WOODY STRUCTURAL MODELLING IN SOUTHERN AFRICAN SAVANNAHS USING MULTI-FREQUENCY SAR AND OPTICAL INTEGRATED DATA APPROACHES: ONE STEP TO REGIONAL MAPPING

K&C Phase 3

Renaud Mathieu[a], Laven Naidoo[a], Konrad Wessels[b], Chris Schmullius[c], Christian Thiel[c], Mikhail Urbazaev[c], Gregory Asner[d], Brigitte Leblon[e]

[a] Earth Observation Research Group (EO), CSIR, PO Box 395, Pretoria, 0001, rmathieu@csir.co.za, lnaidoo@csir.co.za
[b] Remote Sensing Research Unit, Meraka-CSIR, PO Box 395, Pretoria, 0001, kwessels@csir.co.za
[c] Department of Geography, Friedrich-Schiller-University Jena, Loebdergraben 32, 07743 Jena, Germany, c.schmullius@uni-jena.de, mikhail.urbazaev@uni-jena.de
[d] Department of Global Ecology, Carnegie Institution for Science, 260 Panama St., Stanford, CA, 94305, USA, gpa@stanford.edu
[e] Faculty of Forestry, University of New Brunswick, 28 Dineen, Fredericton, E3B 5A3, Canada, bleblon@unb.ca

Science Team meeting #21 – Phase 3 Result Presentations
Kyoto Research Park, Kyoto, Japan, December 3-4, 2014

Project objectives

Aim: Investigate the best approaches to assess woody structural parameters (woody canopy cover/CC, biomass/AGB and canopy volume/TCV) in South African savannahs

Achieved objectives:

1. Assessed and compared various ALOS PALSAR products (FBD, FBS, PLR) considering polarization (including decompositions), season and scale of data
2. Compared accuracies of modelling CC using multi multi-frequency SAR datasets (TerraSAR-X X-band , Radarsat-2 C-band & ALOS PALSAR L-band) to ascertain best SAR frequency/combo using a suite of machine learning algorithms
3. Assessed regional-scale CC using combined SAR (L-band ALOS PALSAR) and optical (LandSAT-5 TM) sensors
4. Produced national scale CC map using ALOS PALSAR FBD Mosaic dataset
5. Validated ALOS PALSAR derived FNF product using extensive high res LiDAR datasets

Project objectives

K&C thematic drivers (**C**arbon cycle science, International **C**onventions, Environmental **C**onservation) addressed in this project:

1. **C**arbon cycle science [*The modelling of woody canopy cover, which when combined with vegetation height can derive AGB*]

2. International **C**onventions [*The provision of new and reliable woody structural modelling methodologies and techniques*]

3. Environmental **C**onservation [*The provision of woody canopy maps and temporal products for focused monitoring and conservation efforts*]

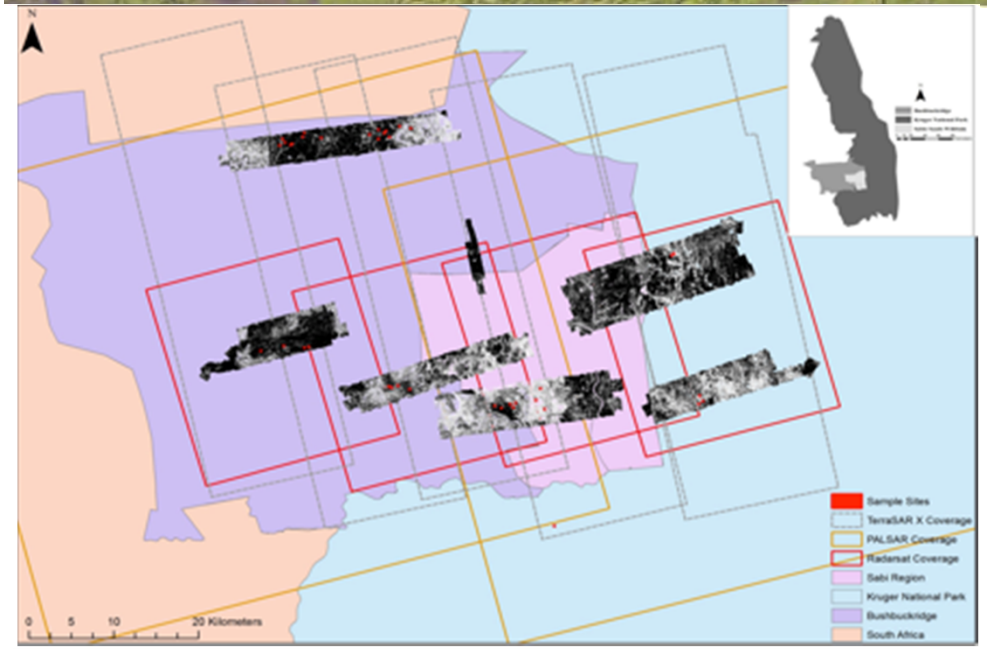
- *Extensive multi-temporal LiDAR datasets were used for training and validation purposes*

