilise CSIRO's CAPS software.
- Continue to improve the products derived from Moderate Resolution Imaging Spectroradiometer (MODIS), AVHRR, and VIIRS sensors.
- Advance the processing of AIRS data from Aqua and Terra.
- Improve the management and access of the WASTAC archive through collaboration with the Pawsey Centre.
- Provide network access to other Earth Observation Satellite receiving stations in Australia.

Operations

WASTAC maintained an L-band reception facility at Curtin University and still maintains a dual X- and L-band facility at Murdoch University. The L-band facility at Curtin University was operational from 1983-2016, 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 archive of L-band images beginning in 1983, and an ongoing near real-time archive of X-band images from 2001.

CURTIN UNIVERSITY - L-BAND

The L-band facility at Curtin University in Bentley consisted 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 (Bureau). This data was ingested into the central processing computers at the Bureau's Head Office.

In February 2016, critical equipment failure resulted in the L-band facility being brought offline permanently. In December 2017, the L-band facility was dismantled and donated to the Australian Space Academy with the assistance of Curtin University (see the sections on "Curtin Dish Removal" and "A New Future for the WASTAC Curtin L-Band Dish" in the 2017 WASTAC Annual Report).

MURDOCH UNIVERSITY - X- AND L-BAND

The X- and L-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. As at 31 December 2018 this facility received data from the Aqua, Terra, MetOp, Suomi-NPP, FY-3B and FY-3C, as well as the L-band satellites such as NOAA-15, NOAA-18 and NOAA-19. The dual band reception capability at Murdoch is particularly beneficial following the L-band facility at Curtin going offline.

The Murdoch University satellite reception facility was maintained by Landgate and Murdoch University staff.

Following the termination of the WASTAC Deeds, the X-band facility was transferred to Landgate, which continues to maintain the facility with support from Murdoch University staff and began receiving JPSS-1 data in early 2019 and JPSS-2 data in late 2023.

WASTAC Data Archive

2018 ARCHIVE

The WASTAC archive of satellite passes continued to be managed and maintained by Landgate's Earth Observation (EO) Team. The EO Team is based at Landgate's main offices in the Perth suburb of Midland.

The 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 9,486 passes were archived at Murdoch in 2018 (Table 1).

TOTAL ARCHIVED PASSES FOR 2018

MONTH	NOAA 15	NOAA 18	NOAA 19	FY3B	FY3C	METOP A	METOP B	TERRA	AQUA	NPP	TOTAL
JAN	94	136	130	0	0	60	74	73	66	48	681
FEB	85	118	116	0	0	84	89	94	86	73	745
MAR	101	130	129	0	0	90	89	100	100	83	822
APR	82	131	123	0	0	92	80	90	84	75	757
MAY	86	129	128	0	0	81	93	91	105	86	799
JUN	94	126	120	0	0	95	116	94	92	95	832
JUL	91	137	135	0	0	85	83	103	110	94	838
AUG	97	130	130	0	0	88	90	97	95	100	827
SEP	83	128	133	0	0	83	87	92	102	89	797
OCT	85	132	135	0	0	85	100	92	116	101	846
NOV	65	114	134	0	0	95	95	79	99	99	780
DEC	67	116	136	0	0	101	102	70	73	97	762
TOTAL	1,030	1,527	1,549	0	0	1,039	1,098	1,075	1,128	1,040	9,486

Table 1: Summary of number of passes archived each month by satellite and by receiving dish during 2018.

At the time the L-band and X-band Consortiums were dissolved, WASTAC had accumulated 311,717 passes from 22 different satellites from 1981 to 2018. 1981 was a lean year with only 27 passes from 2 satellites being captured. 2006 had the highest number of passes with 22,922 from 10 different satellites (Figures 1-3 and Table 2).

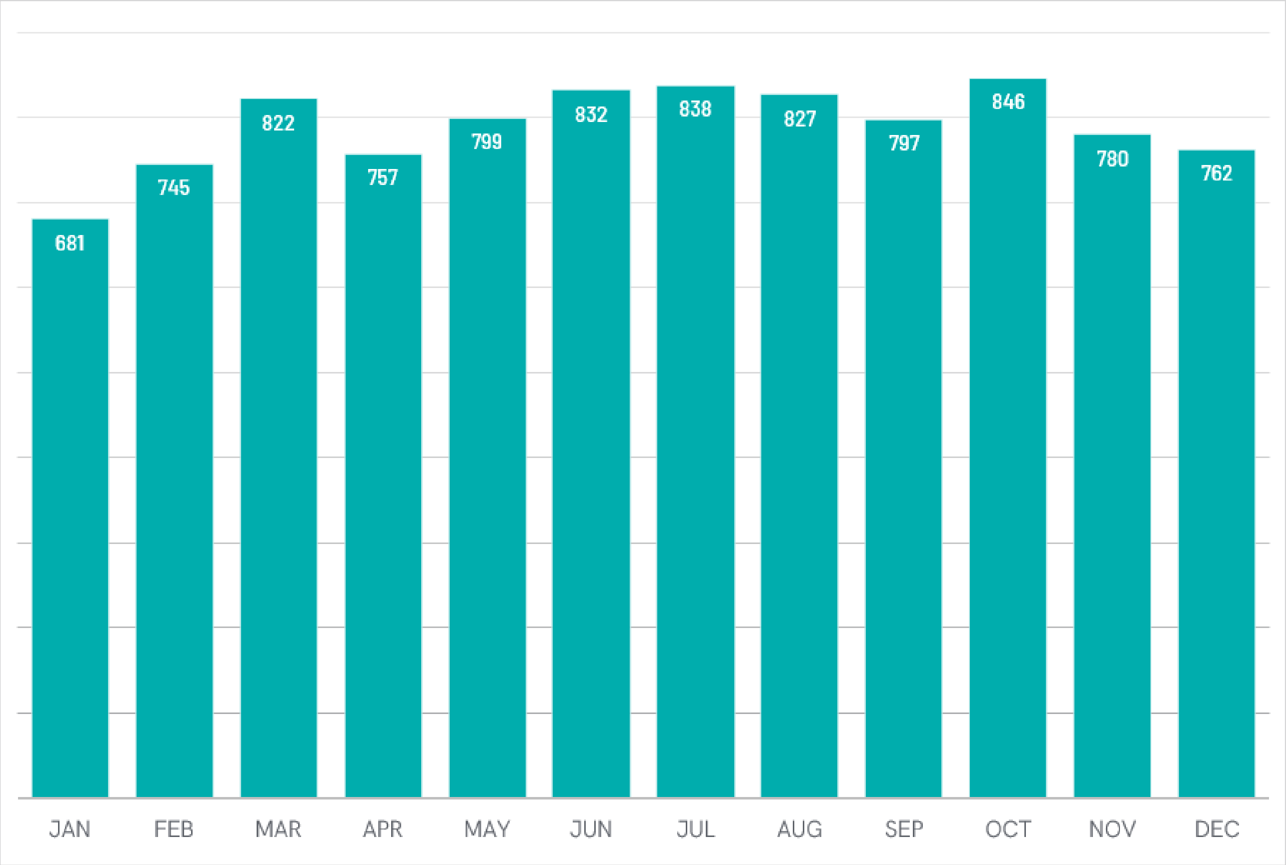

Figure 1: Total number of archived passes for Murdoch dish in 2018.

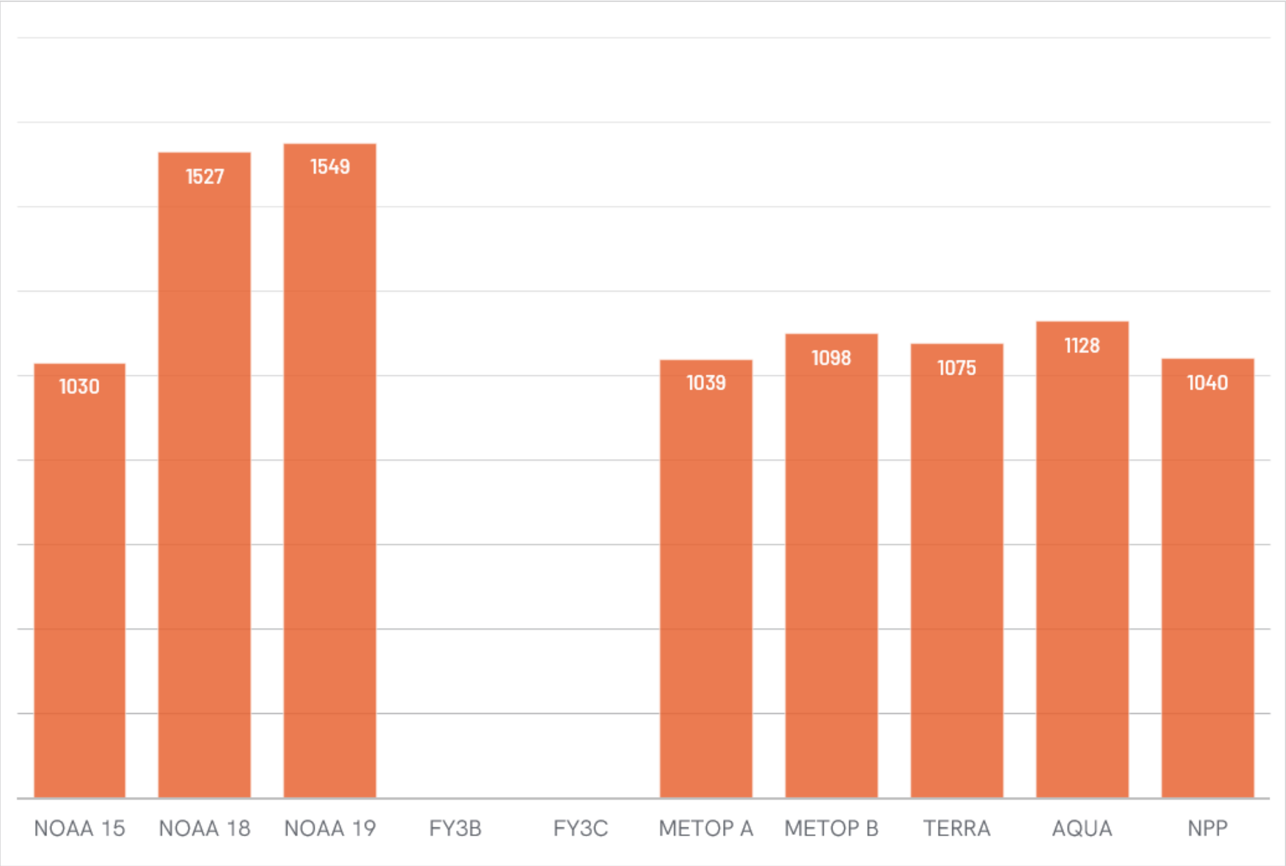

Figure 2: Total number of passes archived for each satellite for Murdoch dish in 2018.

TOTAL ARCHIVED PASSES 1981-2018

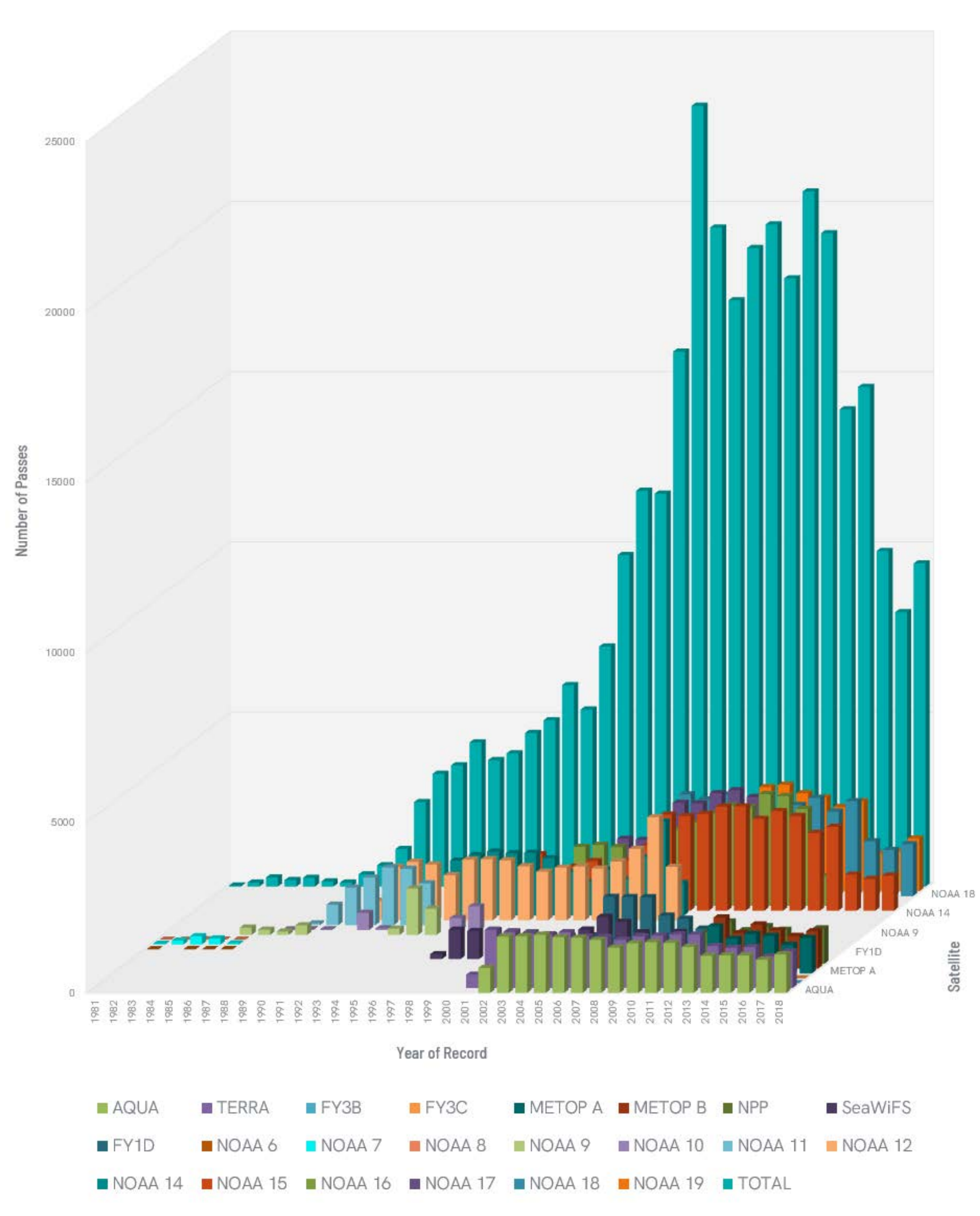

Figure 3: Summary of archived passes recorded by year and by satellite from 1981-2018.

YEAR	AQUA	TERRA	FY3B	FY3C	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	0											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															1,103								1,103
1991														506	1,399	575							2,480
1992														47	1,693	1,571							3,311
1993													183		1,656	1,720							3,559
1994													1,362		1,227	1,641							4,230
1995													770			1,326	1,615						3,711
1996														354		1,780	1,776						3,910
1997								142						694		1,797	1,876						4,509
1998								859								1,763	1,828	432					4,882
1999								822								1,589	1,839	1,663					5,913
2000								843								1,427	1,681	905	341				5,197
2001		390						811								1,548	1,271	1,292	1,733				7,045
2002	734	1,710						780								1,579	976	1,455	1,789	709			9,732
2003	1,651	1,645						696								1,521	1,351	1,200	1,728	1,827			11,619
2004	1,665	1,602						680								1,727	1,058	1,481	1,524	1,797			11,534
2005	1,705	1,577						863	553							2,101	1,706	1,904	1,743	2,212	1,339		15,703
2006	1,635	1,639						1,239	1,683							3,030	2,761	2,823	2,240	2,883	2,989		22,922
2007	1,615	1,512						1,092	1,678							1,571	952	2,777	2,442	2,869	2,839		19,347
2008	1,553	1,495						787	1,673									2,844	2,711	3,165	2,985		17,213
2009	1,327	1,411						687	1,132									3,055	2,951	3,254	2,622	2,306	18,745
2010	1,454	1,516						793	1,040									3,061	2,895	3,054	2,567	3,058	19,438
2011	1,485	1,537							751									2,692	3,282	2,527	2,453	3,128	17,855
2012	1,465	1,571	775		1,118	316	924		255									2,923	3,223	2,278	2,677	2,880	20,405
2013	1,349	1,569	557		1,383	1,503	1,243											2,781	2,845	316	2,883	2,752	19,181
2014	1,085	1,232	536		1,021	1,044	987											2,282	866		2,484	2,473	14,010
2015	1,101	1,179	845	82	1,161	1,300	1,106											2,463			2,790	2,642	14,669
2016	1,096	1,203	545	0	1,102	1,123	999											1,059			1,612	1,112	9,851
2017	971	931	99	0	841	962	781											934			1,360	1,175	8,054
2018	1,128	1,075	0	0	1,039	1,098	1,040											1,030			1,527	1,549	9,486
TOTAL	23,019	24,794	3,357	82	7,665	7,346	7,080	11,094	8,765	31	593	21	3,055	1,665	7732	28,266	20,690	41,056	32,313	26,891	33,127	23,075	311,717

Table 2: Total number of archived passes recorded by year and by satellite for 1981-2018.

THE FUTURE OF THE WASTAC ARCHIVE

The near real-time quick-look archive of VIIRS, MODIS and AVHRR data continues to be maintained by the EO team in Landgate. This archive extends back to 1983 for AVHRR, 2001 for MODIS and 2012 for VIIRS. A similar archive of SeaWiFS quick-look data is also held by Landgate. The quick-look archive of MODIS, NOAA, VIIRS and SeaWiFS data can be viewed on request to the EO team in Landgate.

The data archive has been jointly managed between Landgate and CSIRO with Landgate using Amazon Web Services (AWS) and CSIRO using the National Computation Infrastructure (NCI) to store the data. CSIRO has a copy of the SeaWiFs archive in a stitched format and this is available via:

Level 1A
https://geonetwork.nci.org.au/geonetwork/srv/eng/catalog.search#/metadata/f8227_3874_4626_8108

Level 2
https://geonetwork.nci.org.au/geonetwork/srv/eng/catalog.search#/metadata/f4593_3601_6324_5182

Level 2 Remapped
https://geonetwork.nci.org.au/geonetwork/srv/eng/catalog.search#/metadata/f7001_8949_3878_9898

Duplicate copies of the raw data archive are produced for a national archive program hosted at the National Computing Infrastructure (NCI) in Canberra that is coordinated by CSIRO.

