Forest information monitoring in Tasmania using Synthetic ApertureRadar GEO Forest Carbon Tracking task

A.L. Mitchell¹, A. Milne¹, I. Tapley¹, K. Lowell², P. Caccetta³, E. Lehmann³, Z-S. Zhou³, A. Held⁴

¹Cooperative Research Centre for Spatial Information (CRC-SI), School of Biological, Earth and Environmental Sciences, The University of New South Wales, Sydney, Australia (a.mitchell@unsw.edu.au; t.milne@unsw.edu.au, hgciant@bigpond.net.au)

²CRC-SI, Department of Geomatics, University of Melbourne, Carlton, Victoria, Australia (klowell@unimelb.edu.au)

³CSIRO Mathematics, Informatics and Statistics, Floreat, Western Australia (peter.caccetta@csiro.au; eric.lehmann@csiro.au; zheng-shu.zhou@csiro.au)

⁴CSIRO AusCover Facility, Canberra, Australia (alex.held@csiro.au)

7th ISDE Wallis Forum 2011, 23-25 August, Perth,

GEO Forest Carbon Tracking (FCT) task

- Global forest information monitoring
 - Consistent wall-to-wall time-series forest change estimates
 - Standardised methods: link, extract, evaluate
 - Reliable forest information for accurate carbon modelling
 - Contribute to MRV and international reporting
- 'Tasmania Demonstrator'
 - SAR capabilities for forest monitoring
 - Independent (recent) source
 - Interoperable use with optical time-series (NCAS)
 - Spatially and temporally consistent, wall-to-wall radar mosaics
 - Standard forest information products
 - Change detection and trend metrics



Tasmania ND site



Tasmania 62,409 square kilometres : 49.5% (3.4mHa) of the island is forest – 98% native forest 2% plantation forest 2009 PALSAR mosaic shows extent of Australia's non-tropical rainforests and wet sclerophyll forests



TAS Demonstrator SAR data

Sensor	Availability	Mode	Inciden ce angle	Spatial resoluti on (m)	Swath width (km)
ALOS PALSAR (JAXA)	189 images Aug-Oct 2007 – 2010	FBD L-HH, HV Asc.	34.3	12.5	70
JERS-1 (JAXA)	37 images Mar 1994	L-HH Desc.	32 – 38	18	75
Radarsat- 2 (CSA)	38 images July-Dec 2009 – Jan 2010 2010 (to be	W3 C-VV, VH Asc.	39 – 45	13.5 x 7.7 (rng x az, 1x1 looks)	150
ASAR (ESA)	18 images July-Sept 2009 2010 (to be	Alternating pol mode (AP) IS4, C- VV, VH Desc.	34	30	81
TerraSAR -X (DLR)	8 images Mar-May 2010	Scansar X-HH Stripmap X-VV, VH or HH, HV Asc.	31		
Cosmo- SkyMed	1 image				

Available DEMs

- Statewide coverage:
 - TAS DPIPWE 25 x
 25 m
 - SRTM 90 x 68 m
 - SRTM 30 x 30
 - ASTER 30 x 30 m
- Investigate influence of DEM resolution on





Tasmania calibration/validation sites



- Calibration sites (50x50 km):
 - Mathinna (NE)
 - Takone (NW)
 - Warra (S)
- Validation squares:
 - 53 10x10 km sample squares
 - Collate available in situ and satellite data for each square





Validation data

- DPIPWE TASVEG: 154 communities
- FTAS expert field mapping, permanent inventory plots

VEC

tus amypdalina forest and wo

DKW, King tylend Euraket weedland

Wet eucalypt forest and woodland WOL Eucalyptic despatience with the WOB Eucalyptic despatience fored with the WOR Eucalyptic despatience over anthree WOL Eucalyptic despatience forest over La WRE Eucalyptic despatience with their WRE Eucalyptic despatience with their