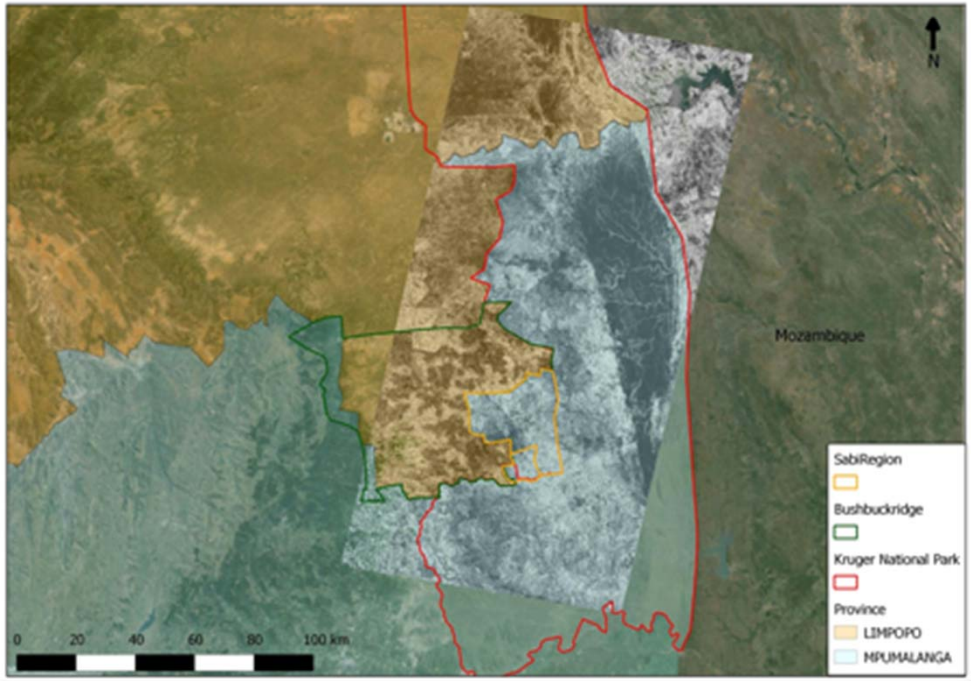
ALOS

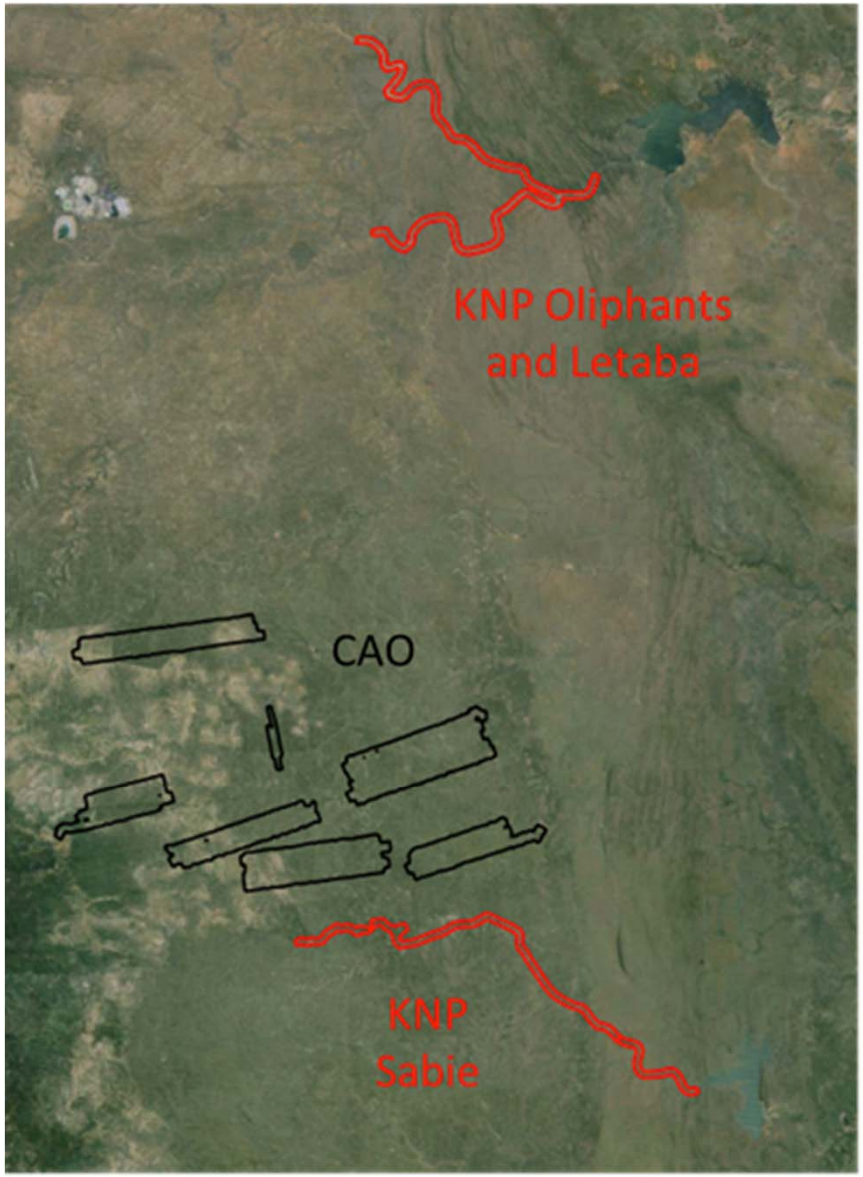
K&C Initiative

An international science collaboration led by JAXA

Study areas and regions







LiDAR Dataset

National maps

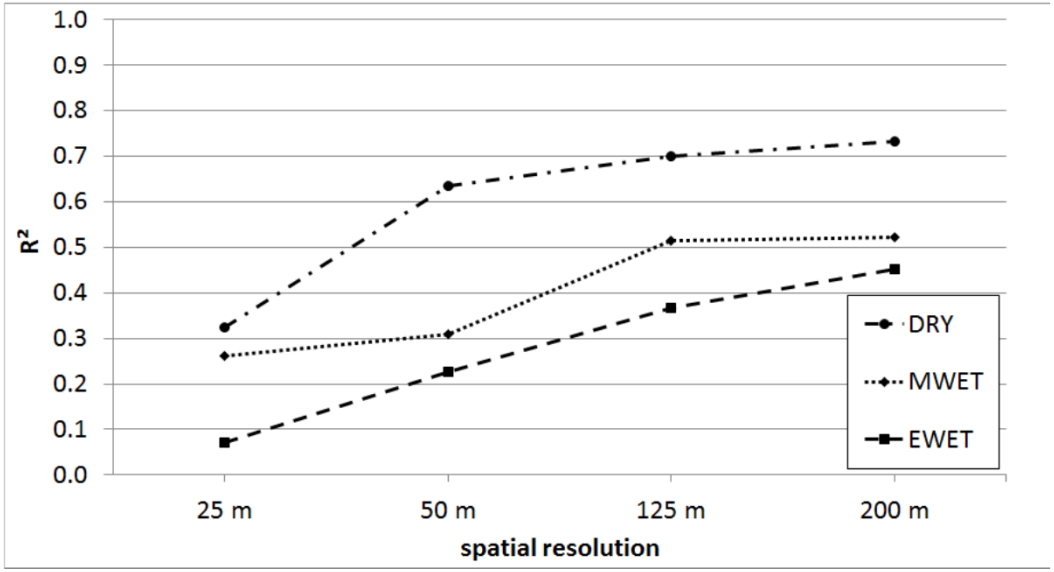
Validation FNF

Savannahs and woodlands