Curtin L-Band Archive Information

Dates	Satellite	Storage Method	Custodian	Point of Contact	Location at Deed Termination	Location as at Jan 2024
1997 - NOV 2007	SeaWiFS	Encrypted 4mm DAT	Landgate	Mike Steber	Destroyed	NCI (CSIRO)
DEC 2007 - 2010	SeaWiFS	Encrypted 4mm DAT	Landgate	Mike Steber	Refer below - ensure Dec 2007 - 2010 is transferred to CSIRO for NCI; request to destroy after NCI catalogue is updated.	NCI (CSIRO)
1997 - 2007	SeaWiFS Stitched L1A Collection	Unencrypted NCI https://geonetwork.nci.org.au/geonetwork/srv/eng/catalog.search#/metadata/f8227_3874_4626_8108	CSIRO	Edward King	Maintain	NCI (CSIRO)
1997 - 2007	SeaWiFS Stitched L2 Collection	Unencrypted NCI https://geonetwork.nci.org.au/geonetwork/srv/eng/catalog.search#/metadata/f4593_3601_6324_5182	CSIRO	Edward King	Maintain	NCI (CSIRO)
1997 - 2007	SeaWiFS Stitched L2 Remapped	Unencrypted NCI https://geonetwork.nci.org.au/geonetwork/srv/eng/catalog.search#/metadata/f7001_8949_3878_9898	CSIRO	Edward King	Maintain	NCI (CSIRO)
MAR 2006 - DEC 2010	SeaWiFS	s3://wastac/seawifs	Landgate	Mike Steber	Transfer to AWS Glacier; FTP Dec 2007 - 2010 to CSIRO for transfer to NCI;	AWS S3 (s3://wastac/seawifs/Murdoch)

Dates	Satellite	Storage Method	Custodian	Point of Contact	Location at Deed Termination	Location as at Jan 2024
1997 - 2003	SeaWiFS	Unencrypted CDs	Landgate	Mike Steber		CDs destroyed and data stored in NCI (CSIRO)
1981 - 1992	NOAA / AVHRR	Tapes	Landgate	Mike Steber	Maintain; Transfer to AWS; Ensure copies are held by CSIRO	AWS S3 (s3://wastac/avhrr/Curtin)
APR 1992 - 2016	NOAA / AVHRR	Tapes	Landgate	Mike Steber	Destroyed	AWS S3 (s3://wastac/avhrr/Curtin)
APR 1992 - 2016	NOAA / AVHRR	Tapes	CSIRO	Edward King	Black Mtn tape store, ACT	
1981 - 22 SEP 1987	NOAA / AVHRR	Tapes	Landgate	Mike Steber	Additional copy in Landgate Glacier account	Tapes destroyed and data stored in AWS S3 (s3://wastac/avhrr/Curtin)
SEP 1987 - MAY 1991	NOAA / AVHRR	s3://wastac/avhrr/Curtin/	Landgate	Mike Steber	Additional copy in Landgate Glacier account	
APR 1991 - DEC 1996	NOAA / AVHRR	s3://wastac/avhrr/Curtin/	Landgate	Mike Steber	Additional copy in Landgate Glacier account	
SEP 1996 - MAY 2000	NOAA / AVHRR	s3://wastac/avhrr/Curtin/	Landgate	Mike Steber	Additional copy in Landgate Glacier account	
MAY 2000 - SEP 2006	NOAA / AVHRR	s3://wastac/avhrr/Curtin/	Landgate	Mike Steber	Additional copy in Landgate Glacier account	
SEP 2006 - JUL 2008	NOAA / AVHRR	s3://wastac/avhrr/Curtin/	Landgate	Mike Steber	Additional copy in Landgate Glacier account	
JAN 2007 - FEB 2016	NOAA / AVHRR	s3://wastac/avhrr/Curtin/	Landgate	Mike Steber	Additional copy in Landgate Glacier account	
FEB 2016 - CURRENT	NOAA / AVHRR	s3://wastac/avhrr/	Landgate	Mike Steber	Additional copy in Landgate Glacier account	
1992 - 2007	NOAA Stitched	NCI https://geonetwork.nci.org.au/geonetwork/srv/eng/catalog.search#/metadata/f5263_5504_2663_8841	CSIRO	Edward King	Maintain, duplicates in CSIRO and at NCI	
1992 - 2007	NOAA Station - reformatted; common format	CSIRO - location TBD, likely CSIRO datastore or https://data.csiro.au	CSIRO	Edward King	Maintain	
2007 - 2016	NOAA Stitched	NCI https://geonetwork.nci.org.au/geonetwork/srv/eng/catalog.search#/metadata/f5263_5504_2663_8841	CSIRO	Edward King	Maintain, duplicates in CSIRO and at NCI	
2007 - 2016	NOAA Station - original format	CSIRO - location TBD, likely CSIRO datastore or https://data.csiro.au	CSIRO	Edward King	Maintain	

Murdoch X/L-Band Archive Information

Dates	Satellite	Storage Method	Custodian	Point of Contact	Location at Deed Termination
Dec 31 1999 - Current	MODIS (Aqua / Terra) Australasian Raw Data	NCI https://geonetwork.nci.org.au/geonetwork/srv/eng/catalog.search#/metadata/f5801_7088_4632_1957	CSIRO	Edward King	Maintain, also accessible from US
Dec 31 1999 - Current	MODIS (Aqua / Terra) Australasian Level 1B data	NCI https://geonetwork.nci.org.au/geonetwork/srv/eng/catalog.search#/metadata/f3633_7369_2730_8213	CSIRO	Edward King	Maintain, also accessible from US
Nov 30 2010 - Sep 9 2015	MODIS (Aqua / Terra)	Tape	Landgate	Mike Steber	Transfer to AWS; dispose of tapes after transfer
Sep 24 2015 - Current	MODIS (Aqua / Terra)	s3://wastac/modis/	Landgate	Mike Steber	Transfer to AWS
Jan 31 2012 - Current	VIIRS (NPP) Australasian Raw Dataset	NCI https://geonetwork.nci.org.au/geonetwork/srv/eng/catalog.search#/metadata/f5222_1399_1336_1489	CSIRO	Edward King	Maintain; also accessible from the US.
Mar 3 2012 - Dec 31 2014	VIIRS (NPP)	Tape	Landgate	Mike Steber	Transfer to AWS; dispose of tapes after transfer
Jan 1 2015 - Current	VIIRS (NPP)	s3://wastac/modis	Landgate	Mike Steber	Maintain; also accessible from the US.
2005 - 2012	FY1D	s3://wastac/mersi	Landgate	Mike Steber	Additional copy on Landgate's Glacier Account
Apr 8 2005 - Apr 10 2014	FY2C	Tape	Landgate	Mike Steber	Transfer to AWS; dispose of tapes after transfer
2012 - Current	FY3B	s3://wastac/mersi	Landgate	Mike Steber	Additional copy on Landgate's Glacier Account
Apr 10 2012 - Apr 12 2015	FY3B	Tape	Landgate	Mike Steber	Transfer to AWS; dispose of tapes after transfer
2015 - Current	FY3C	s3://wastac/mersi	Landgate	Mike Steber	Additional copy on Landgate's Glacier Account
2012 - 2015	METOP A	Tape	Landgate	Mike Steber	Transfer to AWS; dispose of tapes after transfer
2016 - Current	METOP A	s3://wastac/avhrr	Landgate	Mike Steber	Additional copy on Landgate's Glacier Account
2012 - 2015	METOP B	Tape	Landgate	Mike Steber	Transfer to AWS; dispose of tapes after transfer
2016 - Current	METOP B	s3://wastac/avhrr	Landgate	Mike Steber	Additional copy on Landgate's Glacier Account
Jan 2006 - Current	NOAA / AVHRR	s3://wastac/avhrr/Murdoch	Landgate	Mike Steber	Additional copy on Landgate's Glacier Account
Jan 2006 - 2017	NOAA / AVHRR Stitched H	NCI https://geonetwork.nci.org.au/geonetwork/srv/eng/catalog.search#/metadata/f5263_5504_2663_8841	CSIRO	Edward King	Maintain, duplicates in CSIRO and at NCI

A History of WASTAC

WASTAC'S KEY ACTIVITIES 1979-2019

(adapted and updated from "The WASTAC Story" in the 2005 Annual Report)

Alan Pearce (CSIRO), Brendon McAtee, Matthew Adams and Robert Shaw (Landgate)

It was over 25 years ago that CSIRO and the Western Australian Institute of Technology (WAIT; now Curtin University of Technology) signed an historic agreement to establish a NOAA satellite receiving station on the WAIT campus. It took another 2 years for the installation of the first receiving dish on the roof of the Electrical Engineering building.

Since then, the satellite data from that facility and its successors have been increasingly used for agricultural, marine and atmospheric applications such as fire and flood monitoring, weather forecasting, vegetation indices and sea-surface temperatures for the fishing industry. WASTAC has well deserved its enviable record in the acquisition, archiving and distribution of locally-received satellite remote sensing products, and there is now an archive of approaching 100,000 passes from NOAA-AVHRR, SeaWiFS and MODIS.

Four phases can be identified in the development of WASTAC and these notes highlight the major milestones along the way.

1) Pre-WASTAC beginnings: The pioneers (1979 to 1986)

- 1979: Initial agreement between CSIRO (Dr. Frank Honey) and WAIT (Dr. Bill Carroll) to establish a NOAA satellite receiving station.
- May 1981: First manually-operated receiving facility established at WAIT as a joint CSIRO/WAIT project.
- August 1981: First NOAA-6 and NOAA-7 passes archived (partial pixels on every second line), using 9-track 6250 bpi magnetic tapes.
- June 1983: First full passes with every pixel of every line received.
- 1985: Early discussions between CSIRO, WA State Government agencies, Bureau of Meteorology and Curtin University on establishing an upgraded reception facility to provide operational remote sensing data on a regular basis. This led directly to the establishment of WASTAC, under the chairmanship of Henry Houghton of the Department of Land Administration (DOLA; now Landgate).

2) Establishment and growth of WASTAC: New deed, new dish, new partners (1987 to 2000)

- July 1987: Upgraded automatic L-band reception facilities at WAIT officially commissioned by the Hon. Barry Jones (Federal Minister for Science) and the Hon. Keith Wilson (State Minister for Housing and Lands).
- September 1987: First satellite pass using the new WASTAC reception facilities. While the antenna and controller were retained at Curtin University, the data were relayed in real-time via analogue micro-wave link for ingest into a Dual computer system at the Bureau of Meteorology offices in Wellington Street (Perth); data archiving and distribution were undertaken by DOLA at Jardine House in the city.
- January 1989: First WASTAC deed signed by the Bureau of Meteorology, CSIRO, Curtin University (ex- WAIT) and the Department of Land Administra-tion (DOLA), with the stated objectives:

  (a) to acquire operate and maintain the facility;

  (b) to maintain an archive of remotely sensed data acquired by the Facility from satellites of the National Oceanic and Atmospheric Administra-tion (hereinafter called "NOAA");

  (c) to provide remotely sensed data for the day-to-day operational requirements of the Bureau;

  (d) to provide facilities and remotely sensed data for the parties here to conduct research and development projects from time to time;

  (e) to provide in accordance with the provisions of this Deed remotely sensed data to members of the Consortium for their own requirements or purposes or for supply by them to those to whom they may be responsible or for sale by them to their respective customers or clients as the case may be on terms and conditions determined by the Board.

- December 1989: First formal WASTAC Annual Report published.
- January 1993: The Leeuwin Centre for Earth Sensing Technologies opened, providing accommodation for the remote sensing sections of DOLA, CSIRO, Curtin University, TAFE and some commercial clients.
- March 1995: WASTAC deed renewed for second 5-year period. This included a re-structure of the WASTAC Board of Management to meet twice a year separately from the ongoing Standing Committee.
- December 1995: Henry Houghton retired as inaugural Chairman of WASTAC and was replaced by Richard Smith (DOLA).
- September 1996: Upgrade to the ingest facility with HP workstations replacing the IBM PS/2 system, and a high speed microwave link established for transferring satellite data directly to the Leeuwin Centre.
- December 1996: The WASTAC receiver assisted in the rescue of a stricken yachtsman in the Southern Ocean.
- 1997: WASTAC Strategic Plan prepared, with the 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".
- March 1997: WASTAC "quicklook" facility for AVHRR passes established on the World Wide Web.
- October 1997: First SeaWiFS pass received by WASTAC.
- April 2001: Implementation of CAPS software into the WASTAC/DOLA processing stream.

3) X-band expansion and operation: A new generation of satellites (2001 to the 2012)

- August 2001: Expanded WASTAC-X consortium formed by the Bureau of Meteorology, CSIRO, Curtin University, DOLA, Geosciences Australia and Murdoch University.
- September 2001: New X-band facility (with a 3.6 m radomed autotracking antenna) installed at Murdoch University to receive MODIS data; the facility was officially commissioned in November.
- September 2001: First MODIS/TERRA pass received and archived.
- September 2001: WASTAC website established: www.wastac.wa.gov.au.
- November 2001: The digital microwave link was upgraded from 2 to 4 Mbits/sec.
- July 2002: First MODIS/AQUA pass received and archived.
- November 2002: Three MODIS development working groups established for atmosphere, land and ocean.
- June 2004: WASTAC-X deed signed by the 6 Consortium partners.
- August 2005: L-band upgrade to the Murdoch antenna, allowing reception of NOAA/AVHRR, SeaWiFS and FY-1D.
- 2006: X-band computer at Murdoch University was upgraded by Seaspace to incorporate ingest from new X band satellites.
- 2006: Installation of a new antenna mount for the 2.4m L band tracking antenna at Curtin University.
- Late 2007: A high speed bidirectional microwave unit was installed at Curtin University to facilitate high speed transmission of raw and processed satellite data from Curtin University to the Buruea of Meteorology and the Leeuwin Centre in Floreat.
- April 2008: AVHRR ingest and display systems developed by the Bureau were installed.
- Late 2008: LNC upgrades allow for METOP reception by both the L band dish at Curtin University and the X band dish at Murdoch University.
- December 2010: Last SeaWiFS pass received and archived.
- 2011: A high speed bidirectional microwave unit was installed at Murdoch University to facilitate high speed transmission of raw and processed satellite data from Murdoch University to the Bureau of Meteorology and the Leeuwin Centre in Floreat via existing microwave link at Curtin University.
- March 2012: First NPP and METOP-A passes received and archived.
- March 2012: Last FY1-D pass received and archived.
- April 2012: First FY-3B pass received and archived.
- October 2012: First METOP-B pass received and archived.

4) Transitioning to a new mode of operation and winding up (2013 to 2019) following the release of the Australian Space Utilisation Policy on 21 May 2013

- 2013: WASTAC Board agree 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 (NEOS-IP).
- 2013: WASTAC funds CSIRO to make more readily available CAPS (Common AVHRR Processing Software) which produced state vectors to more accurately geolocate satellite imagery from the AVHRR sensor on NOAA satellites.
- June 2014: X-band demodulator replaced at Murdoch University.
- April 2015: Computer hardware upgraded at the X-band facility at Murdoch University.
- April 2015: First pass from FY-3C received and archived.
- May 2015: Last pass from FY-3C received and archived as satellite fails on 31 May 2015.
- February 2016: Inaugural Secretary for WASTAC, Richard Stovold, retires after 27 years in the role.
- February 2016: Curtin L-band receiver fails. It was decided to not repair or upgrade the capability. In December 2017, the equipment was donated to the Australian Space Academy which relocated the equipment to Meckering, Western Australia to support education opportunities to work with a tracking satellite system and gain experience in processing high resolution data. Refer to the 2016 Annual Report for a summary of notable events related to the Curtin L-band station and the 2017 Annual Report for the disposal of the dish and associated equipment.
- September 2016: The WASTAC Board conducts a Strategic Workshop considering the current state of implementation of the NEOS-IP and the future reception options paper that was approved for procurement in 2013 and commissioned in 2015.
- November 2016: The WASTAC Board agrees to wind up WASTAC, fund a new reception capability (Orbital Systems X-band dish) for the Bureau of Meteorology, support a Geoscience Australia led project to publish satellite reception schedules, and investigate options how to support training and development in earth observation satellite operations.
- February 2017: Australian National Ground Segment Technical Team (ANGSTT) created as an outcome of the September WASTAC Board Strategic Workshop and formally replaces the WASTAC Technical Committee. ANGSTT coordinates the operation of a national earth observations from space ground network that provides access to data generated by satellites from a wide variety of government and potentially non-government sources.
- 2017: The WASTAC Board agrees to wind up WASTAC by 31 December 2018.
- June 2017: Last FY-3B pass received and archived.
- September to November 2018: The WASTAC Board agrees to the creation and funding of a Research and Education Entity Framework (REEF) to build capacity in the earth observation community in Western Australia through support of research and education opportunities.
- December 2018: WASTAC winds up on 31 December 2018.
- August 2019: Final Audits of WASTAC accounts completed.

The success of WASTAC over the three decades of its existence may be summed up in simple terms: "competence and cooperation" -- the high level of competence of the individuals comprising the WASTAC Technical Committee, WASTAC Standing Committee and WASTAC Board, and the encouraging degree of co-operation between the participating organisations. These hallmarks ensured that WASTAC met the challenges of ensuring that researchers, government and industry had access to data from satellite sensors and to develop marine, terrestrial and atmospheric applications that supported economic development and monitoring of the Australian environment.

Figure 4. The first NOAA receiving dish at Curtin University, c.1982.

WASTAC BOARD FOR 1991

(L-R) Mr Don Ward, Bureau of Meteorology; Dr Richard Smith, CSIRO; Dr Doug Myers, Curtin University of Technology; Mr Henry Houghton (Chairman), Department of Land Administration; Mr Alan Pearce, CSIRO; Mr Richard Stovold (Secretary), Department of Land Administration; Assoc. Prof. Merv Lynch, Curtin University of Technology; Mr L Broadbridge (absent), Bureau of Meteorology.

Figure 5. WASTAC Board for 1991

RETROSPECTIVES FROM FORMER CHAIRS AND SECRETARIES OF WASTAC

As this is the final Annual Report for WASTAC, it is worthwhile capturing the reflections of the key people who started and came along the journey that was WASTAC. This next section captures the thoughts of all former Board Chairs and Secretaries for WASTAC throughout its 30 year history.

My Reflections as Secretary of WASTAC 1990-2016

Richard Stovold, WASTAC Secretary, 1990-2016

My career started back in 1972 when I graduated from the Western Australian Institute of Technology in Bentley as a cadet surveyor under the then Department of Lands and Surveys. Two years later I finalised my practical surveying training and became a licensed land surveyor in 1974 and proceeded to perform cadastral land surveying in metro and regional areas of WA including assessment of agricultural land for agricultural release and state-wide geodetic surveys. I always had an interest in agricultural and farming enterprises and pursued further studies in environmental science at Curtin University in 1980. These studies spurred my interest in the remote sensing work being done by Frank Honey and others at the CSIRO in Floreat and resulted in an eventual transfer from my land surveying work to join Henry Houghton at the Lands and Surveys Department Remote Sensing Application Centre (RSAC) in Perth and later at the Leeuwin Centre in Floreat.

Henry with support from the Surveyor General of WA John Morgan set up the RSAC as the first state government remote sensing centre in Perth to acquire, through WASTAC satellite derived steamed data, and use this valuable data in practicable applications for the benefit of the state land, environmental and natural resources.

WASTAC was formally established by deed of agreement in 1989 to set up, acquire and distribute satellite data to the partners including WA Department of Lands and Surveys, CSIRO, Curtin University and Bureau of Meteorology. The inaugural Chairman of WASTAC was a young and enthusiastic Surveyor and Manager of RSAC Henry Houghton supported by its first Secretary surveyor Bill Holman. Just prior to the formal signing of the partnership new satellite receiving dishes and facilities were set up at Curtin University. All of this data was received and distributed by new science qualified staff at RSAC. The following year, 1990, Henry and Bill asked if I would take on the task of WASTAC Secretary. I was excited to be asked and thankful I was able to commit to this task for 25 years until my retirement in February 2016. It was a highlight of my many years of public service to the state of WA.

As WASTAC Secretary I was honoured to work with so many dedicated, clever and enthusiastic people from all partner organisations many of whom had great passion to provide science driven solutions to environmental, land and marine questions. Some of these included Merv Lynch and Doug Myers from Curtin, Len Broadbridge, Alan Scott and Don Ward from the Bureau of Meteorology, Frank Honey, Alan Pearce from CSIRO. My time as Secretary was fun organising the many meetings and hopefully providing an efficient and well documented record of the years of achievement by all of the people associated with WASTAC. I supported and provided an administrative link to all four Chairman and their support staff over this time.

I was fortunate to be allowed to develop my interest in the use of WASTAC and other satellite data for the practicable improvement and understanding of agricultural practices. As a young remote sensing Research Scientist, we worked closely with the CSIRO scientists, including Graham Donald and Rob Kelly, and agricultural land managers to develop weekly interpreted satellite information such as Agimage, Pastures from Space and many early pioneer Landcare products. I recall with great satisfaction when a group of American NASA remote sensing scientists were astonished that our RSAC team (and more recently renamed Satellite Remote Sensing Services (SRSS)) of experts had managed to extract interpreted agricultural data daily and delivered to end users weekly as an online subscription service. They admitted that this seamless delivery of WASTAC like data from satellite to end user had not been practicably achieved in their country. Over the years we had many other scientists admire how we had achieved this largely faultless production line of products. The dedicated staff at RSAC and SRSS should be congratulated for this remarkable and continuing achievement.

Collaboration at WASTAC was a hallmark of our existence and in 2001 I was able to conclude a new legal deed of agreement after nearly 2 years of legal support and discussions which culminated in the inclusion of new partners Murdoch University and Geoscience Australia in the WASTAC X band agreement. This agreement resulted in the establishment of a new jointly owned X band receiving facility at Murdoch University determinedly negotiated by the then WASTAC Chairman Richard Smith. The amount of data received at RSAC by Landgate staff doubled and was always ably managed by Ron Craig and his team, a feat not easily achieved by other organisations.

Improved applications were now possible including daily and weekly delivered data feeds to end users in the state and within Australia from our FireWatch, Floodwatch, Pastures from Space, RangeWatch and other land and ocean programmes.

I was extremely honoured and proud to be able to contribute to the early development of remote sensing applications in WA including the ongoing successful on-line delivery of Agimage, Pastures from Space and RangeWatch products in collaboration with my recent colleagues Adrian Allen, Matt Adams, Norm Santich, Sarfraz Khokhar and Arjen Tjalma. These achievements were possible under the watchful guidance of WASTAC Chairman and RSAC and SRSS managers Henry Houghton, Richard Smith and Matt Adams.

A small group of RSAC and SRSS colleagues were hugely instrumental in the high standing of our centre and contributed to many award-winning state Premiers and other awards for excellence.

WASTAC provided the foundation for this success and was highly regarded as a model of collaboration between often competing business interests.