- Aerial photography 1:25,000
- Scattered IKONOS chips



TASVEG 2.0 Vegetation Communities

		WDA	Eucalyphic delympleane forest	Saltn	harsh	and wetland	Moor	land,	sedgeland, rushland an
		WOK	Bucelyptus plobulus King Island forest		AUNU	Wetland (undifferentiated)		MBR	Sparse buttongrass moorland
		WOL	Eucelyptus globulus wet forest		AHF	Fresh water aquatic herbland		MBE	Eactern buttongrace moorland
		wsu	Eucelyptus subcrenulate forest and woodland	111	AHL	Lecuchine herbland		MOP	Pure buttongrace moorland
		wvi	Eucalyptus viminalis wet forest	2222	AHS	Saline aquatic herbland		MBS	Buttongrass moorland with an
		wou	Eucalyphys obligue wet forest (undifferentiated)		ASE	Frech water equatic cedgeland and ruchland		MBU	Buttongrace moorland (undiffe
poolts		woe	Eucelyptics oblique forest with broed-leaf shrubs		A55	Succulent saline herbland		MOW	Heatern buttongraco moorian
		WOR	Eucabotus oblique forest over rainforest		AUS	Salmarch (undifferntiated)		MSW	Western lowland sedgeland
		WOL	Eucalyptus oblique forest over Leptospermum	151	ARS	Saline pedgeland/hushland		MSP	Spheprum peetiend
		WNL	Eucalyphia nitida forest over Leptospermum	Scrul	b, hea	thland and coastal complexes		MRR	Restonaceae rushland
		WNR	Eucalyptus nitida forest over rainforest		SCH	Coastal heathland		MGH	Highland graccy cedgeland
		WNU	Euce/yptvs nitide wet forest (undifferentiated)		SSK	Scrub complex on King Island		MDS	Subalpine Diplamena latifolia r
	Rainf	orest	and related scrub		SSW	Western subajoine zorub		MAP	Alkaline pano
		REP	Attrotavic celeginoidec rainforect		sow	Heathland corub complex at Wingaroo	Nativ	e gra	ssland
d		REF	Attrotaxis seleginoides - Nothofegus gunni short reinforest		SCK	Coastal complex on King Island		OCL.	Lowland grassland complex
		RPW	Athrotaxic cuprecooldec open woodland		ssc	Coastal scrub		GHC	Coastal grass and herbfield
		RKS	Athrota-is selapinoides subalpine scrub		SCA	Coastal corub on alkaline cando		OPH	Highland Poe gracoland
		RICK	Highland rainforect corub with dead Athrotavic celepinoidec		SHL	Lowland cedgy heathland		OPL	Lowland Pos labilardierel gra
		RPF	Athrotaxis cupressoides Nothofagus gunnii short rainforest		SHS	Subajoine heathland		GRP	Rockplate gracoland
	1000	RPP	Athrotavia cupressoides rainforest	111	SHG	Heathland on granite		OSL	Lowland graccy pedgeland
		RMU	Nothofeous rainforest undifferentiated		SHF	Heathland south mosaic on Rinders Island		on.	Louland Thereola Mandra or
		RCO	Coastal rainforest		SHC	Heathland on calcarenite	Agric	ultur	al, urban and exotic veg
		RFE	Rainforect femiand		SHW	Wet heathland		FAG	Agricultural land
		RFS	Notholegus gunnii reinforest and sorub		SHU	Inland Heathland (undifferentiated)		FPF	Pteridium ecculentum femiano
		RHP	Legerostrobos franklini rainforest and sorub		SAM	Melaleuca opuamea heathland		FMG	Marram grassland
		RLS	Laptospermum with rainforest scrub	_	58M	Bankola marginata wet porub		FRG	Regenerating cleared land
		RML	Notholegus - Leptospermum short rainforest	1111	SBR	Broad-leaf scrub		FSM	Spertina marshland
	2027	RSH	Highland low rainforest and scrub	91113	SMP	Melaleuca puctulata corub	8749	FPL.	Plantations for pilviouture
	Non-	eucal	pt forest and woodland		SMR	Melaleuca oguarroca corub	162	FPU	Plantations unverified
		NAD	Acacia dealbate forest		SUW	Leptospermum zorub		PWU	Weed infectation
		NAF	Acaola melanoxyton oxamp forest		SQR	Queenstown regrowth mosaic		FPE	Permanent excements
		NAL	Allocasuarina littoralis forest		SRC	Seabird rookery complex		FUM	E-tra-urban miscelaneous
		NAR	Acaola melano-y/on forest on rises		SRI	Riparian zorub		FUR	Urban areas
		NAV	Allocacuarina verticillata forect	1.1.1	SWW	Weatern wet acrub	Maqu	arie I	sland vegetation
nď		NBA	Bursaria-Acaola woodland and sorub		SOU	Dry ecse		MMT	Marine terrace coactal mocald
	78.5	NDS	Bankola cemata woodland		SAC	Acecia longifolia coastal scrub		MCS	Coastal slope complex
		NCR	Calibic rhomboldea forest	High	land t	reeless vegetation		MAM	Maguarie Island mosaic
		NLA	Explospermum poparium-Acapia muoronata forest		HHE	Eactern alpine heathland		MTS	Tall tusseek & atilbecarpa
	1112	NLE	Leptospermum forest		HCH	Alpine coniferous heathland		MTP	Short tusseek gramineists & pi
		NLM	Leptospermum laniperum-Melaleuca oquarroca owamp forest		HCM	Cushion moorland		MM	Mire
		NLN	Subalpine Leptoopermum nitidum woodland		HSE	Eactern alpine cedgeland		MOK	Giant kelp beda
	***	NME	Melaleuca eriofolia oxamp forest		HUE	Eastern alpine vegetation (undifferentiated)	Othe	r natu	ral environments
	10	NNP	Notelaea-Pomademiz-Beyeria forest		HSW	Western alpine sedgeland/herbland		OAQ	Water, cea
				1111	HHW	Western alpine heathland	820	ORO	Lichen ithooere
								0.544	fand mud