Indigenous forests

Grassland / plantations

Objective 1: Multi-temporal and polarimetric assessment of ALOS PALSAR

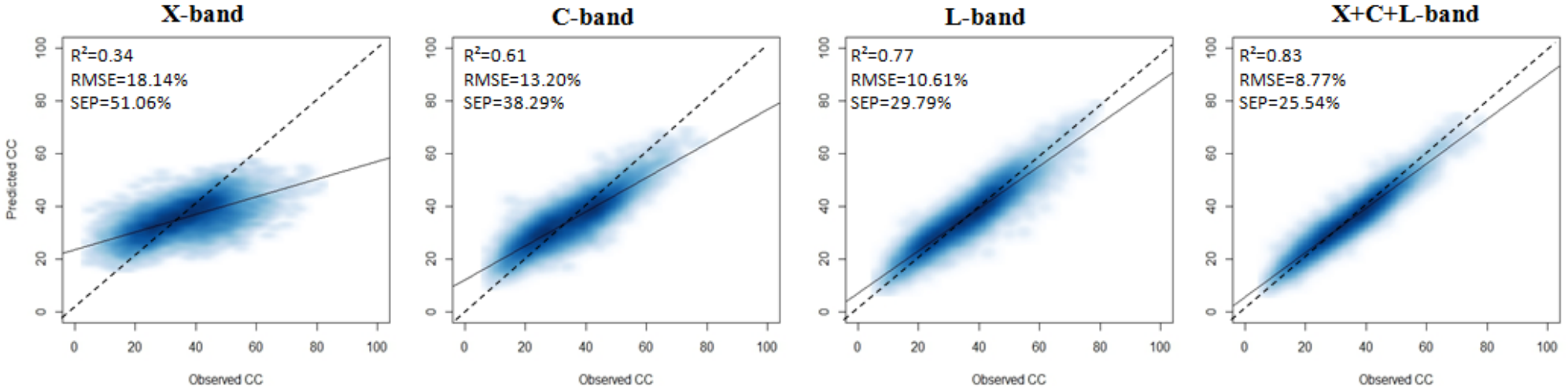


- R^2 values were the highest at all grid resolutions during the winter or DRY season, followed by the summer or MWET season
- 50-125m grid resolution was best compromise between modelling detail and accuracy
- HV and HH products yielded highest relationships during winter season
- Volume components from polarimetric decompositions (Freeman-Durden and Van Zyl) yielded similar (not improved) correlations with LiDAR CC than co- and cross pol backscatter of same