I was saddened at the winding down of WASTAC and am hopeful that the enthusiasm and dedication to the delivery of useful science derived information products continues with a new national emphasis on coordination of space science and the establishment of a national Australian Space Agency. I congratulate all the remote sensing staff over many years for being such beacons of success and wish all future national efforts every success hopefully with the full and continued commitment of Landgate remote sensing personnel. I feel very privileged to have been a part of this success.

WASTAC Formative Years 1986-1993

Henry Houghton, WASTAC Chairman, 1987-1993

During the early 1980s CSIRO (Dr Frank Honey) and Curtin University (Dr Bill Carroll) established a ground receiving station for NOAA satellite data at Curtin University using parts salvaged from various components left by USA monitoring systems at Carnarvon, in WA's north. This system demonstrated the potential of space observation to see the earth from space.

Imagery from this observation system (EYE in the Sky) demonstrated for the first time the ability to see major events in real time from space, such as a major flood event, one being the Fitzroy River floods of 1983. Soon after, bushfires and drought effects were monitored on a regular basis, demonstrating the value of regular satellite surveillance.

Based on these early demonstrations of the power of regular satellite coverage, Land Administration (later Landgate) negotiated with CSIRO, the Bureau of Meteorology and Curtin University to establish a joint venture that could better use the satellite date for mutual benefit. Land Administration realised that it was essential to secure regular data from NOAA satellites, but more importantly to archive these data for future use. Therefore, initial discussions ranged around securing an ongoing archive of earth orbiting satellite data, particularly of NOAA-AVHRR information from the visible and infra red spectrum, to record daily events which impacted the State's environment and social welfare. Happenings such as drought, flood, fire, vegetation change, ocean temperature (Leeuwin Current), and weather events. So with this in mind, Len Broadbridge (BOM), Dr Fred Prata (CSIRO), Prof. Merv Lynch (Curtin University), Henry Houghton (Land Administration) met to define objectives and what each party was prepared to commit. The shared belief that satellite data could mutually benefit the State and nation in the better monitoring our renewable resources, helped shape WASTAC's objectives.

Each member of the future WASTAC articulated their belief and hope for development of applications of earth observation from using NOAA data. Henry Houghton's (Land Administration) goal was to establish an archive of data and to develop applications of land based applications from regular satellite surveillance of bushfires, vegetation change, ocean current circulation.

CSIRO and Curtin University were interested in R&D opportunities, and BOM to aid to weather predictions. These diverse objectives were focussed by the parties in the agreement that established the WASTAC with a set of mutual objectives for State and National benefits.

It became obvious that a combined resource of infrastructure, technical and scientific skills was essential to give continuity and certainty of data supply for development of future applications by the members.

Thus, WASTAC was born, an agreement, soon to be a binding Deed, set out mutual objectives and responsibilities. So, in July 1987, the then Federal Minister for Science, Hon. Barry Jones, State Minister Keith Wilson, and Curtin Vice Chancellor John deLaeter officially commissioned the WASTAC facility. The satellite receiving dish and processing facility was based at Curtin University with a microwave data link to the Bureau of Meteorology in Perth. Funding was calculated and a contribution from each party agreed, to purchase and maintains the satellite reception and distribution facility. The WASTAC agreement more importantly committed expert staff to make the concept a reality. So, in July 1987 the WASTAC was established to meet the mutual goals of members. Early applications included monitoring of the Leeuwin Current along the west coast of WA, vegetation change and sea surface temperature variations. From the outset the WASTAC Board established a regular annual reporting on assets, funding and the applied research and development undertaken by the WASTAC members. This annual reporting ensured public accountability and provided an on-going record of results.

The first WASTAC NOAA/AVHRR image was recorded on the 9th September 1987. In 1993 some 3559 passes were recorded to archive, and pre-WASTAC passes dating from 1981 held by Curtin University, but not readily accessible were transferred to readable copies.

The strength and value of WASTAC is evident through the continuous commitment of all parties over 30 years to fund the infrastructure, the research, and applied application to bushfire monitoring, vegetation change, and event monitoring of floods, fires, drought and cyclones. This collaboration must continue if the ongoing benefits of satellite remote sensing are to be realised for the social, environmental sustainability of Western Australia – the second guiding principle of Landgate's, Land Information Authority Act 2006.

Therefore, during the 1980s WASTAC's prime concern was to maintain certainty of supply and to demonstrate the value satellite information brings to earth observation. The ongoing commitment to archiving satellite data is in doubt due to recent changes to Landgate's interpretation of its mandate. Nevertheless, the need for better satellite monitoring is vital if the status of the State and Nation's land and ocean resources are to be understood, valued and appropriately managed by its citizens enabled by Government Land Information.

As the foundational Chairperson of WASTAC I must acknowledge the professional dedication of the many people who made WASTAC a reality. In particular the continuous endeavour of Ron Craig and Don Ward who made the technical aims of receiving, archiving and distributing NOAA/AVHRR data possible. I also thank the pioneers whose foresight gave this State an early introduction to earth observation through space.

A WASTAC Retrospective

Richard Smith, WASTAC Chairman, 1996-2007

When asked "Why should humankind go to the Moon", Neil Armstrong answered:

"It will enlighten the human race and help us to comprehend that we are an important part of a much bigger universe that we can normally see from the front porch. … Perhaps going to the Moon and back in itself isn't all that important. But it is big enough to give people a new dimension in their thinking."[1]

May be this changed my career direction from farm economics to earth science. When CSIRO transferred me back to WA in 1990, I discovered that WASTAC's data offered boundless research opportunities. The data source, a product of a rare collaborative venture between an inquisitive CSIRO scientist and university engineer, capitalised on by a small group of innovative surveyors led by Henry Houghton, Dept. Land and Surveys. Henry in developing his Centre had foresight to employ two physicists, one for software development, the other to manage WASTAC's data reception and archive, and me a CSIRO earth scientist to develop information products for the sustainable management of the State's natural resources. How lucky I was.

In my period as Chairman, ready availability of WASTAC data advanced the oceanography of the

Leeuwin Current, benefiting the fishing industry and knowledge of WA's climate and marine ecology. Information from WASTAC data revolutionised fire management in Australia's northern savannas, when it revealed that cessation of traditional aboriginal fire-stick farming had caused the savanna fire regime to move from early to late dry season. A change that was devastating biodiversity, degrading soils, causing massive erosion, ocean dead zones, and boosting greenhouse gas emissions. WASTAC data enabled collaboration with the Cooperative Research Centre for Tropical Savannas in Darwin that led to the reintroduction of indigenous-type burning regimes in the north, earning valuable carbon credits from the Commonwealth Emissions Reduction Fund. These credits are employing indigenous rangers to return to their ancestral lands to manage fire. As scientists develop remote sensing methods of measurement, many millions of carbon credits remain to be earned from Carbon sequestered from regenerating of woody and shrub species by processes known as Carbon Farming[2]. My analysis of burnt areas mapped from WASTAC's data from 1988-2015 revealed that total burnt area across Australia is increasing by an average of 2 million ha/year from impacts of climate change and cessation of traditional aboriginal burning. In addition to wild fires, WASTAC's data helped protect critical infrastructure and remote communities from extensive flooding that followed in the wake of cyclones. In a period of accelerating climate change the economic, social and environmental benefits of WASTAC has been vast and benefits have probably exceeded costs tenfold[3]. A fact widely recognised by other nations who continue the development and deployment of new and more advanced environmental satellites[4].

Ready access to WASTAC data enabled me to attract significant Commonwealth and Industry research funding to employ staff with the scientific skills to develop applications. Achieved was the two-weekly measurement of green vegetation cover at continental scale leading to new methods of forecasting crop and pasture yields for agriculture and rangelands. The routine green vegetation cover information was purchased by Commonwealth Agencies for delineating drought areas and plague locust breeding grounds. For fire management, the information was used by bush fire management agencies to assess risk from fuel load build up and fuel flammability. All these products were enhanced when WASTAC's reception capability was upgraded for MODIS data with an X-band receiver at Murdoch University. WASTAC data helped train a generation of research scientists through MSc and PhD's projects many who became valuable employees. All these developments would not have been possible without a commitment to research into satellite remote sensing applications which from 1978 to 1997 produced a total of 276 scientific publications, an average of 13.8 per year[5]. The rate of publication then declined as the focus turned to marketing and commercialisation, hopefully with the prudent commercial principles[6] expected of Corporations[7,8], WASTAC's annual reports continued providing short summarises of research and development projects, peaking at 48 reports in 2001 declining to 4 in 2017 as WASTAC's role of capturing and archiving of satellite data was coming to an end.

As the Commonwealth is investing again in Earth Observations from space[9] and for the first time in an earth observing satellite itself[10], it is interesting to note that WASTAC's collaborative structure preceded by 30 years the second guiding principle of WA's Land Information Authority Act, 2006 that:

"The Authority perform its functions under this Act in a way that supports the sustainable economic, social, and environmental management and development of the State."

Landgate's location data strategy[11] recognised many of these challenges as involving the *"careful use, conservation and enhancement of resources"* and adapting to climate change of *"sea-level rise, storm surges, reduced rainfall and hotter, drier summers which will impact significantly on Western Australia."* But the strategy failed to recognise that each pixel of WASTAC's Satellite data with its unique latitude and longitude was location data par excellence, eminently suited for addressing these challenges. Maybe because the multi-spectral and historical time series nature of such data needed specialist scientific skills to extract the information and knowledge required for these challenges. As WASTAC demonstrated, without Government investment in such scientific skill there is only data and a pretty false colour images to hang on the wall[12].

From its Annual Reports[13], WASTAC's legacy can be summarised as[14]:

- Earth observations provide a unique window and perspective on our world, serving the betterment of all humankind by supporting policies aimed at sustainably managing natural and societal resources on an ever more populous, affluent, and interconnected planet Earth
- Earth observations should be regarded as critical societal infrastructure. There is strong evidence that publicly open Earth observations are making

positive, cost-effective contributions to solving a variety of high-priority environmental and societal problems.

- Studies on the socioeconomic benefits of improved global Earth observation systems showing that the benefits outweigh the costs by orders of magnitude when subject to a free and open data policy. The European Copernicus program, for instance, is expected to return benefits to taxpayers valued 10 times higher than the costs.

We have only 12 years to act before the earth's climate reaches the tipping point of irreversible warming[15]. To address this challenge, a WASTAC No. 2 will be needed, not for collection and archiving of data, but to command the array of scientific skills and infrastructure to extract the information WA requires as a matter of urgency to adapt to the accelerating realities of global climate change.

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WASTAC Over the Decades

Merv Lynch, WASTAC Chairman, 2007-2009

The Formation of WASTAC

At the outset the formation of WASTAC was not assured. The uncertainty related to whether the interest was sufficiently broad and the potential partners, both locally and nationally, were sufficiently collaborative in orientation to justify the next step. There also was a minor difference of opinion between the scientists and the engineers at Curtin over taking this next step. This difference was resolved by the then Director / Vice Chancellor, Prof Don Watts confirming the Curtin (WAIT) view that WASTAC should proceed. A significant factor in this decision was that Prof John de Laeter (Dean, School of Science and Engineering, Curtin) and Dr Ray Perry (Chief, CSIRO Exploration and Mining, Floreat) had agreed that this was a sensible and way to proceed – financially beneficial and collectively a manageable task. Further, Dr John Zillman, Director, BoM at the time, appreciated that a satellite downlink facility in Perth would add the much needed satellite observational dataset from the Indian Ocean region (specifically, the TOVS products from the HIRS instrument on the NOAA environmental satellite platform). As noted elsewhere, Henry Houghton, a real champion of remote sensing in WA, had done the groundwork at Land and Surveys, Perth (now Landgate) to ensure State membership of the proposed entity WASTAC. Geoscience Australia soon identified as a willing partner. My recollection is that Dr Lawry White, Head of Surveying (later Spatial Sciences) at WAIT/Curtin put forward the name WASTAC and it stuck. It is encouraging to record that that despite the 2 WASTAC joint ventures (JV; one for L-band and the other for X-band data reception) and their renewal every ~ 5 years, there was not one issue that ever caused dissent or a split of the Board. Consensus was always easily achieved. WASTAC's membership did expand with the addition, at a later date, of Murdoch University when the siting of WASTAC's X-band antenna was under consideration.

It took several years between the 1981 and 1989 (when the first WASTAC L-Band JV or Deed was negotiated) for the legal structure to be bedded down. Special recognition should be accorded to both Prof John de Laeter of Curtin and Dr Ray Perry, Chief of CSIRO Exploration and Mining, for their promotion of the venture and for chairing a loosely formed interim local Committee to progress the concept of a WA-based remote sensing consortium. This dedicated team was endorsed by Prof Don Watts who saw the WASTAC initiative as innovative and an Australian "first" with respect to public sector and university collaboration for the national good in an the emerging space sector.

The Early Years of Operation

Certainly, it was the initiative and drive of Dr Frank Honey of the CSIRO Division of Exploration and Mining in Perth and his collaboration with Dr Bill Carroll of Electrical Engineering (EE) at Curtin (WAIT) that led to the initial 5 m dish being installed on Building 207 at WAIT Bentley campus. The claim was made that the dish and signal processing electronics was put together for $5,000! However, the Mechanical Workshops at Curtin, under Mr Bill Gordon, Workshop Manager, were a major contributor of the labour to construct the dish itself and to measure its mechanical integrity were a significant in-kind contributions. Dr Doug Myers of EE, ably assisted by Mr Man Vuong, supported the installation and maintained its operation. I wanted to identify the valuable support provided by two of my very enthusiastic students at that time, namely, Mr Len van Burgel and Mr Ron Hille who put in many late nights on the rooftop of Building 207 manually tracking the 5m dish across the sky so that they could collect research data sets primarily on WA's tropical cyclones. Len was a BoM staff member at the time and completed an MSc (co-supervised by Dr John Le Marshall at BoM, Head Office, Melbourne) using WASTAC's NOAA series satellite data. Ron Hille, formerly a BSc graduate from Curtin's Department of Applied Physics was working for Telstra at the time but subsequently switched to meteorology, joined the BoM Training Program and became a meteorologist.

It was interesting to observe how the data downlink really pushed the modest ground segment infrastructure capability. This was reflected in the data formats on the 6250 reel-to-reel magnetic tapes. When finally it was possible to record all pixels in the satellite's swath for every scan line (ie the full record was collected), another student of mine, Liam Gumley, revewed the satellite data archive and detailed the growing range data formats on the tapes. He listed formats such as Ancient, Very Old, Old, New and Current which reflected the growing capability from recording most (~ 70 %) of a cross-track scan line, to being able to record a complete scan line but only for every alternate scan line to finally recording all transmitted data. It is a credit to WASTAC's Board that almost all of these recorded satellite data sets, from 1981 to the present, have been transcribed over the years to new media (the sequence was reel-to-reel tape, digital cassette tape, CD, DVD and finally hard drives). The data are presently archived at Landgate in Midland with a duplicate set on the national supercomputer, the NCI, in Canberra.

There were some notable events that took place in these early years of utilisation of the data. The investigation of Dr Frank Honey and Dr Peter Hick, in determining that the 11 and 12 micron bands of the AVHRR sensor on the NOAA series of satellites could be used to discriminate volcanic ash clouds from water droplet clouds. This was another world-beating "first" for the WASTAC project.

Building International Links

WASTAC researchers reached out internationally in 1983 to attract Dr Paul Menzel (of the NOAA NESDIS Satellite Applications Branch located at the University of Wisconsin, Madison, WI). Curtin / WAIT and CSIRO combined resources to bring Paul and his wife Nancy to Perth to undertake research and education / training at CSIRO and Curtin. Paul on a subsequent visit to WA (1990) was awarded a Haydn Williams Fellowship by Curtin. This was a significant milestone in expanding research linkages and opening up opportunities for Curtin students who, through exposure to WASTAC, had gained experience and a strong interest in research using satellite data. In all, some 11 Curtin students travelled to University of Wisconsin and with the support of both Prof Willian Smith and Dr Paul Menzel undertook research at the Cooperative Institute for Meteorological Satellite Studies (CIMSS). 7 students stayed for extended periods and 5 of our PhDs made it permanent while they waited (and waited!) for Australia's space industry to mature. Three Curtin students, with encouragement from Paul Menzel, migrated to

Dr Michael King's group at NASA Goddard (GSFC) to work on the MODIS project. Michael was the MODIS Project Scientist. Additionally, over the intervening years, a series of staff from the CIMSS/ Space Science and Engineering Center (SSEC) visited Curtin. In all, Paul Menzel (made 8 visits to Curtin), Prof Verner Suomi (he designed and negotiated the launch the first meteorological satellite; the currently deployed NOAA Suomi NNP satellite was named after him), Prof Bill Smith (Prof of Meteorology, Univ of Wisconsin made 2 visits), Mr Bob Fox (Exec Director of SSEC), Mr Ralph Dedecker (1 visit). Collaborative research was initiated and continues to this day.

The United Nations Committee on the Peaceful Uses of Outer Space declared 1992 as the International Space Year. WASTAC, by this stage, had built a reputation such that it was invited by NASA to participate in celebrating this special year. The plan was to put together a global data set of AVHRR data. The problem NASA had previously was that they could not acquire a full global set of NOAA AVHRR data on-board due to storage limitations. So, being at a unique global location, WASTAC's downlinked data was incorporated into the first truly high resolution (1 km) global satellite data set. As part of this international initiative NASA organised a telephone hook-up with WASTAC. The Board was in attendance for the 'phone call. At the NASA end was Dr Diane Wickland who, I recall, headed the Biological program at NASA HQ and called to express NASA's appreciation for the WASTAC participation in the ISY and for the contributed AVHRR data.

It was just a couple of years later (1996) that NASA launched its international program "Mission to Planet Earth" https://web.archive.org/web/20210511020732/https://www.hq.nasa.gov/office/nsp/mtpe.htm in an attempt to stimulate global collaboration in Earth observations from space (Tilford, Asrar and Backlund, 1994). This was a high level program with many international heads of state attending the opening function in New Hampshire. Dr Graham Harris, Chief, CSIRO Land and Water was invited to attend. Amazingly, I was invited and funded to attend under the WASTAC banner by Dr Moustafa Chahine, Director of JPL. The strong theme included the benefits for the world's citizens and the promotion of cooperation in promoting the benefits of space-based information.

Interests in Environment, Agriculture and Economic Benefits of Remote Sensing from Space

Several key initiatives impacted WASTAC's activities during the late 1980s. A set of significant documents emerged from the Bretherton Committee (a NASA-appointed the Earth Science Advisory Committee, chaired by Prof Francis Bretherton, Director NCAR, Boulder, CO). The lead document was titled "Earth System Science: A Closer View" (1988; 208 pages). It, and a series of companion documents, were an impressive and comprehensive review of the specific requirements to monitor global change and an indication of how remote sensing observations could make a major contribution to programs to understand and protect the environment for the long term benefit of the World's citizens.

The Australian Federal Government of the day engaged Dr Ralph Slatyer to address the need to ensure that research was critically relevant to the national social and economic benefit. As part of his brief, Slatyer visited WA and through the efforts of Prof John de Laeter, Dr Ray Perry (CSIRO) and Dr Ken McCracken (CSIRO, Canberra; later Director of the Australian Space Office, Canberra; https://www.globalsecurity.org/space/world/australia/aso.htm). Dr Slatyer was convinced that WASTAC was the exact model he had been searching for in Australia. He promoted the WASTAC model to the Federal Government as a working example of his concept for the planned national Cooperative Research Centre (CRC) program. Slatyer arranged for Prof de Laeter and Dr Ken McCracken to travel to Canberra and to deliver an oral presentation, prepared by WASTAC, to the PM's Science Council. In 1990 in response to this opportunity, WASTAC's Board prepared and had printed a document titled "Predicting and Managing Global Change" (WASTAC, 1990) that had the backing of the WA Technology Industry Development Authority (TIDA). This document was submitted to the Science Council when de Later and McCracken delivered their presentation.

In 1990 the Federal Government approved the establishment of CRCs:

"Cooperative Research Centres (CRCs) are an Australian Federal Government program and are key bodies for Australian scientific research. The Cooperative Research Centres Programme was established in 1990 to enhance Australia's industrial, commercial and economic growth through the development of sustained, user-driven, cooperative public-private research centres that achieve high levels of outcomes in adoption and commercialisation."

(see https://en.wikipedia.org/wiki/Cooperative_Research_Centre)

Despite several attempts to secure a CRC based around applications of remote sensing, WASTAC itself was not successful. However, several of its partners were members of other CRCs. It is worth noting that, in drafting the original JV, there was considerable discussion among partners of writing in the option for collaborative research. This option, however, was rejected by the Board and the scheme where each partner takes their datasets and performs their own R&D and applications was preferred. At the outset, it may have been that these agencies had not any significance experience of interacting with each other in collaborative research. This stance did not prohibit very successful collaborative activities occurring between subsets of partners.