itation

PALSAR geo-locational accuracy assessment

 Pixel-to-pixel accuracy achieved between multidate ALOS PALSAR imagery

Individual point error	Error X (Eastings)	Error Y (Northings)
Mean (m)	6.53	-6.82
Minumum (m)	0.195	-12.46
Maximum (m)	12.44	-0.11
RMSE (m)	3.196	

- Comparison with 91 GCPs provided by FTA
 - Ongoing as more GCPs become available
- Co-registration accurac with SPOTmap data

 (To do)



Radar data and processing

- 189 Fine Beam Dual (FBD) ALOS PALSAR images acquired between Aug-Oct timeframe over 2007 – 2010
- Ascending mode, 34.3° incidence angle
- Pixel-to-nixel co-registration
 - 79
 30

 78
 30

 71
 41

 97
 11

 72
 11

 72
 11

 72
 12

 72
 12

 73
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 74
 12

 75
 12

 76
 12

 77
 12

 78
 12

 79
 12

 70
 14

 70
 14

 70
 10

 71
 10

 72
 10

 74
 10

 75
 10

 76
 10

 77
 10

 78
 10

 79

t full resolution



Processing sequence applied to generate wall-to-wall PALSAR mosaics



Terrain Illumination Correction

- TIC uses cosine of surface tilt angles to correct for terrain slope illumination ² variations (Zhou et al., 2011) ²
 - Compensates for local illumination
 - Reduced intensity across illuminated foreslopes (LIA 0 – 30°) and smoothing/increase in intensity in back-











PALSAR mosaics

- Annual, ortho-rectified, radiometrically calibrated, seamless, wall-to-wall mosaics
- HH:HV:HH in RGB
 12.5 m spatial resolution





RSAT-2 mosaic Aug 2009 VV:VH:VV





ASAR mosaic July-Sept 2009 VV:VH:VV



Land cover classification strategy

- Initial exploration over 3 calibration sites
 - Identification of cover classes: field survey, TASVEG and optical data
 - Object-based approach to classification using Definiens eCognition
 - Inputs: HH + HV, DEM
 - Fine scale segmentation
 - Rule set development: spatial and spectral incl. HH and HV backscatter, height, segment shape and area, distance...
 - Membership functions and/or region growing
- Export mean HV segments for