		25 m	50 m	125 m	200 m
DRY	FBD_HH_06aug07	0.36	0.65	0.72	0.75
	FBD_HH_23sep08	0.32	0.66	0.72	0.75
	FBD_HH_11aug09	0.26	0.64	0.67	0.67
	FBD_HH_29sep10	0.33	0.56	0.67	0.73
	FBD_HV_06aug07	0.40	0.68	0.73	0.76
	FBD_HV_23sep08	0.35	0.67	0.72	0.74
	FBD_HV_11aug09	0.29	0.65	0.66	0.66
	FBD_HV_29sep10	0.35	0.57	0.67	0.71
	Mean (HH DRY)	**0.32**	**0.63**	**0.70**	**0.73**
	Mean (HV DRY)	**0.35**	**0.64**	**0.69**	**0.72**
MWET	FBS_HH_03feb07	0.32	0.38	0.50	0.72
	FBS_HH_08feb09	0.33	0.33	0.53	0.49
	FBS_HH_27dec09	0.26	0.32	0.42	0.48
	FBS_HH_11feb10	0.12	0.22	0.61	0.39
	Mean (HH MWET)	**0.26**	**0.31**	**0.52**	**0.52**
EWET	PLR_HH_14apr07	0.05	0.16	0.26	0.30
	PLR_HH_19apr09	0.09	0.29	0.47	0.61
	PLR_VV_14apr07	0.02	0.09	0.16	0.19
	PLR_VV_19apr09	0.06	0.21	0.38	0.51
	PLR_HV_14apr07	0.10	0.30	0.45	0.51
	PLR_HV_19apr09	0.14	0.39	0.57	0.70
	PLR_VH_14apr07	0.09	0.26	0.42	0.49
	PLR_VH_19apr09	0.12	0.34	0.53	0.67
	Mean (HH EWET)	**0.07**	**0.23**	**0.37**	**0.45**
	Mean (VV EWET)	**0.04**	**0.15**	**0.27**	**0.35**
	Mean (HV EWET)	**0.12**	**0.34**	**0.51**	**0.61**
	Mean (VH EWET)	**0.10**	**0.30**	**0.47**	**0.58**
EWET	Freeman_Vol_14apr07	0.19	0.38	0.47	0.53
	Freeman_Vol_19apr09	0.24	0.47	0.59	0.70
	VanZyl_Vol_14apr07	0.19	0.38	0.47	0.52
	VanZyl_Vol_19apr09	0.24	0.47	0.59	0.70
	Mean (Freeman Vol)	**0.21**	**0.42**	**0.53**	**0.61**
	Mean (VanZyl Vol)	**0.21**	**0.42**	**0.53**	**0.61**