The formation of the Leeuwin Centre for Earth Sensing Technologies was a significant development supported by the WA Government in collocating interested groups from industry, government and academia in working closer together on a range of problems in the environment, agriculture and exploration, The common goals included economic benefit, a sustainable environment and education and training. The WA Government provided funds to erect a new building in Floreat to house groups collaborating in remote sensing research and applications. The record shows that three WASTAC partners, namely DOLA (Landgate), CSIRO and Curtin University took up residence in the new special purpose building constructed, namely the Leeuwin Centre. The private sector airborne exploration company, World Geoscience Corporation (that had some 20 offices worldwide), was a welcome resident. The then founder and Managing Director of WGC, Mr Pat Cunneen, proved to be a great asset to the Leeuwin Centre. It was not long before Curtin UG and graduate students studying remote sensing and exploration geophysics were working collaboratively with WGC staff on joint research projects with Curtin remote sensing scientists also involved.

What was a surprise to many was, at the official opening of the Leeuwin Centre, the WA Premier handed the building's keys to the Prime Minister, Mr Paul Keating, who subsequently passed them to CSIRO! The upshot of this rather unexpected and very generous act was that the WA occupiers of the Leeuwin Centre, from that point on, were required to pay rent to CSIRO for research space in a building funded by the WA taxpayer! This was not a stumbling block and the Leeuwin Centre's activities prospered and were an indication of a strong support for these new technologies by the WA Government.

Meanwhile in the Federal arena the Australian Space Office was established by Government in 1987. The intention was to promote the development of commercially viable industries based on space technologies, and to directly stimulate a greater involvement by industry in the space R&D sector. *"However, in 1992, the Bureau of Industry Economics (BIE) Review of the National Space Program concluded that there was little demonstrable benefit to Australia from the Program. The BIE recommended that industry development objectives for the space sector be delivered through the existing range of industry assistance programs. Government abolished the Australian Space Office and the Australian Space Council in 1996, and terminated National Space Program funding in June 1996. The Australian Space Council Act 1994 was repealed in 1999."* https://www.globalsecurity.org/space/world/australia/aso.htm

Education and Research Training

A major benefit to Curtin University in being a partner in WASTAC was the opportunity to train students in the basic physical principles and applications of remote sensing of the Earth environment. In 1980s Curtin established the Remote Sensing and Satellite Research Group (RSSRG) in the then Department of Physics and Geoscience to provide a focus for research activities primarily using WASTAC satellite data. While RSSRG undertook investigations into ocean, land and atmosphere applications, there was consistently a focus on the underlying science including radiative transfer modelling, solution of a range of numerical problems including the solution of ill-conditioned, ill-posed inverse problems; algorithm development from radiative transfer formulations, sensor calibration, geoscience / environmental product validation – namely, remote sensing science. In all, RSSRG has graduated 37 PhD students and 13 MSc students in the field of remote sensing science. This effort continues to this day. In addition, programs in Spatial Sciences and in Electrical and Electronic Engineering at Curtin made additional contributions but precise numbers have been difficult to confirm. These RSSRG research students primarily were linked to WASTAC partners (particularly CSIRO and BoM), WA industry (eg. rpsMetOcean, WGC, Woodside, Pt Hedland Port Authority, Shell, BHP,...), USA industry (eg Wetlabs), international agencies (NASA, NOAA, JAXA and EUMETSAT) and universities (University of Wisconsin and Scripps Institution of Oceanography (SIO, Univ of California at San Diego). As early as 1983 and with the assistance of Prof Paul Menzel (NOAA NESDIS) and Prof William Smith (CIMSS/SSEC at Univ of Wisconsin), Dr Jim Simpson (SIO) and Dr Robert Frouin (SIO), Curtin established research

MoUs with NOAA NESDIS, University of Wisconsin and Scripps (SIO) to embrace collaborative research activities, staff exchange and student exchange. These interaction also continue to this day.

It would be an error not to mention the very significant contribution that Prof Paul Menzel made to education and training during his eight visits (between 1983 and 2017) to Curtin and WASTAC. Prof Menzel, as mentioned, was awarded a Haydn Williams Fellowship by Curtin University (with co-sponsorship by CSIRO) in 1990. He undertook to develop and offer a course of lectures In the Department of Physics and Geosciences in Satellite Meteorology. The course was offered as an Honours level program both as an in-house course and for external study. It was pleasing to report that there were 15 local students and some 17 participating via external study that undertook the initial course. The bulk of the externals were from WASTAC's partner, namely BoM's regional offices around the country. Many BoM staff, at that time, had not received any training in satellite remote sensing and its application to meteorology and so the initiative did address a significant demand. This course was offered over many years at Curtin. Paul expanded his reach into offering this course internationally in Europe (France, Italy, Germany, UK), South America and Asia.

Wisconsin, in particular, has provided many benefits to Curtin students with 10 Curtin PhD students spending time in Madison undertaking research at the Cooperative Institute for Meteorological Satellite Studies within the Space Science and Engineering Center (CIMSS/SSEC, UW). Additionally, some 7 scientists from CIMSS/SSEC have visited Curtin and WASTAC as part of this collaboration. CIMSS generously funded a PhD scholarship at Curtin to undertake a study of regional cloud climatology under global change forcing.

A particular and unexpected benefit to WASTAC has been the link to Space Science and Engineering at University of Wisconsin through Liam Gumley, a Curtin RSSRG student who travelled to Madison with sponsorship from CIMSS. He completed an MSc with Prof Menzel and subsequently worked at NASA GSFC, in DC. On returning to UW he became heavily involved in the recommendation of satellite reception facilities and associated processing software. This was particularly beneficial when WASTAC purchased its combined L and X band satellite receiving dish to be located on Murdoch University campus. Liam has maintained his links with WASTAC and has visited and delivered seminars during each visit. These seminars are typically on processing software for current and new satellite sensors. Post-launch he delivered a seminar on the Suomi NPP satellite. In fact, he presently supports an international processing package at SSEC/ CIMSS, namely, the Community Satellite Processing Package (CSPP) relevant to reception, processing and applications of data acquired by direct broadcast from a large selection of meteorological satellites including NOAA-20, Suomi NPP, GOES-16/17, FY-3/4, Metop, Himawari, EPS-SG, Meteor-M and GCOM. In 2017, Liam became the co-chair of the ~ 150 strong international user group of the CSPP software package use in processing an ever expanding array of environmental satellite datasets. In fact, RSSRG is using this package presently. The CSPP user group holds an annual conference / workshop. A number of WASTAC scientists have attended these meetings over the years.

Recent Developments

The appearance of the Report, the National Earth Observations from Space - Infrastructure Plan (NEOS- IP) issued by Government initiated the closure of WASTAC. If one analyses the relevant recommendation, it is difficult to see that this is a money saving initiative. It is also difficult to explain it as beneficial in terminating a joint venture (ie WASTAC) that had delivered an excellent service in satellite data reception for 30 years. The NEOS-IP Report was very much focused on the role of the Commonwealth agencies and ignored the role of the States and the university sector with respect to research and innovation. The word university, in fact, was only mentioned twice in the Report sector which is surprising given the role of the sector in working with the Federal agencies in, for example, CRCs, NCRIS TERN and NCRIS IMOS. But also, the role of the university sector in the training of both UG and PG students to support those same Federal agencies as well as industry initiatives in space sector developments.

The satellite data archive assembled by WASTAC (and pre-WASTAC reception) covered the bulk of the Australian continent and has created a remotely sensed record of the Australian continent and oceans stretching back almost 40 years. Perhaps one of the more significant achievements of WASTAC was that it brought together researchers from the 3 national agencies, two universities and a State Government agency in collaborative activities that extended well beyond the strict set of objectives prescribed in the Joint Venture. WASTAC became an excellent vehicle for building interactions among partner agency personnel and led to collaborative research initiatives, membership of science TEAMs (eg. SeaWiFS, MODIS, POLDER, etc), working groups to support new national ventures such as NCRIS TERN and NCRIS IMOS and participation in joint delegations to space agencies of other countries (eg China, India, Korea, France etc) led variously by CSIRO, the Australian Academy of Science etc. It had a significant role in research training and, in particular, with students working on research problems of interest to the Australian Commonwealth agencies. But more than that; in agency staff interactions with university students, they gained valuable exposure to the capabilities and interests of students – an aid to their staff recruitment programs. It is unclear why our agencies have not seen the benefits and hence adopted the practice of the US agencies (NASA, NOAA, USGS) in which those agencies have deliberately placed clusters of their staff (typically between 5 and 10 in number) within university centres (eg University of Wisconsin, Colorado State University, University of Oklahoma, Scripps etc) with the specific aim of ensuring that research topics of interest to these agencies attract the interest of both academic staff and their graduate students. Stimulating the maintenance of a strong cohort of potential agency recruits within the university sector is an evident benefit as is the ability to achieve a sustained focus on research topics and engaging an expanded team to assist in solving obstinate and curly research problems.

In response to the recent establishment of the Australian Space Office one can really only respond – about time! The closure of the Australian Space Office in 1996 and the repeal of the relevant 1994 Commonwealth legislation in 1999 illustrates how little time the Government-of-the-day was prepared to assign to the establishment and growth of Australian space industry. The problem would appear to be that for decades Australia has lacked senior politicians interested in championing the case for a space industry. At one time Australia also had the beginnings of a semiconductor fabrication industry with companies, such as Fairchild, manufacturing semiconductors in Australia. However, for the exact same reasons that industry also failed and the international corporate investment withdrew.

While we are reminded that Australia was the 3rd country to launch a satellite, WRESAT, into space, a review (Doherty, 2017) of the circumstances, https://web.archive.org/web/20190327012047/http://www.iafastro.org/wresat-australias-first-satellite/, suggests that this success was almost an accident:

"... the Liberal government of the period had not shown any particular support for developing an Australian space program and had already declined to take up an earlier US offer to launch an Australian built satellite." (Doherty 2017).

Further, *"The fact that WRESAT had no successors was not due to any failure on the part of its technical and scientific development teams, but to government disinterest and an inability to perceive the long-term benefits to Australia that could have accrued from a home-grown satellite program built upon the success of WRESAT 1." (Doherty 2017).*

It may also be that our politicians don't try too hard to innovate. There has always been a comfort zone – eg Australia grew on the sheep's back! More recently, the comfort zone of having huge deposits of iron ore and other minerals! Almost the world's largest exporter of natural gas! 200 years of coal deposits! Diversification of our industrial base remains problematic as we see evident in the slow adaption to an Australian renewable energy program. It will be a long haul before the establishment of the ASA has significant economic impact.

In a review of remote sensing in WA, Smith (1997) records the range of activities that were in progress at that time. The record shows that commencing from 1978, scientists, a number who later became participants in WASTAC, were using remote sensing data from satellites to investigate a range of environmental issues including wind erosion, bushfire mapping, wetland monitoring, mangrove health, rainforest condition, waterlogging impact on agriculture, lithography, inter-annual variability of ocean and coastal currents and ocean biological productivity. Much of this effort took place at the WA Government funded Leeuwin Centre for Earth Sensing Technologies in Floreat where three of the WASTAC partners CSIRO, DOLA/Landgate and Curtin University had collocated laboratories. In fact, the industry participant located at the Leeuwin Centre, World Geoscience Corporation, for several decades had demonstrated that there was a market nationally and internationally for advanced space and airborne sensing technologies. While the State of WA and WA scientist were promoting the applications and utility of remote sensing for public good, the Australian Government was severing its direct promotion of a space industry and space applications. Despite the huge impact that the revolution in space communications has had on areas such as media, communications, the internet and TV over the decades and the very significant impact of GPS technologies, the Commonwealth Government has certainly been slow to react. A question that would be great to answer is - what has been the cost to Australia in not having a space-related domestic capability? The outsourcing to overseas entities of almost all our relevant infrastructure and space-related services would be huge.

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Reflections

Wendy Thompson, WASTAC Secretary, 2016-2018

In 2018, wrapping up the WASTAC consortium was an interesting road down the history and evolution of the consortium activities, functions and technology. The legacy of WASTAC was very clearly being felt in the build of the ground station facility at the Bureau of Meteorology site at Learmonth Airport, near Exmouth. While the new ground station facility was going to be managed via the Bureau of Meteorology, it clearly represented the contemporising of what WASTAC was set up to deliver all those decades ago. I've since been fortunate enough to see the facility at Learmonth representing the final WASTAC investment.

The other important legacy of WASTAC was the establishment of the research funds to continue the investment in research and science applications using WASTAC derived data. We established small research grant program with the Western Australian Marine Science Institution (WAMSI). The grants were established as a legacy of WASTAC's foundations of collaboration and research. WAMSI graciously agreed to host and administer the grants as an extension of common principals of research and collaboration. These grants targeted small scale projects, particularly for undergraduate or PhD projects, operationalising research outcomes and/or improving existing applications using earth observation data. We were particularly interested in furthering the legacy to enhance the contribution of and transfer of strategic scientific and technological research and innovation to Australia's sustainable environmental, social and economic development.

From a governance perspective, it was important to close out the valuable legacy of WASTAC from an accountability and the long-term data and information sharing. These relationships built from the origins of WASTAC continue to deliver good principles for on-going relationships between WASTAC members. From a logistics perspective, removing the original WASTAC L-band dish from the roof of the building at Curtin University was an exercise in patience addressing all the layers of approvals to safely remove the dish permanently.

I was proud to have supported WASTAC in navigating complex governance arrangements (two deeds with different membership and dispersion requirements), logistic arrangements and establishing a legacy benefiting ongoing research and collaboration as a fitting closure to one of the state's long running and successful consortiums.

Mission Successful and Ongoing

Matthew Adams, WASTAC Chair 2010 - 2018

I was the fourth and final Chair for WASTAC. I oversaw ongoing operations (from 2009), a systems upgrade (in 2013) and eventual disposal (in 2018) of the Consortium's assets as well as winding up both Deeds that governed the operation of the two antennas. Until the very end I hadn't realized that the Chair of WASTAC had been with Landgate and its predecessor agencies except in the gap between Richard Smith's retirement and my substantive appointment as the Manager of Satellite Remote Sensing Services when Professor Merv Lynch from Curtin University took up the Chair duties.

I am grateful to the mentoring that Merv Lynch provided in 2008 and 2009. It had been originally planned that I would take over the Chair role in 2009, but I felt I did not have sufficient exposure to the operations and direction of WASTAC to take that role on in 2009.

I am grateful to Ron Craig and Richard Stovold who (along with Merv Lynch) had been with WASTAC since its inception and really ensured that WASTAC operated smoothly and efficiently and helped “show me the ropes”. I’m also grateful to the Curtin Support Staff, particularly Jananee Raguragavan and Joshua Lim who ensured that the financial operations ran smoothly and were particularly critical in 2018 as we wound up the Deeds.

I am also grateful to Adam Lewis from Geoscience Australia, and Mike Bergin, Anthony Rea and Agnes Lane from the Bureau or Meteorology who assisted with setting the policy environment WASTAC was operating within from 2013.

And I cannot express enough gratitude to both Dan Sandison who helped with the Strategic Workshops and operations of WASTAC in 2015 and 2016 before Wendy Thompson replaced Richard Stovold as Secretary of WASTAC. And to Wendy we all owe a huge vote of thanks for the huge amounts of organization, tenacity and dogged determination to get an enormous program of works through the governance processes in 2017 and 2018. This included the most significant capital program WASTAC had undertaken since the X-band dish was installed at Murdoch University in 2001 as well as the development and creation of fund to support earth observation within Western Australia. Unfortunately, Wendy was unable to see out the last months of WASTAC. However, so good had her organizational ability been that I was able to pick up where she left off and finish it out on my own. Thank you, Wendy!

When considering my reflection on WASTAC I remember conversations that long term Board and Steering Committee member from CSIRO, Dr. Edward King and I have had over the years. WASTAC was born out of a need – a gap in Australia’s earth observation capability (reception and archive) to the west, particularly over the Indian Ocean which had been discussed by the Australian Liaison Committee on Remote Sensing by Satellite in 1988 (and earlier). And as Henry Houghton wrote in his retrospective each participating agency in WASTAC had their own drivers in terms of the use of the satellite data received and archived that helped to justify ongoing funding for a capability that could operate 24/7.

The only way that the gap could be filled sustainably in the late 1980s was through meaningful collaboration between the State of Western Australia, relevant Commonwealth Agencies and the Western Australian tertiary institutions. And so, WASTAC was born.

WASTAC thrived through the 1990s and into the 2010s. It had a committed group of individuals that believed in the vision and mission of WASTAC and were able to argue the ongoing relevance of WASTAC to their respective agency interests and maintain a collaborative spirit despite significant changes that happened within agencies from time to time. Stability of tenure of operational staff within the Bureau, Curtin and Landgate helped, as well.

But, when I read through the WASTAC Annual Reports in 2024, I can see that change was coming from the time the Australian Space Utilisation Policy was announced by the Federal Government in the first half of 2013. While it did take a few years for the implications of that Policy announcement to materially flow through to WASTAC, 2013 was the beginning of the end of WASTAC. Through the Space Utilisation Policy, the Commonwealth would agree to provide recurrent funding for the reception and storage of moderate resolution satellites like Terra, Aqua, SNPP, and NOAA to cover the entire Australian continent and territories.

The rest, as you’d say, is history.

Small Grant Reports 2018-2022

LANDGATE, SATELLITE REMOTE SENSING SERVICES, MIDLAND

Fire Spread Simulation from Suomi NPP

Mike Steber, Landgate, Perth

Predicting probable fire spread is vital to the success of fire suppression and protection of lives and property. Fire authorities responsible for deploying resources gain a valuable advantage if they know in advance where the fire is likely to be by the time resources arrive. For about 7 years the Aurora website has used the fire hotspots (FHSs) from the Moderate Resolution Imaging Spectroradiometer (MODIS), onboard the Terra and Aqua satellites, as ignition points for the Australis simulator. This allows simulations of up to 24 hours to be activated automatically each time a set of 1km resolution FHSs from MODIS are detected.

In late 2011 the Suomi National Polar-orbiting Partnership (SNPP) satellite from the NOAA - Joint Polar Satellite System (JPSS) was launched. One of the instruments onboard the satellite, the Visible Infrared Imaging Radiometer Suite (VIIRS), is similar to the MODIS sensor. It has been designed as the follow on to MODIS in the event of MODIS coming to the end of its operational lifetime. During 2012 Landgate implemented the FHS detection algorithm developed by the National Aeronautics and Space Administration (NASA), which works reasonably well across the globe. But like previous NASA algorithms it does not meet Landgate's quality control standards for Australian conditions as there are errors of omission. To meet this standard Landgate developed a FHS detection algorithm that worked well for the Australian continent. This project was completed in 2014 and comparisons show that the Landgate algorithm performs better than the NASA algorithm. With the 3.5μm channel of VIIRS having a nominal resolution of 375m this means that the number of FHS detected on a single pass has increased dramatically.

As part of the windup of WASTAC funding was given to Landgate to derive automatic fire spread simulations from SNPP VIIRS. As the FHSs are derived from data with a resolution of 375 metres the logical choice was to create Aurora tile sets that were of a similar resolution. Due to programming logistics the resolution was rounded to 400 metres. At the same time this development was occurring Landgate was also trialling the use of a higher resolution and more accurate weather dataset from the Bureau of Meteorology (BoM). These two developments in combination have resulted in better quality fire spread simulations for the end users. For example, Figure 6 shows the fire spread simulation derived from FHSs on a MODIS pass at 12:38am 21/2/2019. Compare this to Figure 7. which shows the fire spread simulation derived from FHSs on a SNPP pass at 12:15am 21/2/2019. Apart from the increased number of FHS due to the 1km versus 400m resolution there is also the increase in fire spread simulation points.