change analysis

State-wide vegetation mapping (TASVEG) and calibration sites



Vegetation communities described

Vegetation community	TASVEG location and structural	PALSAR observations
	characteristics	
Buttongrass moorland Second	 Hummock-forming tussock sedge Species: Gymnoschoenus sphaerocephalus Variable structure: dense sedge/heathland to low open scrub/woodland Areas where Tea tree is encroaching on Buttongrass Structural form: height <1 m, 80 - 90 % cover 	L) 2010 PALSAR over Buttongrass moorland, Mathinna. Location of profile indicated in red. R) Multi-date PALSAR spectra extracted over Buttongrass moorland (HH in red, HV in blue), Mathinna.
Highland treeless Image: State of the state	- Occur within alpine zone where tree growth is impeded above a certain elevation - Includes alpine heathland, sedgeland and moorland communities, grassland, herbfields and sedgy grasslands	Spatial Profile - Highland treeless

- Structural form (BL): fairly dense

clumps of low-lying shrubs.

Scattered boulders and streams

and sedgy grasslands

L) 2010 PALSAR over highland treeless vegetation, Ben Lomond summit, Mathinna. Location of profile indicated in red. R) Multi-date PALSAR spectra extracted over highland treeless (HH in red, HV in blue), Ben Lomond summit, Mathinna.





2007 Forest information products: Mathinna



Mathinna: Accuracy assessment

REFERENCE	Agland	Alpineveg	Buttongrass moorland	Forest	Pine plantation	Eucalypt plantation	Scrub	ROW TOTAL
CLASSIFIED Ag land	36					4		40
Alpine veg		8		1				9
Buttongrass moorland		3	7				4	14
Forest	1			201	8	27	7	244
Pine plantation					24			24
Eucalypt plantation	1			6	6	14		27
Scrub								0
COLUMN TOTAL	38	11	7	208	38	45	11	<u>358</u>

	Land cover class		%
Producers accuracy	Agricultural land Alpine vegetation Buttongrass moorland Forest Pine plantation Eucalypt plantation	0.95 0.73 1.0 0.97 0.63 0.31	94.7 72.7 100 96.6 63.2 31.1
Users accuracy	Agricultural land Alpine vegetation Buttongrass moorland Forest Pine plantation Eucalypt plantation	0.9 0.89 0.5 0.82 1 0.52	90 88.9 50 82.4 100 51.9
Overall accuracy		0.8	81





	Forest/non-forest		%
Producer	Forest	0.98	98.3
s	Non-forest	0.87	87.1
Users	Forest	0.97	96.9
accuracy	Non-forest	0.92	92.4
Overall accuracy		0.96	96.1



2007 Forest information products: Takone



PALSAR 2007 HH:HV:HH in RGE



Non-forest Forest Forest/nonforest 2007



TASVEG - urban TASVEG - water Agricultural land Buttongrass moorland Coastal scrub Forest Pine plantation Eucalypt plantation Eucalypt plantation cleared Water Land cover 2007



Highland treeless Moorland Scrub Agricultural land Non-Euc forest Dry Euc forest Wet Euc forest Rainforest Plantation Urban misc Wetland Grassland Other (lichen/mud) Water TASVEG



2007 Forest information products: Warra



PALSAR 2007 HH:HV:HH in RGE

TASVEG - urban TASVEG - water Agricultural land Highland treeless Buttongrass moorland Forest Pine plantation Eucalypt plantation Scrub Land cover 2007



Forest Forest/non-forest 2007





Takone and Warra: Accuracy assessment

TAKONE	Land cover class		%
Producers accuracy	Agricultural land Buttongrass moorland Forest Pine plantation Eucalypt plantation Eucalypt plantation cleared	0.95 0.8 0.96 0.6 0.72 1	95.3 80 96.2 60 72.1 100
Users accuracy	Agricultural land Buttongrass moorland Forest Pine plantation Eucalypt plantation Eucalypt plantation cleared	0.98 0.73 0.88 1 0.92 0.25	98.4 72.7 88.1 100 91.7 25
Overall accuracy		0.9	89.6
	Forest/non-forest		
Producers accuracy	Forest Non-forest	0.97 0.93	97.3 93.3
Users accuracy	Forest Non-forest	0.98 0.91	98.1 90.9
Overall accuracy		0.96	96.4