Objective 2: Multi-frequency SAR CC modelling and mapping

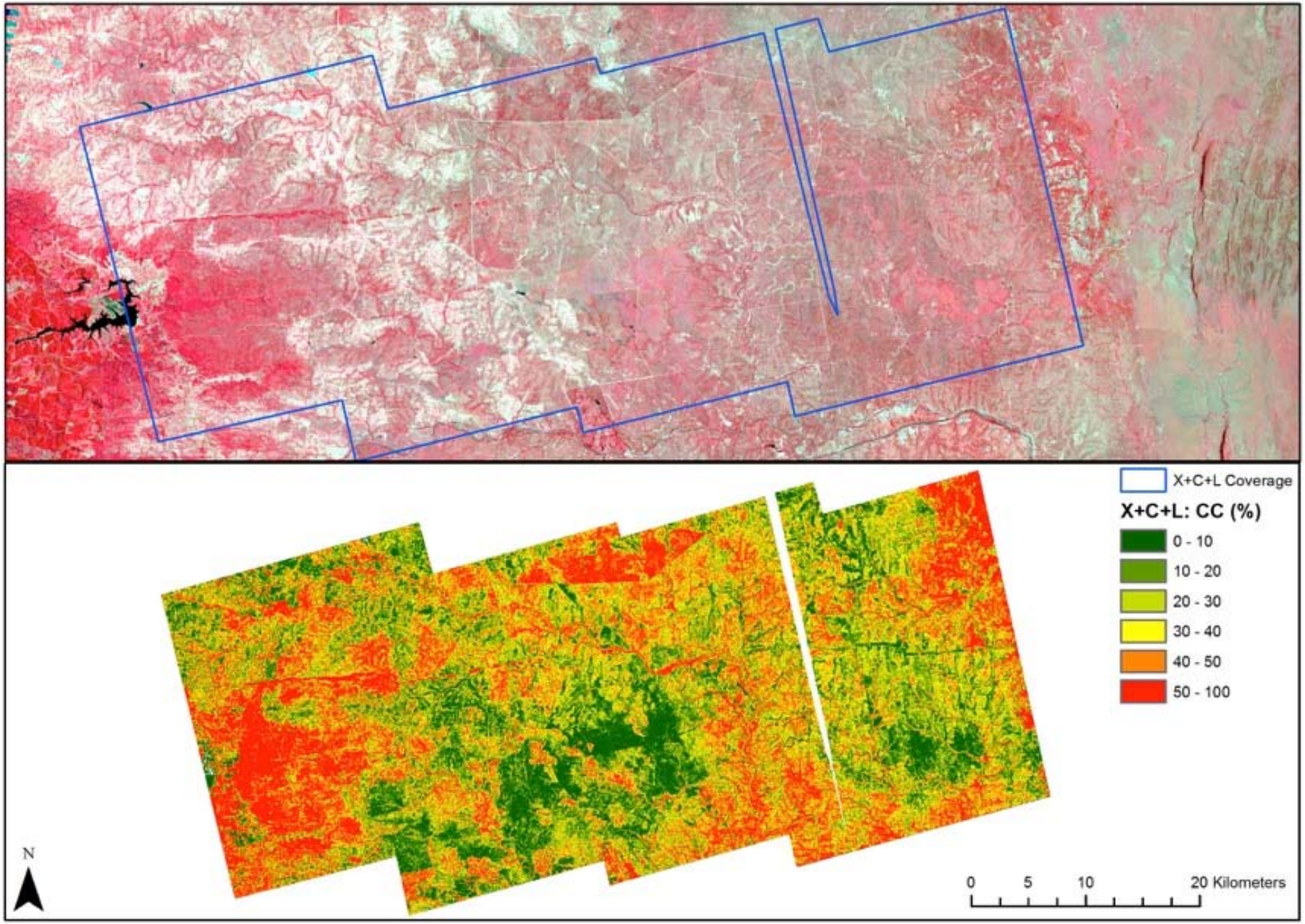
Band	X *[N = 13761]*			C *[N = 11687]*		
Algorithm	**R² (CI)**	**RMSE (CI)**	**SEP (CI)**	**R² (CI)**	**RMSE (CI)**	**SEP (CI)**
LR	0.30 (0.002)	18.57 (0.023)	52.18 (0.084)	0.55 (0.002)	14.04 (0.034)	40.88 (0.123)
SVM	0.30 (0.002)	18.72 (0.036)	52.68 (0.112)	0.55 (0.002)	14.48 (0.099)	42.09 (0.280)
REPTree	0.36 (0.005)	17.74 (0.089)	49.86 (0.282)	0.63 (0.002)	12.91 (0.032)	37.53 (0.127)
ANN	0.39 (0.009)	17.29 (0.152)	48.52 (0.394)	0.65 (0.002)	12.56 (0.033)	36.50 (0.090)
RF	0.34 (0.003)	18.14 (0.040)	51.06 (0.153)	0.61 (0.002)	13.20 (0.031)	38.29 (0.117)
Band	L *[N = 13954]*			X+C+L *[N = 11494]*		
Algorithm	**R² (CI)**	**RMSE (CI)**	**SEP (CI)**	**R² (CI)**	**RMSE (CI)**	**SEP (CI)**
LR	0.71 (0.002)	11.88 (0.050)	33.36 (0.154)	0.74 (0.002)	10.72 (0.041)	31.21 (0.143)
SVM	0.71 (0.003)	12.34 (0.083)	34.65 (0.246)	0.74 (0.002)	11.11 (0.053)	32.40 (0.148)
REPTree	0.78 (0.002)	10.40 (0.045)	29.16 (0.145)	0.80 (0.001)	9.51 (0.034)	27.72 (0.099)
ANN	0.79 (0.003)	10.15 (0.066)	28.49 (0.178)	0.82 (0.003)	9.06 (0.070)	26.35 (0.179)
RF	0.77 (0.001)	10.61 (0.027)	29.79 (0.075)	**0.83 (0.002)**	**8.77 (0.039)**	**25.54 (0.133)**