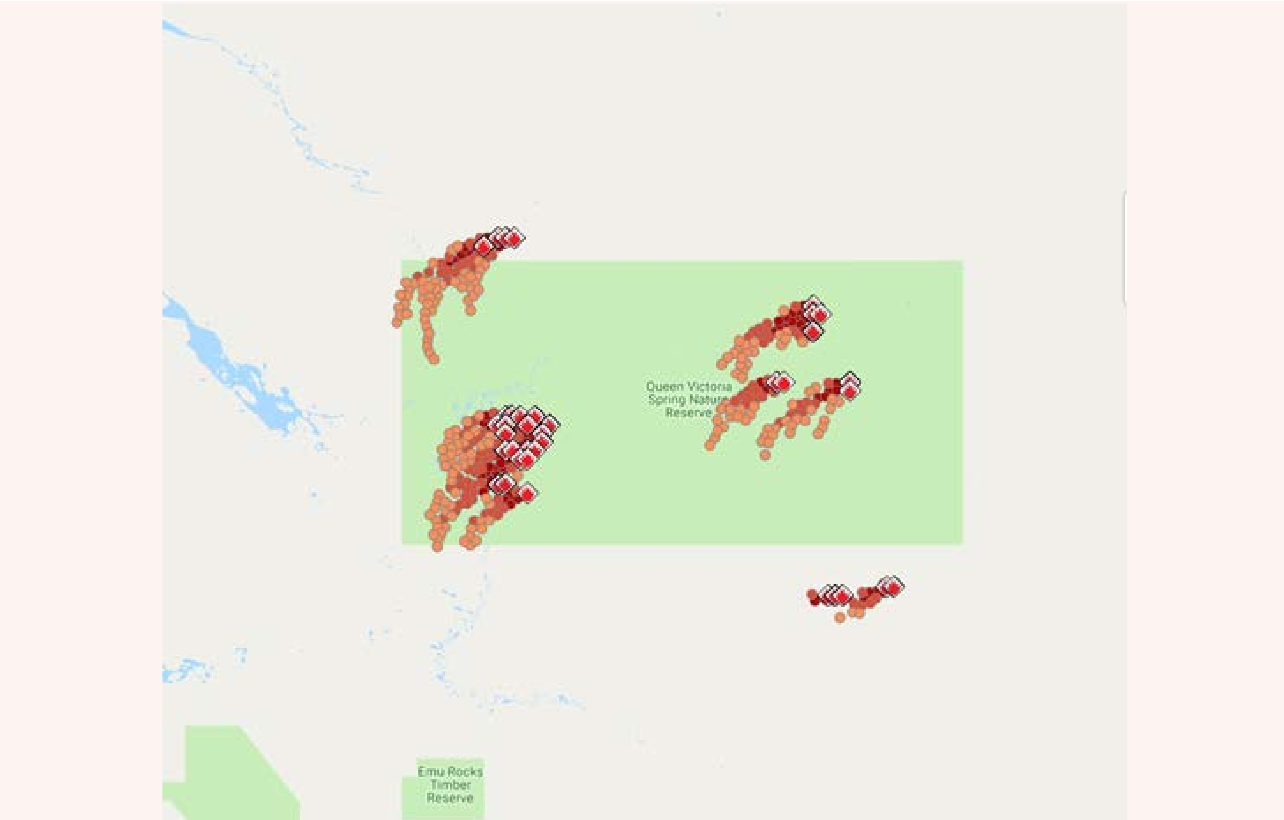

Figure 6. Aurora website showing fires (diamonds) in the Queen Victoria Spring Nature Reserve during February 2019 with simulation points (circles) from MODIS.

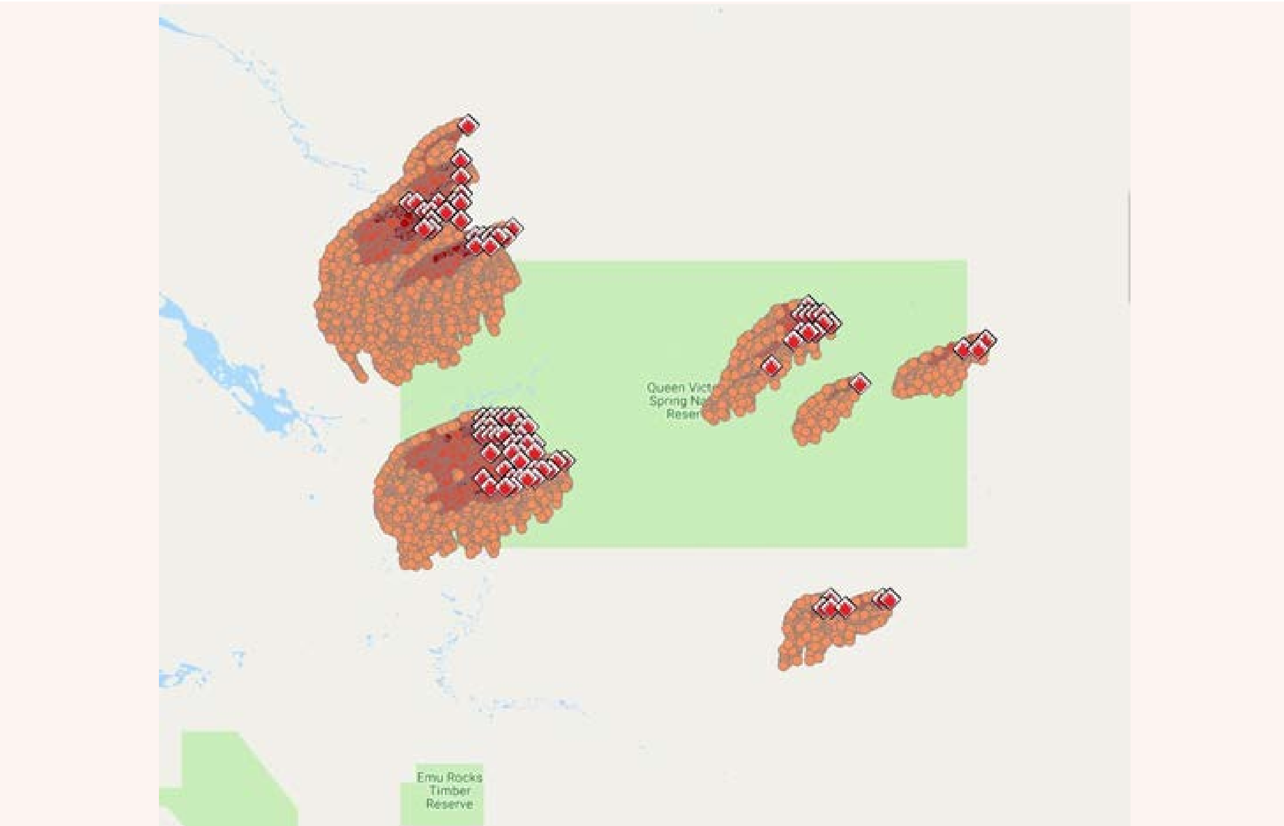

Figure 7. Aurora website showing fires (diamonds) in the Queen Victoria Spring Nature Reserve during February 2019 with simulation points (circles) from SNPP.

CURTIN UNIVERSITY, REMOTE SENSING AND SATELLITE RESEARCH GROUP (RSSRG), PERTH

Improving Satellite Ocean Colour In WA and GBR Waters

Dr. Peter Fearns and Prof. David Antoine, Remote Sensing and Satellite Research Group (RSSRG), Curtin University, Perth;

Dr. Edward King and Dr. Jenny Lovell, Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Background:

We report here on progress with respect to identifying, collating and processing in-situ radiometric data sets. These data have contributed to the Australian Ocean Data Network (AODN) where they are now available for comparison to existing satellite remotely sensed ocean colour products in WA and GBR waters. Also, AODN data are openly available to researchers developing or refining algorithms, and sub-sets are contributed to both the NASA and ESA global in-situ data collections that are used in the development and refinement of global ocean colour products.

Scope, tasks:

The project focused on radiometry measurements only, in particular those collected using the Dynamic Above Water radiance (L) and irradiance (E) Collector (DALEC).

Tasks included:

- Identify projects that collected radiometry data.
- Determine the existence/location of data.
- Collect metadata and data (if available).
- Assess quality of radiometry data.
- Extract radiometry data for matchup analysis with assistance of CSIRO (in its role as IMOS OC operator).
- Deliver the matchup analyses.

A preliminary list of potential data was produced at the inception of the project, then owners/custodians of those data approached with a request to submit the data to this project. Data from the following projects were located and acquired:

- WAMSI Dredge Science Node project
- Water quality and shallow water mapping around coral islands in the off-shore Kimberley (WA Museum).
- Kimberley data around Montgomery Reef (WAMSI project).
- Shark Bay shallow water mapping of the Faure Sill.
- GBR ARC Linkage project led by UQ/Curtin, and
- Other sundry data

Deliverables:

- List of in situ radiometry data sets contributed to IMOS/AODN
- Validation assessment of MODIS

Data collected:

DALEC data are typically stored as "triplet files", with one file containing radiometric data, one containing instrument attitude data, and the third containing GPS information. Approximately 3,400 files have been acquired, representing approximately 1,130 triplets. DALEC data are typically collected from a moving vessel along a transect so each DALEC triplet can contain hundreds to thousands of individual spectra.

The contents of some DALEC files are obvious from the file name, but many are assigned generic file names. It is clear from some of the file names that data represent land-based "spectral library" measurements rather than marine radiometric measurements. Although the spectral library data are not of core interest to the current project, they do represent a potentially valuable contribution to a national archive of such data. The spectral library data were not processed as part of the current project.

DALEC Data Processing:

Existing python code, DalecPPT.py, was acquired and tested. The code was originally designed to read and process DALEC data and output text files of derived reflectance. The code produced errors on initial testing so had to be fixed.

The code has been enhanced to include calculation of the surface reflectance rho factor using data from Mobley 2015. The required rho table from Mobley 2015 was downloaded from:

https://www.oceanopticsbook.info/view/remote_sensing/level_3/surface_reflectance_factors

A new routine was created to write the DALEC reflectance data to netCDF files. Appendix A shows a listing from a sample netCDF file (using ncdump -h). The netCDF files adhere to the IMOS required conventions (IMOS_NetCDF_Conventions.pdf).

The DaledcPPT.py code was also adapted to include some quality control in terms of constraining data based on factors such as solar position, instrument attitude or orientation of the instrument relative to the sun. Only data within relative azimuth limits of 135 +/- 40 were included in the netCDF file. All data were then flagged as 'good', unless they fell outside the pitch or roll > 3 degrees, or std(pitch or roll) > 2 degrees, in which case they were flagged as 'probably good'.

The DALEC instrument should be deployed within specific geometries relative to the solar position. The vertical pointing direction is monitored by the roll and pitch, and the horizontal orientation is monitored by an internal compass. Figure 8 shows an example of geometry extracted from processed DALEC data, plotted through time. The time spans approximately 6000 sec (~100 min). The solar zenith angle (sza) is calculated using location and time information.

Figure 9 shows an example of a time series of DALEC-derived reflectance at 550 nm. Figure 10 shows the full spectra associated with the data in Figure 2. The spectral reflectance data are colour coded from red to blue with increasing time.

After the manual removal of files that were definitely land-based or simply contained measurements of spectral end-members, all remaining files were processed. Some files failed to process to completion due to various issues (usually missing, incomplete or unreadable raw data). Of the original 1130 DALEC triplet files, 128 netCDF files were produced.

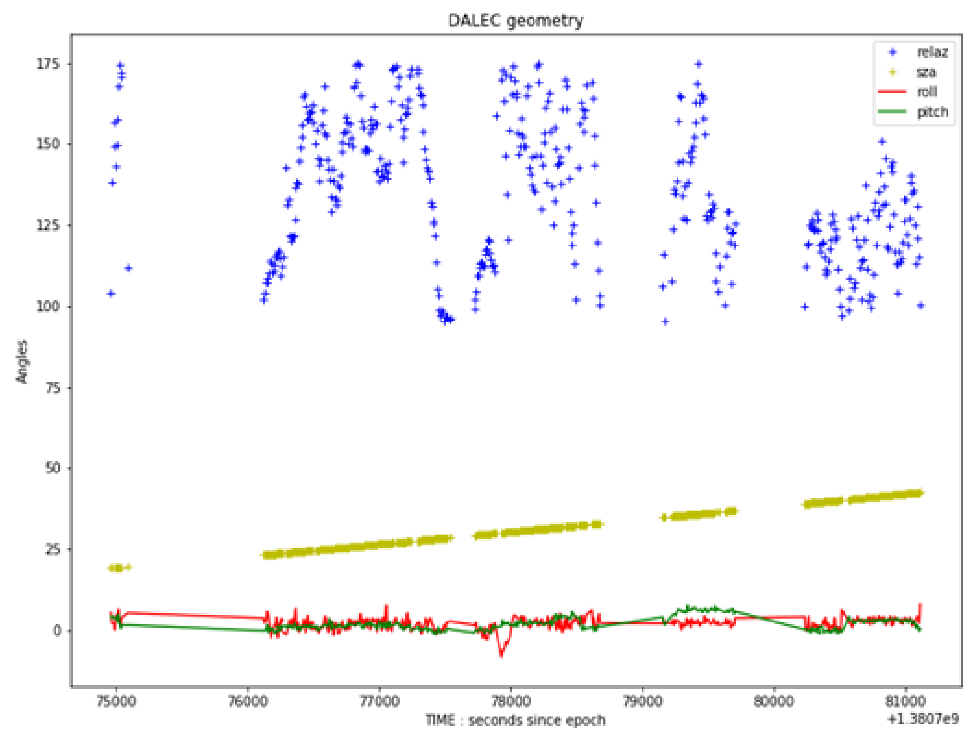

Figure 8. DALEC geometry.

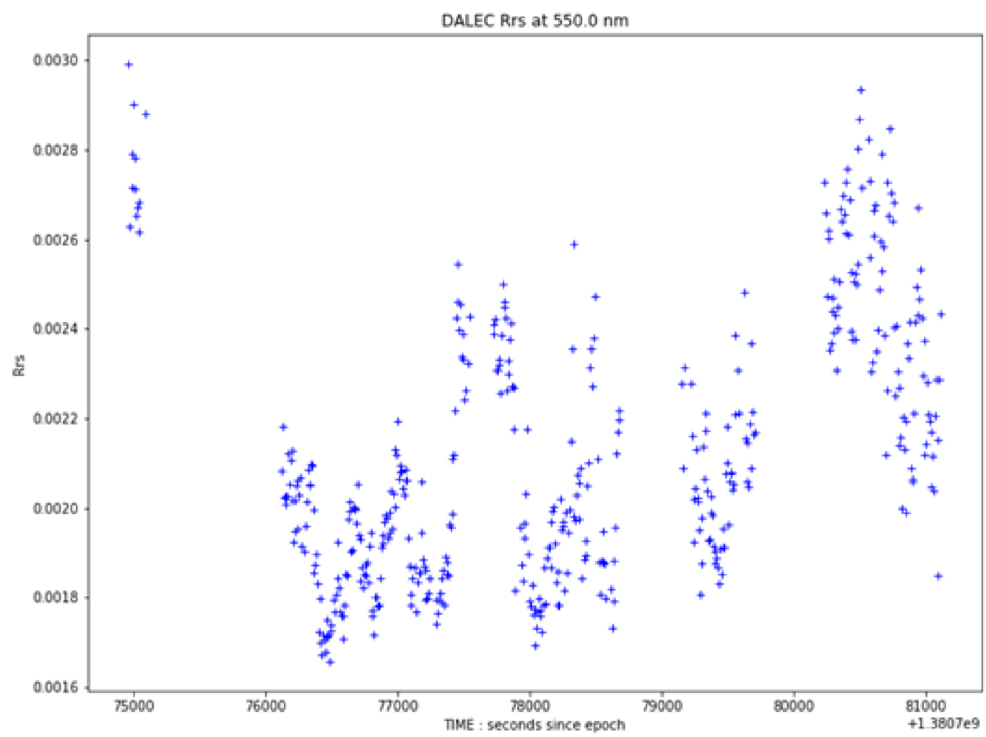

Figure 9. DALEC reflectance at 550 nm.

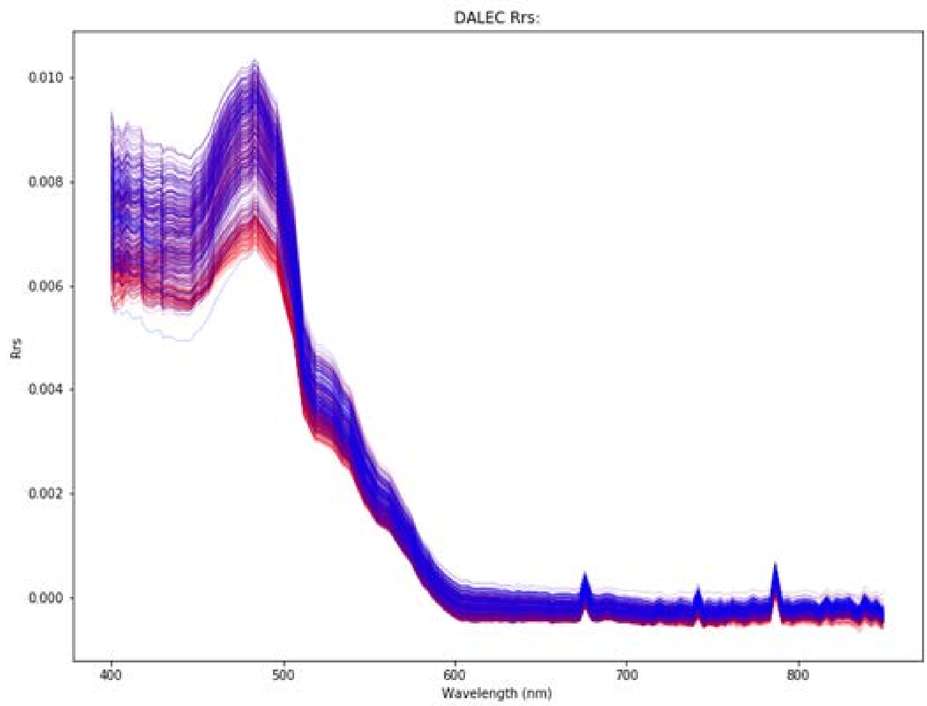

Figure 10. DALEC reflectance spectra. Curves gradually change from red to blue with increasing time.

Matchup data extraction and comparison:

DALEC netCDF files were delivered to CSIRO/IMOS for extraction of coincident MODIS reflectance data. DALEC data were divided into 5-minute sections to calculate a mean reflectance as well as standard deviation of the spectral data. Coincident (nearest time) MODIS data were extracted for a 21x21 pixel region surrounding the DALEC data. All data were then written to "Matchup" netCDF files. The date from the 128 netCDF DALEC files produced 731 valid matchup sets.

For every Matchup file produced figures are produced to show the location of the matchup data (see Figure 11) and to display the range of coincident MODIS and the DALEC spectral reflectances. Figure 12 shows a "reasonable" example of the matchup between the MODIS data and the DALEC measured reflectance at MODIS band central wavelengths. The red line shows the mean DALEC reflectance based on a 5 minute section of data. The error bars indicate 1 standard deviation. The grey curves show the MODIS spectral reflectances of the 441 pixels (21x21 region). The pink dashed curve shows the reflectance of the central MODIS pixel (at the location of the DALEC data). The green line shows the median MODIS reflectance. The thick blue curves indicate the reflectances of the four pixels adjacent to the central pixel (directly N,S,E and W). The dotted blue curves show the reflectances of the next closest pixels, diagonal to the central pixel. The overall spread of the grey curves, as well as the spread in the blue curves, helps to give an impression of the MODIS data variability in the near-field (a few km) and far-field (~10 km).

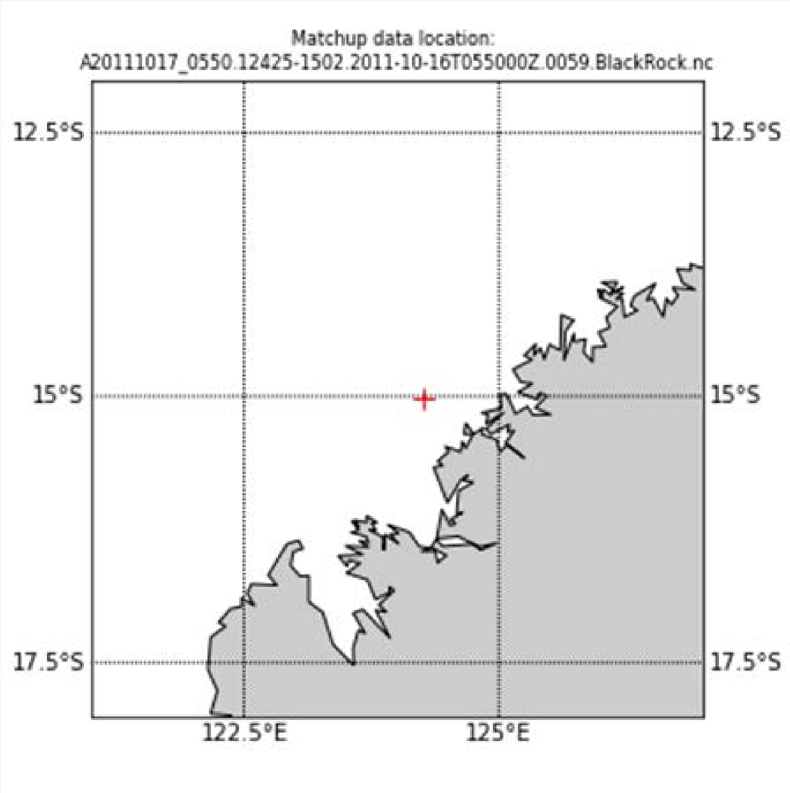

Figure 11. Location of DALEC/MODIS matchup data.