WARRA	Land cover class		%
Producers accuracy	Agricultural land Highland treeless Scrub Buttongrass moorland Forest Pine plantation Eucalypt plantation	0.73 0.71 0.22 0.75 0.91 0.58 0.54	72.7 70.6 22.2 75 90.8 58.3 54.1
Users accuracy	Agricultural land Highland treeless Scrub Buttongrass moorland Forest Pine plantation Eucalypt plantation	0.89 0.71 0.25 0.55 0.83 1 0.65	88.9 70.6 25 54.5 83.5 100 64.5
Overall accuracy		0.8	80.5
	Forest/non-forest		
Producers accuracy	Forest Non-forest	0.95 0.73	95.2 73.1
Users accuracy	Forest Non-forest	0.93 0.79	93.4 79.2
Overall accuracy		0.91	90.8



Mathinna: Annual land cover mapping



Change (>3) Change (2-3) Change (1-2) No Change (-1 to 1) Change (-1 to -2) Change (-2 to -3) Change (<-3)

TASVEG - urban



- TASVEG water Agricultural land Alpine vegetation Buttongrass moorland Forest Eucalypt plantation Eucalypt plantation cleared
- Pine plantation Pine plantation cleared



Change mapping



Change mapping examples



Change mapping





Change detection: Clearing of pine plantation



Change detection: Regrowth





7-8 yr old Eucalyptus nitens



Eucalyptus nitens seedlings



12-15 yr old Pine plantation



Mathinna: Land use/cover change mapping

- Summarise spatial extent and location of deforestation (red), regeneration (blue) and no change (green – forest, grey – non-forest)
- Re-classification of annual land cover maps
- Extract trend metrics
- Applicable to modelling scenarios

1 Non-forest (no change)
 2 Forest (no change)
 3 Deforestation
 4 Regeneration



08	to.			
09	en te			
	1.	~	2	
and the second s		i y		
				-1

Change 2007 – 2008	Area (ha)	Area (%)
No change (forest)	210,210. 7	84.09
No change (non-forest)	36,909.6	14.76
Deforestatio	2,733.6	1.09
Regeneratio	137.7	0.06
TOTAL	249,991. 6	100

Change 2008 – 2009	Area (ha)	Area (%)
No change (forest)	210,826. 6	84.33
No change (non-forest)	37,480.9 5	14.99
Deforestatio	1,430.5	0.57
Regeneratio	253.6	0.1
TOTAL	249,991. 6	100



2007 Baseline land cover mosaic

- Initial masking of mosaics using TASVEG (water and urban)
- Object-based approach to classification
 - Local tiling: 34 tiles
 - Chessboard and multi-resolution segmentation
 - Local stitching using variables
 - Rule set development: adjust per tile
 - Apply classification and export
- Change analysis and generation of annual forest information products



Local tiling approach applied to PALSAR 2007 mosaic



PALSAR derived land cover (2007) and TASVEG

PALSAR TASVE 2007 Highland treeless Moorland Highland treeless Scrub Moorland Agricultural land Scrub Non-Euc forest Agricultural land Dry Euc forest Forest Wet Euc forest Eucalypt plantation Rainforest Euc plantation cleared Plantation Urban misc Pine plantation Urban misc Wetland Wetland Grassland Other (lichen/mud) Other Water Water



PALSAR derived forest/non-forest (2007) and

PALSAR 2007 Forest 63.5 % Non-forest 36.5 %

Non-forest

TASVEG Forest 57.5 % Non-forest 42.5

%

Non-forest

Forest

Annual forest information products



Land use/land cover change



>rest non-forest maps - radar/optical interoperability ?



Landsat,



Lidar (hgt)



SPOT



Landsat,





Radar,

TasVEG

Deforestation leaves one tree behind



Acknowledgements:

GEO IFCI, Department of Climate Change and Energy Efficiency Forestry Tasmania, Sarmap, JAXA, Geoscience Australia

http://www.geo-fct.org