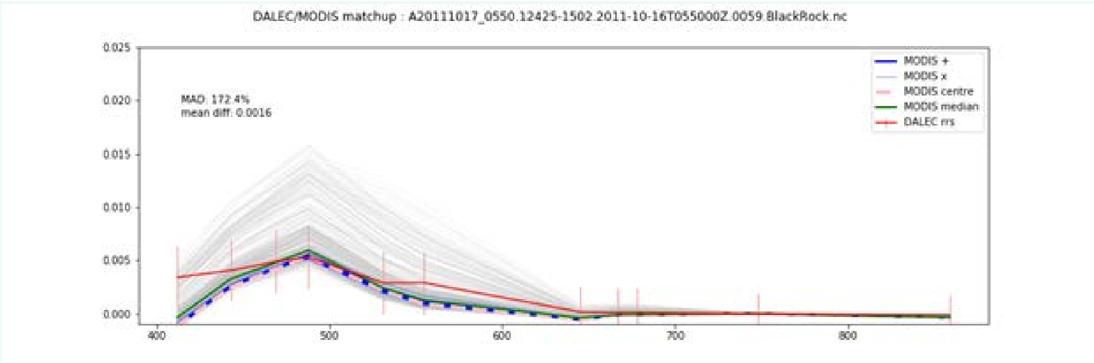

Figure 12. DALEC and MODIS spectra.

The following figures show samples of the matchup scenarios. All are based on data within the region indicated by Figure 11.

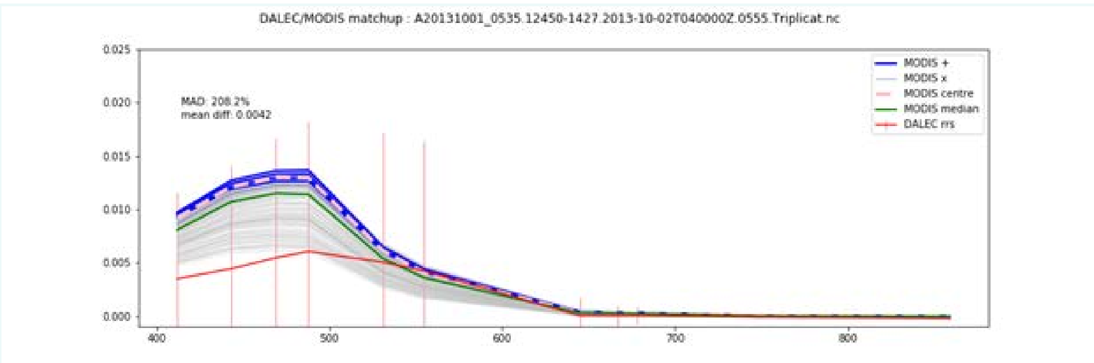

Figure 13. Large error bars on the DALEC data suggest a reasonable matchup with the MODIS data.

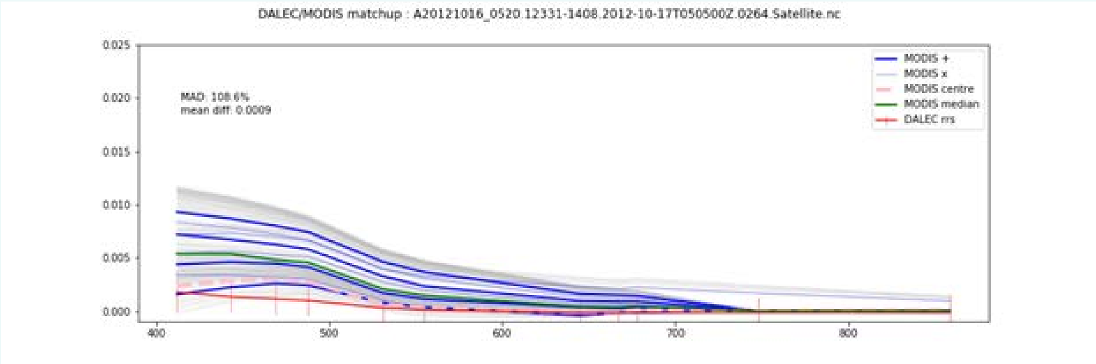

Figure 14. DALEC reflectance is close to the central MODIS pixel reflectance (dashed pink curve), but the MODIS data is very variable, indicated by the spread in the blue curves.

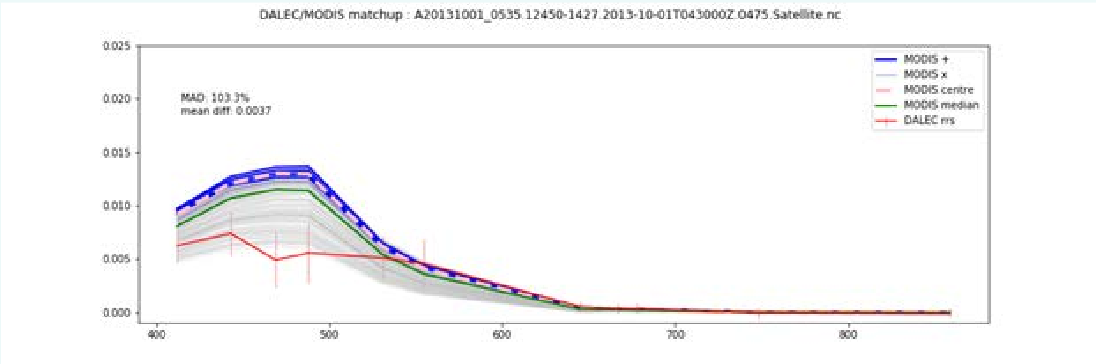

Figure 15. MODIS data shows reasonable uniformity, indicated by the close blue curves, but the DALEC reflectance is clearly not similar.

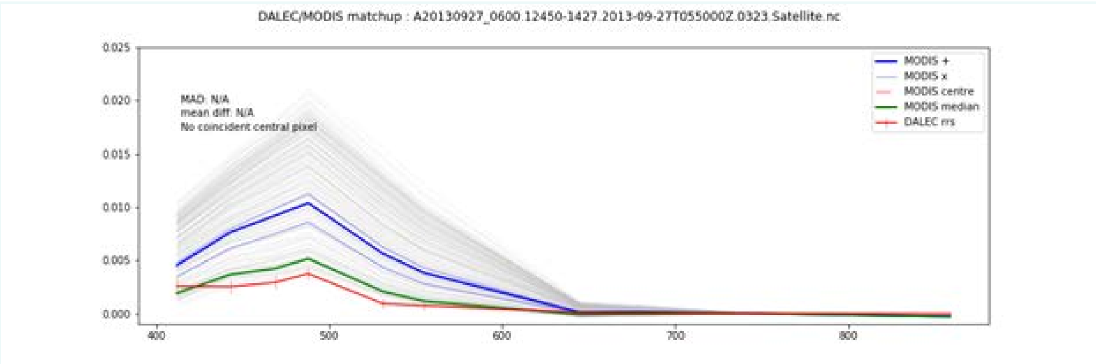

Figure 16. The central MODIS pixel did not pass the MODIS processing quality control tests. However the median MODIS reflectance (green curve) suggests a reasonable matchup with the DALEC data.

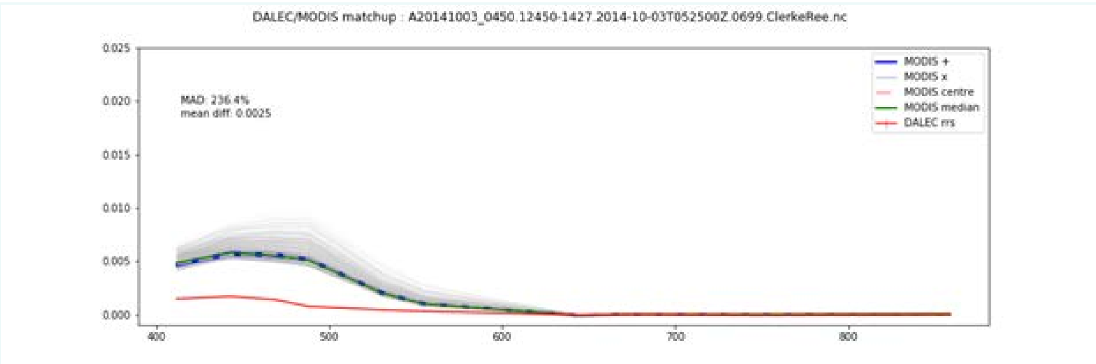

Figure 17. The MODIS data appear to be very uniform over a large area, indicated by the tightness of all the grey curves, however the DALEC reflectance is clearly not similar.

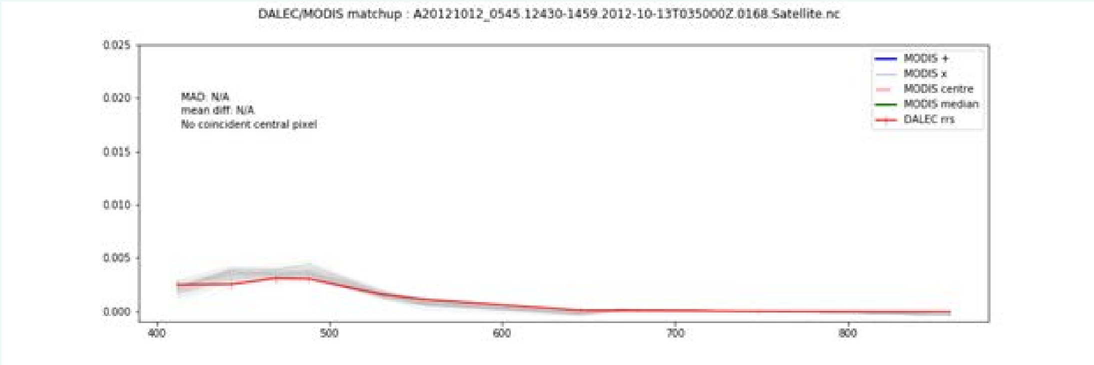

Figure 18. None of the central or near-field MODIS pixels were processed to reflectance, indicated by the absence of the pink, green and blue curves, however the grey curves suggest low spatial variability and a reasonable match to the DALEC-derived reflectance.

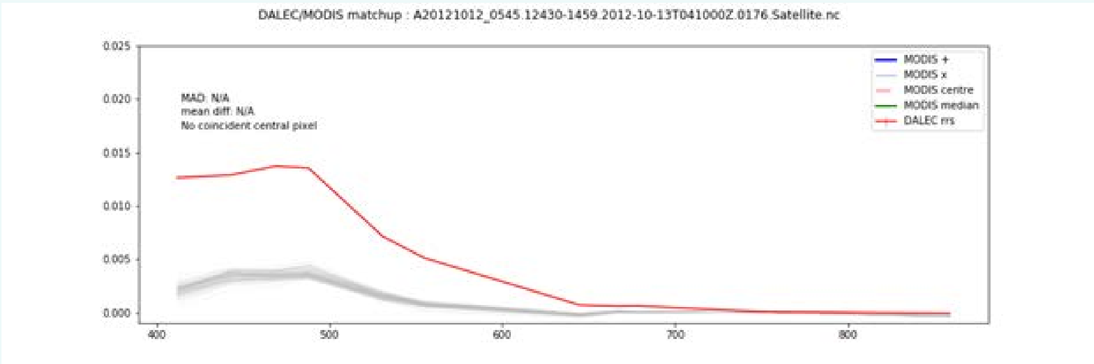

Figure 19. A similar scenario to Figure 11, however in this case the MODIS and DALEC-derived reflectances do not match.

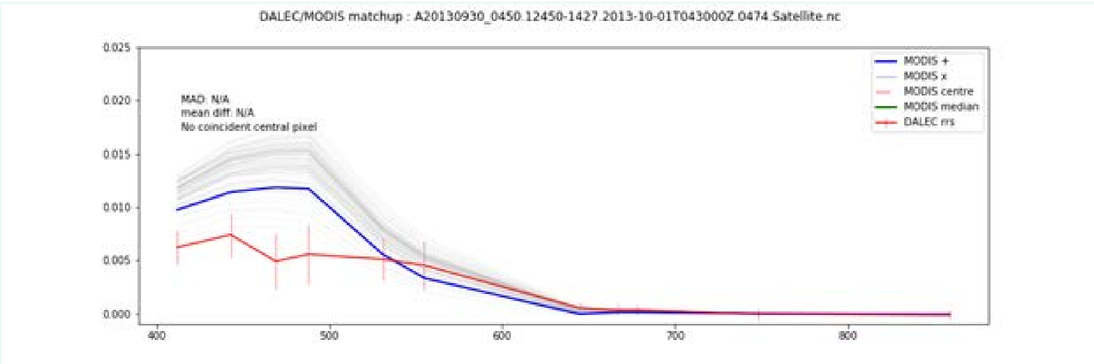

Figure 20. Most of the near-field MODIS pixels failed to process, indicated by the fact only one blue curve is present. The DALEC-derived reflectance does not match the MODIS spectra.

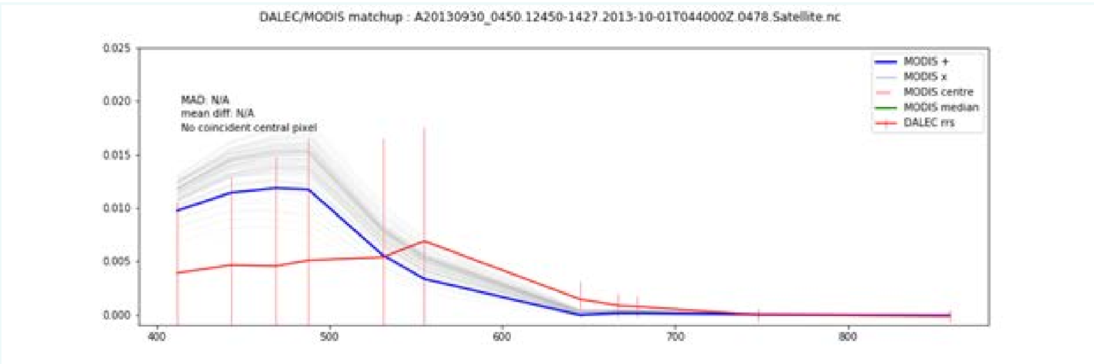

Figure 21. Near-field MODIS data failed to process fully. The large error bars associated with the DALEC data suggest a reasonable matchup.

Conclusions/Comments

This project successfully collected a large number of raw DALEC data, spanning 2010 to 2014, and representing data from the west coast of WA, the Kimberley region of WA and the GBR. Improvements were made to the DalecPPT.py tools and workflows were developed to support the extraction of DALEC/MODIS matchup data. Some of the DALEC data were land-based or represented measurements of spectral end-members, appropriate for inclusion in a spectral library.

Although we managed to locate and collect a large number of raw DALEC data, meta-data was essentially non-existent. It appears, and was assumed for all processing in this project, that the DALEC data were all collected in "local time".

The DALEC includes an internal GPS. The GPS data contained in the raw DALEC files was used for all processing (mapping, calculation of solar angle and selection of MODIS matchup location). Figure 22 shows an example of the DALEC data location (red cross) used to select the MODIS matchup data. The red cross on the map is not at the location of the Faure Sill, indicated by the blue line. This mismatch in location suggests the GPS data are suspect. This may cast some or all other (or subsequent) DALEC location data as suspect.

Some DALEC calibration files were located, but the lack of meta-data made it difficult to assign a specific calibration file to a specific DALEC data file. All data were therefore processed with the same calibration.

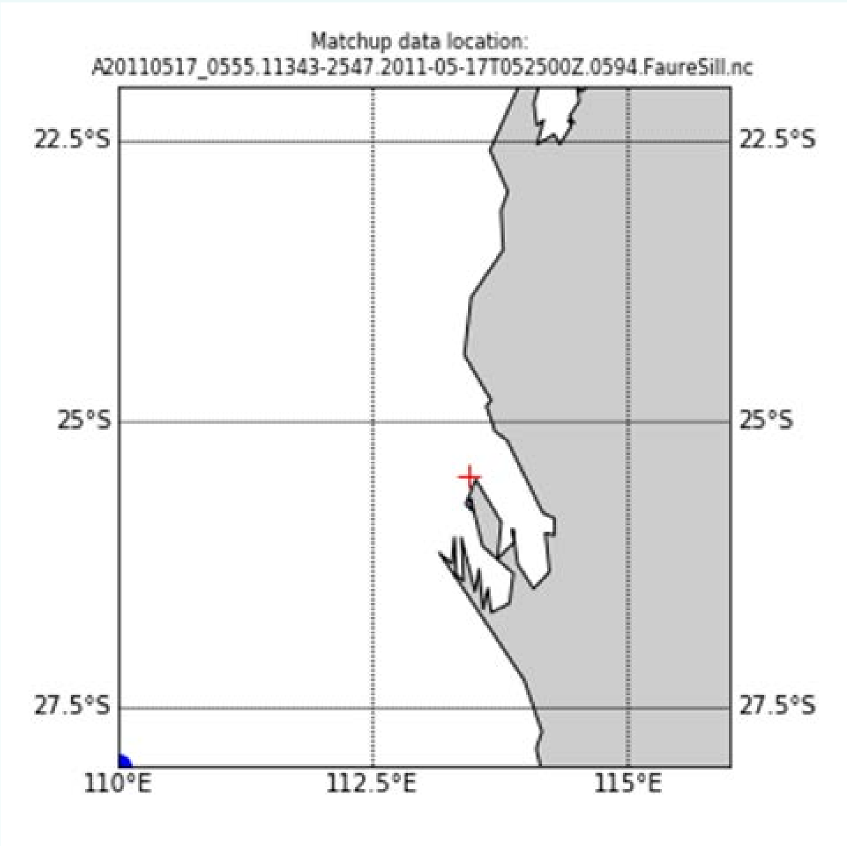

Figure 22. Location of field data associated with a Faure Sill data set.

Reference:

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Australian Land Surface Spectral Emissivity

Dr Owen Giersh and Emeritus Prof Mervyn Lynch, Curtin University, Perth

The aim of this research project is to determine the precise value land surface temperature Ts (in kelvin) and land surface spectral emissivity ε(λ) from satellite data. Whilst this may seem relatively straightforward, this problem does not have a simple solution, and almost all of the methods proposed have significant limitations. For a review of various techniques refer to Li et al. [2013]. Why is this work important? Emissivity ε(λ) determines how efficient a surface is at emitting thermal radiation. Its value typically varies from ~ 0.7 to 1.0. If we had two surfaces at identical temperatures but with differing emissivities, they would be measured by an infrared radiometer (such as on a satellite) as having widely differing (perhaps ~ 10s of K) temperatures. The scheme and associated algorithm we are implementing in this project determines simultaneously the spectral emissivity and the true surface temperature in *K*. We utilise data from the AIRS hyperspectral sensor on the MODIS platform because its data is received and archived by WASTAC.

Fundamentally, the problem involves solving the radiative transfer equation which can be written at the top of the atmosphere (TOA) as,

$$L_\lambda = L_s + L_{a\uparrow} + L_{a\uparrow\downarrow} \,, \quad (1)$$

or in full as,

$$L_{ToA} = \epsilon_\lambda \tau_\lambda B_\lambda(T_s) + \int_{p=p_s}^{p=0} B_\lambda(T_p) \frac{\partial \tau_\lambda(p)}{\partial p} dp + (1-\epsilon_\lambda)\tau_\lambda \int_{p=0}^{p=p_s} B_\lambda(T_p) \frac{\partial \tau_\lambda(p)}{\partial p} dp, \quad (2)$$

where L_{ToA} is the radiance at wavelength λ detected at the top of atmosphere (for example as would be measured by a satellite-based spectroradiometer), L_s is the surface radiance emitted at wavelength λ, *B*λ(*Ts*) is the Planck function evaluated at the surface temperature T_s, ϵ_λ is the surface spectral emissivity at λ, τλ is the transmittance at wavelength λ of the entire atmospheric column at λ, τ_λ(p) is the transmittance from pressure level *p* to *TOA*, $L_{a\uparrow}$ is the upwelling atmospheric column radiance, *B*λ(T_p) is the Planck function at temperature T_p at wavelength λ for pressure level *p, p=0* and *p=ps* are the top of atmosphere and surface pressure respectively and $L_{a\downarrow\uparrow}$ is the atmospheric column downwelling radiance reflected at the surface.

In equation 2, the forms of two integrals are almost identical. However, the pressure increments *dp* are of opposite sign (corresponding to upward or downward integration through the atmosphere) and the limits on the integral are transposed. However, both integrals contribute positively to the top of atmosphere radiance. Thus, we let,

$$\alpha = \int_{p=0}^{p=p_s} B_\lambda(T_p) \frac{\partial \tau_\lambda(p)}{\partial p} dp \,, \quad (3)$$

and substitute α into equation 2 yielding,

$$L_{ToA} = \epsilon_\lambda[\tau_\lambda B_\lambda(T_s) - \tau_\lambda \alpha] + \tau_\lambda \alpha + \alpha. \quad (4)$$

Equation 4 now may be rearranged to obtain ϵ_λ explicitly as a function of the other terms as follows,

$$\epsilon_\lambda = \frac{L_{ToA} - \alpha - \tau_\lambda \alpha}{\tau_\lambda (B_\lambda(T_s) - \alpha)}. \quad (5)$$

In equation 5, L_{ToA} is measured by a satellite-based sensor; τ_λ and α must be model-derived, and ϵ_λ and T_s are the two unknowns. With one equation and two unknowns, in principle, we have a difficulty. However, as discussed below, we use an iterative scheme to identify the correct solution.

However, it is not possible to solve equation 5 without additional information on the atmospheric column transmittance τ_λ and also the atmospheric column spectral radiance α as a function of wavelength λ. To estimate these two quantities we use a radiative transfer model RTTOVS (Hocking et al 2011) and a local radiosonde released close to the time of overpass of the AIRS satellite. In Australia, however, this is frequently problematic. The number of observing stations where radiosondes are routinely released is now very limited and widely separated spatially. Further the AIRS satellite overpass time and that of sonde releases can be well separated in time by at least 6 or so hours. With the RTTOVS products estimated we are able to proceed to determine the surface temperature and land spectral emissivity.

The approach to finding a solution to equation 5 is to iterate through a sequence of temperatures in order to find a temperature that produces the smoothest ε(λ) over the range of wavelengths investigated. That is, for each temperature a spectral smoothness is calculated for the derived spectral emissivity. One such measure is the mean squared derivative (MSD) [Bower, 2001]:

$$MSD(T) = \frac{1}{N}\sum_{i=2}^{N}[\epsilon(\lambda_i, T) - \epsilon(\lambda_{i-1}, T)]^2, \quad (8)$$

where *N* is the number of wavelength channels, λi is the wavelength of channel *i* and *T* is the surface temperature being tested. Figure 23, which here uses (i) the Perth radiosonde to compute the atmospheric column spectral transmittances and column downwelling radiances and (ii) the AIRS radiometric observations for that same day as inputs to equation 5, shows that the MSD of emissivity is a smoothly varying function as the guessed temperature is adjusted. It reaches a minimum value at ~ 293 K showing that the land and atmospheric radiances have been correctly partitioned and the surface temperature and the spectral emissivity have been determined.

Specifically, if the estimate of surface temperature is too low (or high) we find that the land and atmospheric radiometric terms are not correctly determined and the emissivity will be contaminated by atmospheric emission (or absorption) lines. See Figure 24 that illustrates this process. However, when the MSD reaches a minimum, the atmospheric absorption and emission lines are no longer contaminating. The upshot is that we simultaneously obtain the spectral emissivity and an emissivity corrected surface temperature [Bower, 2001; Li et al., 2013]. Satellite sensors such a LANDSAT and AVHRR cannot resolve the gaseous emission and absorption lines. One requires hyperspectral satellite sensors such as AIRS and IASI to extract such corrections to the land surface's properties such as ε(λ) and the temperature *T*.

Other techniques exist for determining spectral emissivity and land surface temperature. A particularly attractive procedure was developed Zhou et al., 2011. The advantage this technique is that the atmospheric transmittances and radiances do not need to be modelled using radiative transfer code such as RTTOVS. Zhou et al's code is being provided to Curtin by Zhou for implementation over Australia. However, we are awaiting its clearance for shipping under the US export control legislation.

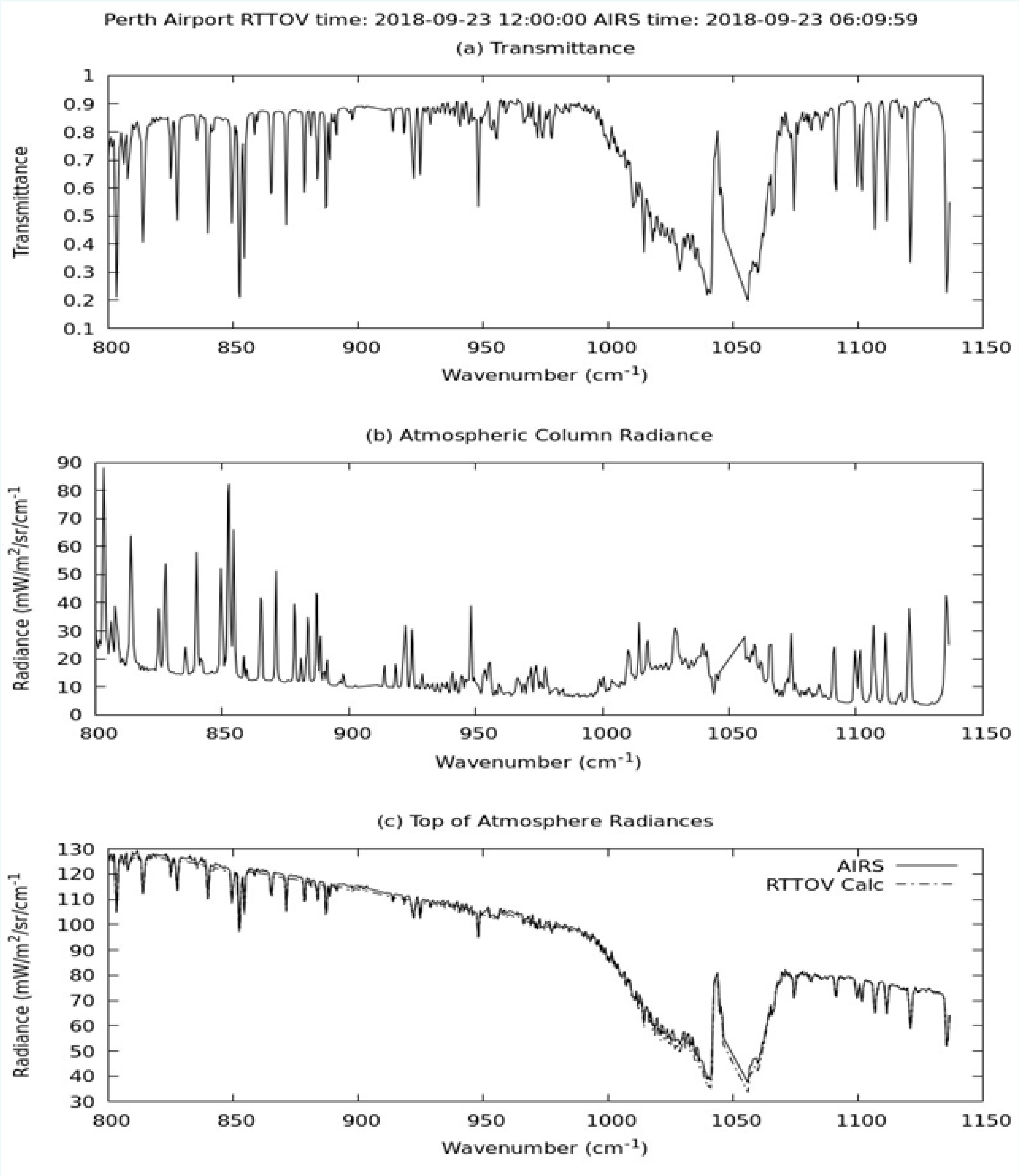

Figure 23. Illustrates the key quantities that appear in the expression for the spectral emissivity, equation 5, that are derived from the radiative transfer equation 2. The top panel presents the atmospheric column spectral transmittance $\tau\lambda$, the central panel shows the downwelling atmospheric column spectral radiance α (see eqn 3). The lowest panel compares (*i*) the top of atmosphere radiances computed using a local radiosonde and the RTTOVS radiative transfer code with the radiance (L_{ToA}) observed by the overpassing AIRS hyperspectral satellite sensor on the MODIS platform.

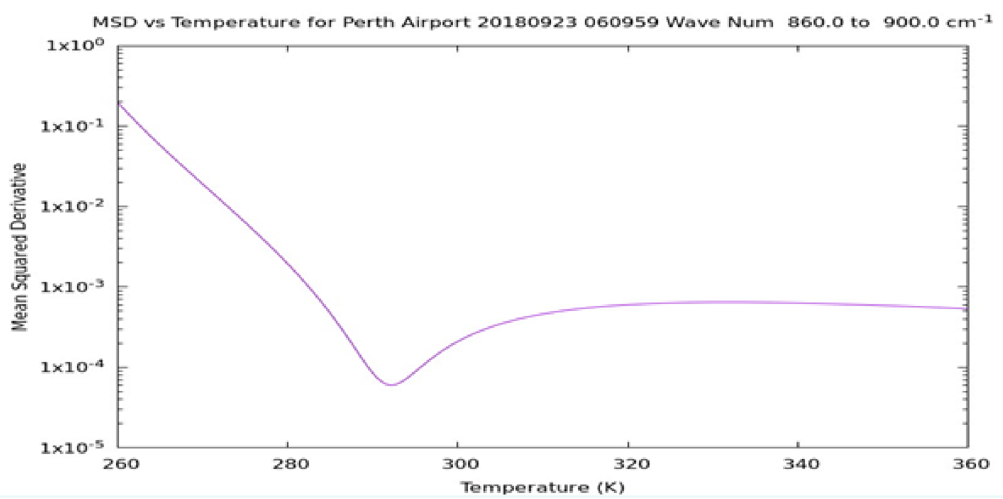

Figure 24. Illustrates the convergence of the mean squared deviation (MSD) of the spectral emissivity with surface temperature variation. The MSD's value or smoothness traverses a minimum as the estimated surface temperature approaches the true value. At the MSD minimum value of 293 K, the surface spectral emissivity is essentially free of any contaminating atmospheric molecular line features.

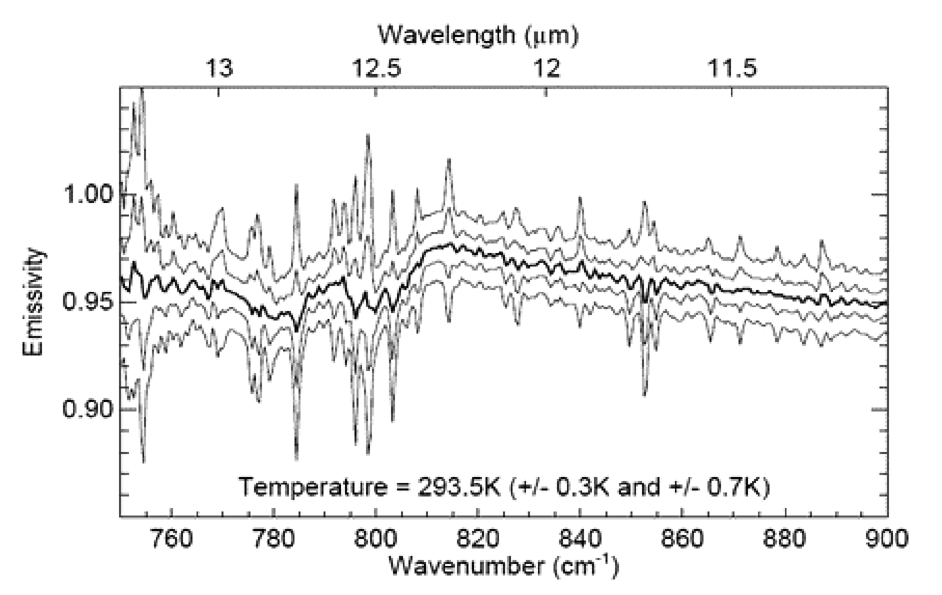

Figure 25. Shows that the land emissivity will be determined incorrectly with contamination from atmospheric emission / absorption line features if we have not guessed the land surface temperature [LST] correctly. The solution scheme progressively estimates the LST typically in 0.05 K increments and selects the smoothest emissivity (ie with all atmospheric lines absent). The procedure is very accurate in yielding the surface temperature and spectral emissivity (λ) of soils etc.

References

- Bower, N. 2001. *Measurement of Land Surface Emissivity and temperature in the thermal infrared using a ground-based interferometer.* PhD thesis, Curtin University, Perth, Australia.
- Hocking, James, Peter Rayer, Roger Saunders, Marco Matricardi, Alan Geer & Pascal Brunel. 2011. *RTTOV v10 Users Guide.* https://nwpsaf.eu/oldsite/deliverables/rtm/docs_rttov10/users_guide_10_v1.5.pdf
- Li, Z.L., H. Wu, N. Wang, S. Qiu, J.A. Sobrino, Z. Wan, B.H. Tang, and G. Yan. 2013. *Land surface emissivity retrieval from satellite data. International Journal of Remote Sensing.* 34 (9-10), 3084-3127.
- Zhou, D.K., A.M. Larar, X. Liu, W.L. Smith, L.L Strow, P. Yang, P. Schlüssel, and X. Calbet. 2011. *Global land surface emissivity retrieved from satellite ultraspectral IR measurements.* IEEE Transactions on Geoscience and Remote Sensing, 49 (4), 1277-1290.

Acknowledgements
We gratefully acknowledge the support of this research by WASTAC, the Bureau of Meteorology (Head Office, Melbourne), and by Curtin University's School of EECMS and the Faculty of Science and Engineering.

Improving Honey Crop Prediction from Remotely Sensed Data

WASTAC Small Grants Completion Report: May 2021

Tristan Campbell and Dr. Peter Fearns, Curtin University, Perth

Introduction

Doctoral research by Tristan Campbell (supervised by Peter Fearns) led to the development of a model to predict honey harvest volumes from Marri tree (Corymbia calophylla) apiary sites in Western Australia to 85% accuracy.

The model was developed using a combination of:

- Machine learning (random forest and gradient boosted trees)
- Weather station data from Bureau of Meteorology (BOM) terrestrial weather stations
- Vegetation-related data products from the MODIS satellite-based sensor

This WASTAC Small Grants project built on the work with a focus on improving the model to increase the prediction's accuracy and reliability and increase industry utilization of the model to improve the economic return.

As such, we defined three scopes of work:

- Increase apiarist engagement and utilisation of the data portal. This will both increase the economic return and improve the model by:
- Increasing the honey harvest data points used to generate the model.
- Broadening the model's utility by creating new models for other honey harvests.
- Optimise the weather input data, particularly summer rainfall data. This has been identified as a key variable but is likely not captured well by the BOM weather station network due to the localized nature of summer rainfall.
- Incorporation of bushfire and prescribed-burn data. This has been identified by the apiculture industry as a key factor in honey harvest variability. It is anticipated that the addition of this this input will have a significant impact on the model's performance as the dataset is relatively independent of the current weather and vegetation index inputs.

Project Scope 1: Increase apiarist uptake of the model

Over the course of the project, the prediction model and geospatial portal (Figure 26) were presented at three different apiarist association meetings, in Perth, Bunbury and Margaret River. As a result of this, the number of apiarists subscribed to the geospatial portal tripled, with similar increase in the volume of historical honey harvest data points used to calibrate updated models.

The increased harvest records allowed development of Marri models for three different DPIRD CVT zones, compared to the single model used for previous seasons. There were marked differences in the key factors influencing honey production from the different zones and this geographic separation of models has improved the accuracy of the predictions.

The model also incorporated optimised weather data and initial burn severity metrics as discussed below under project scopes 2 and 3.

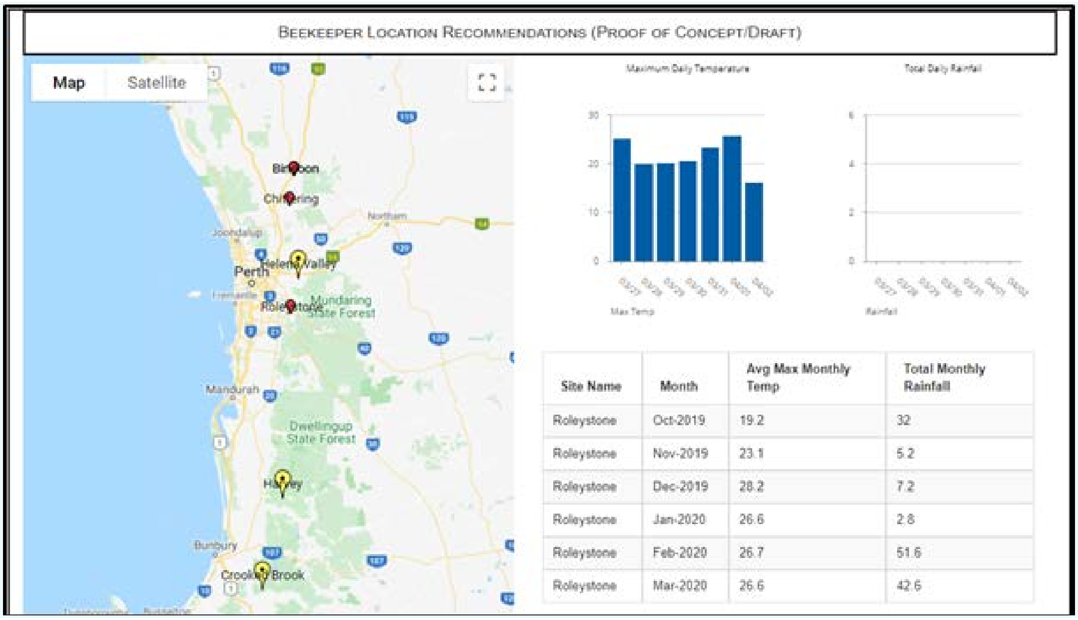

Figure 26. Example of the beta version of the geospatial data portal.

Project Scope 2: Optimisation of input weather data

Extensive validation of multiple weather products was undertaken, assessing both spatial and seasonal variations in accuracy of both terrestrial and satellite derived weather parameters. As per the scope, this analysis has been used to generate annual and monthly maps detailing the most accurate weather data source for different parameters across the study area.

Opportunities to improve accuracy of some satellite products from localised use of on-ground weather data were identified and included in the validation process (example in Figure 27 below).

This research is currently in the review process for the Journal of Meteorological Research (https://www.journals.elsevier.com/atmospheric-research) under the title "Spatial and temporal validation of in-situ and satellite weather data for the South West Agricultural Region of Australia" (Campbell and Fearns).

Project data, both raw and mapped, have been published as "Monthly Department of Primary Industries and Regional Development (DPIRD) weather station data for the South West Agricultural Region (SWAR)" at https://doi.org/10.25917/fry7-nx79.

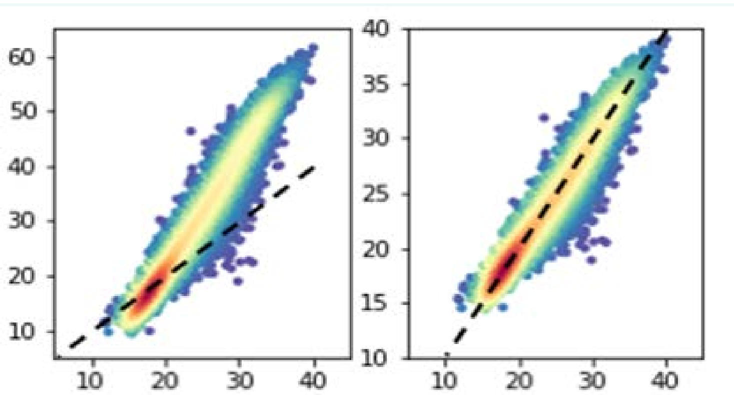

Figure 27. Daily maximum temperature from Copernicus LST (Himawari-derived) before and after correction applied. Dashed line indicates 1:1 ratio.

Project Scope 3: Incorporation of bushfire data into honey prediction model

This scope has focused on two main aspects:

1. Incorporation of MODIS burn indices into the honey prediction model. Difference Normalised Burn Ratio (dNBR) and Normalised Difference Vegetation Index (NDVI) have been assessed, but for initial burn intensity as well

as recovery to pre-burn levels of the metrics. Some promising results were found when dividing the dNBR by the number of years since the fire, effectively reducing the impact of fire over time. While this approach did improve the honey prediction somewhat, the feature importance in the model was significantly lower than many other factors. The information from the MODIS dNBR data may be incorporated into a preparatory step for the model in terms of a decision tree (i.e. scaled dNBR above X will only give a low harvest, between X and Y may give low or moderate harvest and between Y and Z will not impact the harvest.

2. Assessing variability of cut-off values for dNBR values from Sentinel-2 data for burn intensity as defined by the Composite Burn Index (higher spatial resolution makes this dataset more applicable for on-ground validation). This has been assessed both on a local scale (across individual fire events) and larger scale (between different regions and floristic communities). While the cut-off values for High Intensity fires, which are what affects honey production the most due to loss of canopy, the distinction between Low and Moderate Intensity varies more. This has ramifications for predicting seasonal effects, with evidence that Jarrah trees will drop their buds if affected by a moderate intensity fire but not a low intensity fire. This aspect of the research has gained considerable interest from the bee industry, forest management and conservation groups and is continuing with community support in the form of data collection for post-fire impacts.

UNIVERSITY OF WESTERN AUSTRALIA, PERTH

Supporting Phd Research in Western Australian Earth Observation

PhD Candidate: Rayigam Korale Kodithuwakku Arachchige Sharani Nishamika Kodithuwakku
Supervisors: Prof. Charitha Pattiaratchi, Dr Simone Cosoli, Dr Yasha Hetzel
School: Oceans Graduate School (OGS), The University of Western Australia (UWA)

Annual Progress Report (2022)

Research Progress

After achieving the Confirmation of candidature milestone in May 2021, I undertook Ocean Data Analysis OCEN5001 (6 credits) course in Aug-Sep 2021 as per the requirement of Oceans Graduate School and successfully completed with 83 marks (HD).

Eddy detection algorithm was applied over the period from 1993 to 2020 using satellite altimetry (Gridded Sea Level Anomaly) data which were interpolated 0.05^0 (~5.5 km) in order to use the higher spatial resolution data. As per the preliminary results that proved the importance of using higher spatial resolution data which increased the success of eddy detection. Then inter-annual and seasonal variability of mesoscale eddies were obtained over the 27 years and spatial variability of eddies were recorded including eddy centres (locations), eddy lifespan, eddy size (diameter), eddy tracks origins, propagation pathways and eddy decays. Currently I'm reviewing the first draft of my Paper 1 and alongside started to analyse the second aim of identifying long-lived eddy originations at Perth canyon over the period of 2010 to 2020.

I got the opportunity to participate Ocean glider recovery, Ocean glider deployment, Ocean mooring deployment field excursions and gained valuable experience of the field work, procedures and training. Additionally, I participated UWA Music Consortium of Music University choir during first semester as a member of Winthrop singers (Soprano voice category). By participating in evensongs and choral events helped me to improve and balance my mental health. During the second semester I participated in Uniswim lessons organized by UWA Aquatic centre (10 weeks programme).

I have achieved all the required milestones during this year and made a good progress towards my first paper and initiated analysis of the second aim of my PhD research.

Independent Auditor's Report – L-band

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AUDITOR'S INDEPENDENCE DECLARATION

Auditor's independence declaration to the Members of the Board of the Western Australian Satellite Technology and Application Consortium (WASTAC) L Band.

In relation to my audit of the special purpose financial report of the Western Australian Satellite Technology and Application Consortium (WASTAC) L Band for the period ended 15 July 2019, to the best of my knowledge and belief, there have been no contraventions of the auditor independence requirements of Australian Professional Accounting Bodies.

Santo Casilli FCPA
Date: 2 August 2019

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INDEPENDENT AUDITOR'S REPORT

The Members of the Board

Opinion

We have audited the final special purpose financial report of the Western Australian Satellite Technology and Application Consortium (WASTAC) L Band, which comprises the balance sheet as at 15 July 2019, the income statement and the statement of cash flows for the period 1 January 2018 to 15 July 2019, notes to the financial report and including a summary of significant accounting policies and other explanatory information. Our audit opinion is provided in order to satisfy the reporting requirements of the Board and its Joint venture participants and to also as part of the winding up of the Consortium.

In our opinion, the accompanying final special purpose financial report of the Western Australian Satellite Technology and Application Consortium (WASTAC) L Band for the period 1 January 2018 to 15 July 2019 is prepared, in all material respects, in accordance with the financial reporting provisions as outlined in Note 1 of the financial statements.

Basis for Opinion

We conducted our audit in accordance with Australian Auditing Standards. Our responsibilities under those standards are further described in the Auditor's Responsibilities for the Audit of the Financial Report section of our report. We are independent of the Western Australian Satellite Technology and Application Consortium (WASTAC) L Band in accordance with the ethical requirements of the Accounting Professional and Ethical Standards Board's APES 110 Code of Ethics for Professional Accountants (the Code) that are relevant to our audit of the financial report in Australia, and we have fulfilled our other ethical responsibilities in accordance with the Code. We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Emphasis of Matter – Basis of Accounting and Restriction on Distribution and Use

We draw attention to Note 1 to the final special purpose financial report, which describes the basis of accounting. The financial report is prepared to assist the Western Australian Satellite Technology and Application Consortium (WASTAC) L Band to meet its reporting obligations between the Board and its Joint Venture participants. As a result, the financial report may not be suitable for another purpose. Our report is intended solely for the Board and its joint venture participants and should not be distributed to or used by other parties. Our opinion is not modified in respect of this matter.

Responsibilities of Management and Those Charged with Governance for the Financial Report

Curtin University management, on behalf of the Board, is responsible for the preparation of the special purpose financial report and for establishing such internal control as Curtin University management determines is necessary to enable the preparation of a special purpose financial report that is free from material misstatement, whether due to fraud or error.

The members of the Board are responsible for overseeing the Western Australian Satellite Technology and Application Consortium (WASTAC) L Band's financial reporting and wind up process.

Auditor's Responsibilities for the Audit of the Financial Report.

Our objectives are to obtain reasonable assurance about whether the final special purpose financial report, as a whole, is free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee

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that an audit conducted in accordance with Australian Auditing Standards will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of this financial report.

As part of an audit in accordance with Australian Auditing Standards, we exercise professional judgement and maintain professional scepticism throughout the audit. We also:

- Identify and assess the risks of material misstatement of the financial report, whether due to fraud or error, design and perform audit procedures responsive to those risks, and obtain audit evidence that is sufficient and appropriate to provide a basis for our opinion. The risk of not detecting a material misstatement resulting from fraud is higher than for one resulting from error, as fraud may involve collusion, forgery, intentional omissions, misrepresentations, or the override of internal control.
- Obtain an understanding of internal control relevant to the audit 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 Western Australian Satellite Technology and Application Consortium (WASTAC) L Band's internal control.
- Evaluate the appropriateness of accounting policies used as described in Note 1 to the financial statements and the reasonableness of accounting estimates and related disclosures made by Curtin University management, if any.

Electronic publication of the audited financial report

It is our understanding that the Western Australian Satellite Technology and Application Consortium L Band intends to electronically present the audited final 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.

We have communicated with the Western Australian Satellite Technology and Application Consortium (WASTAC) L Band Board regarding, among other matters, the planned scope and timing of the audit and, via our management letter, significant audit findings, including any significant deficiencies in internal control that we may have identified during our audit.

We have communicated with the Western Australian Satellite Technology and Application Consortium (WASTAC) L Band Board regarding, among other matters, the planned scope and timing of the audit and, via our management letter, significant audit findings, including any significant deficiencies in internal control that we may have identified during our audit.

Santo Casilli FCPA

Director, Avant Edge Consulting
Date: 2 August 2019, Perth

WASTAC L-BAND BUDGET 2018

Estimated expenditure for the year: January 2018 – December 2018

		2018	2017
1.	Data Tapes	-	-
2.	System maintenance/repairs	-	$5,000
3.	Telecommunications license of facility	-	-
4.	Consultants	-	$5,000
5.	Sundry consumables	$1,500	$1,500
6.	Travelling – Airfares	$3,000	$3,000
7.	Provision for major equipment (NW WA Dish)	$343,730	$343,730
8.	Annual Report	$12,000	$12,000
9.	Melbourne Workshop expenses	-	$3,015
10.	Decommission Curtin site	$16,825	$100.000
11.	Funding to Support Research & Education entity	$48,200	$48,200
12.	Development of website for schedules from all tiers	$12,050	$12,050
13.	Development of national scheduling system (Tier 3)	$24,100	$24,100
14.	Development of Tier 3 stitching	$36,150	$36,150
15.	Improving Satellite Ocean Colour (Curtin; CSIRO)	$59,095	-
TOTAL EXPENDITURE		$556,650	$593,745

Estimated income/revenue for the year: January 2018 – December 2018

		2018	2017
1.	Contributions - $10,000 (BOM, Landgate)	-	$20,000
2.	Interest	$7,153	$13,000
TOTAL INCOME		$7,153	$33,000

Income Statement for the Period: 1 January 2018 to 15 July 2019

	Note	2018-19	2017
REVENUE			
Contributions Received		-	$30,000
Interest Received		$10,470	$15,137
Other Income			-
Total Revenue		**$10,470**	**$45,137**
EXPENDITURE			
Outsourced work		$433,444	$75,000
Depreciation expenses		-	-
Travel & Transport		-	-
Venue Hire		-	-
Hospitality		-	-
Microwave licence		-	-
External Printing Expenses		$2,400	$6,890
Other operating expenditure		$16,826	-
Contributions provided		$59,095	-
Total Expenditure		**$511,765**	**$81,890**
NET OPERATING RESULT FOR THE YEAR		**$(501,295)**	**$(36,753)**

Balance Sheet as at: 15 July 2019

	Note	2018-19	2017
CURRENT ASSETS			
Cash at Bank		-	$576,295
Account Receivable		-	-
Prepayments		-	-
Accrued Revenue		-	-
Total Current Assets		**-**	**$576,295**
NON-CURRENT ASSETS			
Property, plant and equipment	2	-	-
Total Non-Current Assets		**-**	**-**
Total Assets		**-**	**$576,295**
CURRENT LIABILITIES			
Income received in advance		-	-
Accrued Expenses		-	$75,000
Total Current Liabilities		**-**	**$75,000**
Total Liabilities		**-**	**$75,000**
NET ASSETS		**-**	**$501,295**
EQUITY			
Retained Funds	4	-	$501,295
TOTAL EQUITY		**-**	**$501,295**

Cashflow Statement for the Period: 1 January 2018 to 15 July 2019

	Note	2018-19	2017
CASH FLOWS FROM OPERATING ACTIVITIES			
Receipts			
Contributions Received:			
- Landgate		-	$10,000
- CSIRO		-	-
- Bureau of Meteorology		-	$10,000
- Curtin University		-	$10,000
Interest received		$10,470	$15,137
Other Receipts		-	$4,772
Total Receipts		**$10,470**	**$57,865**
Payments			
Payments to suppliers		$(586,765)	$(9,587)
Total Payments		**$(586,765)**	**$(9,587)**
Net cash provided by operating activities		**$(576,295)**	**$35,550**
CASH FLOWS FROM INVESTING ACTIVITIES			
Payments for property, plant and equipment		-	-
Net cash used in investing activities		**-**	**-**
Net increase/(decrease) in cash		**$(576,295)**	**$35,550**
Cash at the beginning of the year		$576,295	$540,745
CASH AT THE END OF THE YEAR		**-**	**$576,295**

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 which has been prepared on an accrual basis.

(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

	2018-19	2017
Computer Equipment		
At cost	-	35,196
Accumulated depreciation	-	(35,196)
Other Equipment		
At cost	-	202,441
Accumulated depreciation	-	(202,441)
Total Property, Plant and Equipment	-	-

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	-	-	-
Additions/(Disposals)	-	-	-
Depreciation expense	-	-	-
Carrying amount at end of year	-	-	-

3. Notes to the Cash Flow Statement

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

	2018-19	2017
Net operating result	(501,295)	(36,753)
Depreciation expense	-	-
Movement in Current Assets & Liability	(75,000)	72,303
Net cash provided/(used) by operating activities	**(576,295)**	**35,550**

4. Retained Earnings

	2018-19	2017
Balance at beginning of the year	501,295	538,048
Operating surplus/(deficit) for the year	(501,295)	(36,753)
Balance at end of the year	**-**	**501,295**

Independent Auditor's Report – X-band

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AUDITOR'S INDEPENDENCE DECLARATION

Auditor's independence declaration to the Members of the Board of the Western Australian Satellite Technology and Application Consortium (WASTAC) X Band.

In relation to my audit of the special purpose financial report of the Western Australian Satellite Technology and Application Consortium (WASTAC) X Band for the period ended 15 July 2019, to the best of my knowledge and belief, there have been no contraventions of the auditor independence requirements of Australian Professional Accounting Bodies.

Santo Casilli FCPA

Date: 2 August 2019

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INDEPENDENT AUDITOR'S REPORT

The Members of the Board

Opinion

We have audited the final special purpose financial report of the Western Australian Satellite Technology and Application Consortium (WASTAC) X Band, which comprises the balance sheet as at 15 July 2019, the income statement and the statement of cash flows for the period 1 January 2018 to 15 July 2019, notes to the financial report and including a summary of significant accounting policies and other explanatory information. Our audit opinion is provided in order to satisfy the reporting requirements of the Board and its Joint venture participants and to also as part of the winding up of the Consortium.

In our opinion, the accompanying final special purpose financial report of the Western Australian Satellite Technology and Application Consortium (WASTAC) X Band for the period 1 January 2018 to 15 July 2019 is prepared, in all material respects, in accordance with the financial reporting provisions as outlined in Note 1 of the financial statements.

Basis for Opinion

We conducted our audit in accordance with Australian Auditing Standards. Our responsibilities under those standards are further described in the Auditor's Responsibilities for the Audit of the Financial Report section of our report. We are independent of the Western Australian Satellite Technology and Application Consortium (WASTAC) X Band in accordance with the ethical requirements of the Accounting Professional and Ethical Standards Board's APES 110 Code of Ethics for Professional Accountants (the Code) that are relevant to our audit of the financial report in Australia, and we have fulfilled our other ethical responsibilities in accordance with the Code. We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Emphasis of Matter – Basis of Accounting and Restriction on Distribution and Use

We draw attention to Note 1 to the final special purpose financial report, which describes the basis of accounting. The financial report is prepared to assist the Western Australian Satellite Technology and Application Consortium (WASTAC) X Band to meet its reporting obligations between the Board and its Joint Venture participants. As a result, the financial report may not be suitable for another purpose. Our report is intended solely for the Board and its joint venture participants and should not be distributed to or used by other parties. Our opinion is not modified in respect of this matter.

Responsibilities of Management and Those Charged with Governance for the Financial Report

Curtin University management, on behalf of the Board, is responsible for the preparation of the special purpose financial report and for establishing such internal control as Curtin University management determines is necessary to enable the preparation of a special purpose financial report that is free from material misstatement, whether due to fraud or error.

The members of the Board are responsible for overseeing the Western Australian Satellite Technology and Application Consortium (WASTAC) X Band's financial reporting and wind up process.

Auditor's Responsibilities for the Audit of the Financial Report.

Our objectives are to obtain reasonable assurance about whether the special purpose financial report, as a whole, is free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee

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that an audit conducted in accordance with Australian Auditing Standards will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of this financial report.

As part of an audit in accordance with Australian Auditing Standards, we exercise professional judgement and maintain professional scepticism throughout the audit. We also:

Identify and assess the risks of material misstatement of the financial report, whether due to fraud or error, design and perform audit procedures responsive to those risks, and obtain audit evidence that is sufficient and appropriate to provide a basis for our opinion. The risk of not detecting a material misstatement resulting from fraud is higher than for one resulting from error, as fraud may involve collusion, forgery, intentional omissions, misrepresentations, or the override of internal control.

Obtain an understanding of internal control relevant to the audit 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 Western Australian Satellite Technology and Application Consortium (WASTAC) X Band's internal control.

Evaluate the appropriateness of accounting policies used as described in Note 1 to the financial statements and the reasonableness of accounting estimates and related disclosures made by Curtin University management, if any.

Electronic publication of the audited financial report

It is our understanding that the Western Australian Satellite Technology and Application Consortium X Band 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.

We have communicated with Western Australian Satellite Technology and Application Consortium (WASTAC) X Band Board regarding, among other matters, the planned scope and timing of the audit and, via our management letter, significant audit findings, including any significant deficiencies in internal control that we may have identified during our audit.

Santo Casilli FCPA

Date: 2 August 2019
Perth

WASTAC X-BAND BUDGET 2018

Estimated expenditure for the Year: January 2018 – 15 July 2019

		2018-19	2017
1.	Data Tapes	-	-
2.	System maintenance/repairs	$40,000	$40,000
3.	Consultants, product development	-	$10,000
4.	Sundry consumables	$2,000	$2,000
5.	Travelling – Airfares	$4,000	$4,000
6.	Provision for major equipment (Murdoch)	$25,000	$25,000
7.	Melbourne Workshop expenses	-	$4,165
8.	ACMA Licensing for Murdoch	$50,000	$50,000
9.	Decommission Murdoch site	$50,000	$50,000
10.	Funding to Support Research & Education entity	$51,800	$51,800
11.	Development of website for schedules from all tiers	$12,950	$12,950
12.	Development of national scheduling system (Tier 3)	$25,900	$25,900
13.	Development of Tier 3 stitching	$38,850	$38,850
14.	Provision of Major Equipment (NW WA Dish)	$156,270	$156,270
15.	Aurora Satellite Data Continuation (LG)	$15,000	-
16.	Emissivity (Curtin, BOM)	$50,000	-
TOTAL EXPENDITURE		**$521,770**	**$470,935**

Estimated income/revenue for the year: January 2018 – December 2018

		2018	2017
1.	Annual Contributions ($20,000 each)	-	$60,000
2.	Interest	$8,060	$18,000
TOTAL INCOME		**$7,153**	**$33,000**

Income Statement for the Period: 1 January 2018 to 15 July 2019

	Note	2018-19	2017
REVENUE			
Contributions Received		-	$86,000
Interest Received		$13,631	$16,824
Other Income		$13,635	$304
Total Revenue		**$27,266**	**$77,128**
EXPENDITURE			
Outsourced Work (Consultancy)		$659,425	$7,570
Freight Expenses		-	-
Other Software & licence <$5,000		-	$13,488
Venue Hire		-	-
Computer Equipment Purchase		-	$1,097
Travel & Transport		-	-
Outsourced work (Software Support)		$20,624	-
Depreciation		$39,398	$27,380
Loss on Disposal of Non-Current Asset		$76,076	$27,380
Total Expenditure		**$795,523**	**$49,535**
NET OPERATING RESULT FOR THE YEAR		**$(768,257)**	**$27,593**

Balance Sheet as at: 15 July 2019

	Note	2018-19	2017
CURRENT ASSETS			
Cash at Bank		-	$652,783
Total Current Assets		**-**	**$652,783**
NON-CURRENT ASSETS			
Property, plant and equipment		-	$115,474
Total Non-Current Assets	2	**-**	**$115,474**
Total Assets		**-**	**$768,257**
CURRENT LIABILITIES			
Income received in advance		-	-
Accrued Expenses		-	-
Total Current Liabilities		**-**	**-**
Total Liabilities		**-**	**-**
NET ASSETS		**-**	**$768,257**
EQUITY			
Retained Funds	4	-	**$768,257**
TOTAL EQUITY		-	**$768,257**

Cashflow Statement for the Period: 1 January 2018 to 15 July 2019

	Note	2018-19	2017
CASH FLOWS FROM OPERATING ACTIVITIES			
Receipts			
Contributions Received:			
- Landgate		-	$20,000
- CSIRO		-	-
- Bureau of Meteorology		-	$20,000
- Geoscience Australia		-	$20,000
Interest received		$13,631	$16,824
Expense Reiimbursement		$13,635	$304
Total Receipts		**$27,266**	**$77,128**
Payments			
Payments to suppliers		$(680,049)	$(25,230)
Total Payments		**$(680,049)**	**$(25,230)**
Net cash provided by operating activities		**$(652,783)**	**$51,898**
CASH FLOWS FROM INVESTING ACTIVITIES			
Payments for property, plant and equipment		-	-
Net cash used in investing activities		-	-
Net increase/(decrease) in cash		**$(652,783)**	**$51,898**
Cash at the beginning of the year		$652,783	$600,885
CASH AT THE END OF THE YEAR		-	$652,783

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 which has been prepared on an accrual basis.

(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

	2018-19	2017
Computer Equipment		
At cost	-	$93,099
Accumulated depreciation	-	$(30,125)
Total Computer Equipment		**$71,625**
Other Equipment		
At cost	-	$852,919
Accumulated depreciation	-	$(781,690)
Total Other Equipment		**$52,500**
Total Property, Plant and Equipment	**-**	**$115,474**

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	**$62,974**	**$52,500**	**$115,474**
Additions/(Disposals)	$(50,009)	$(26,067)	$(76,076)
Depreciation expense	$(12,965)	$(26,433)	$(39,398)
Carrying amount at end of year	-	-	-

3. Notes to the Cash Flow Statement

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

	2018-19	2017
Net operating result	$(768,257)	$27,593
Depreciation expense	$39,398	$27,380
Movement in Current Assets & Liability	-	$(3,075)
Loss on disposal of Fixed Assets	$76,076	-
Net cash provided/(used) by operating activities	**$(652,783)**	**$51,898**

4. Retained Earnings

	2018-19	2017
Balance at beginning of the year	$768,257	$740,664
Operating surplus/(deficit) for the year	$(768,257)	$27,593
Balance at end of the year	-	**$768,257**

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