ALOS

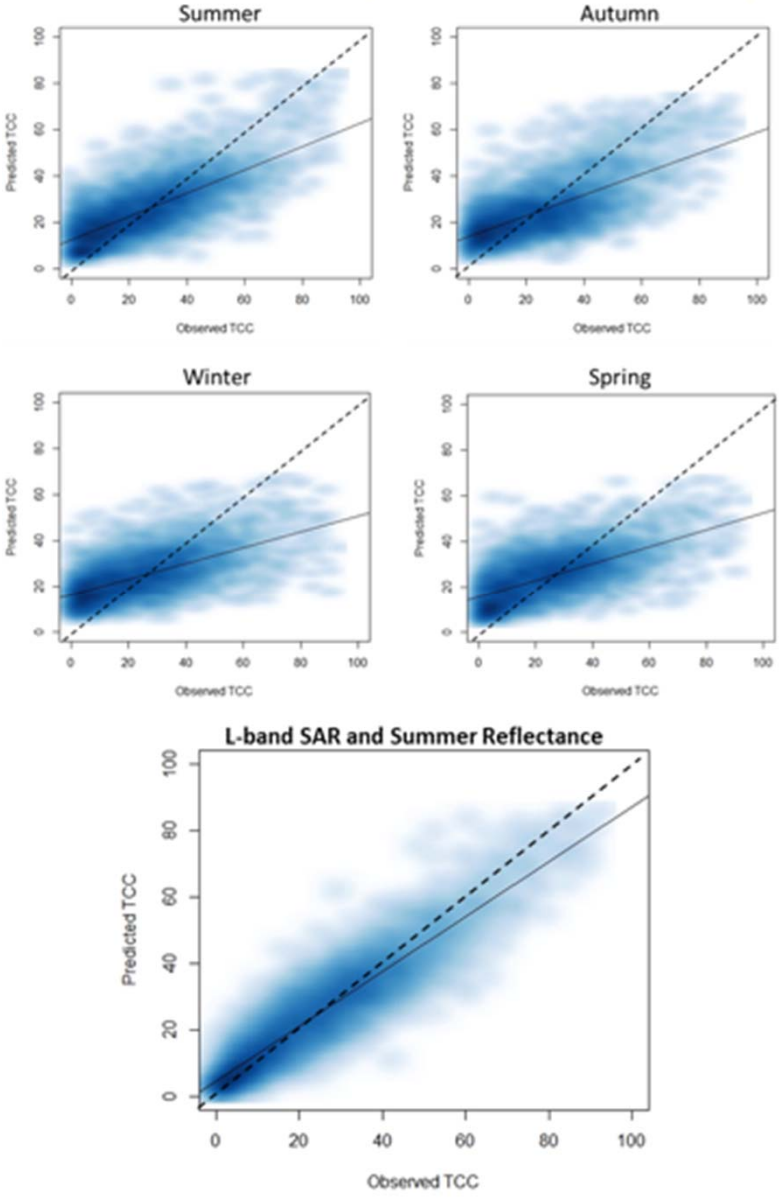
K&C Initiative

An international science collaboration led by JAXA



Objective 3: Integrated optical and SAR CC RF modelling and mapping

Scenarios	R^2	RMSE (%)	SEP (%)
Autumn	0.46	12.82	52.44
Spring	0.40	13.51	55.27
Summer	**0.53**	**11.99**	**49.05**
Winter	0.38	13.78	56.39
Spring and Winter	0.50	12.50	51.14
Summer and Winter	0.60	11.24	45.97
Autumn and Winter	0.57	11.45	46.85
Spring and Autumn	0.57	11.55	47.26
Summer and Spring	0.61	10.98	44.91
Summer and Autumn	0.60	11.11	45.44
Summer and Autumn and Spring	0.65	10.48	42.89
All Four Seasons	**0.66**	**10.33**	**42.24**
L-band SAR only	**0.80**	**7.87**	**32.21**
L-band SAR and Summer Reflectance	**0.85**	**6.78**	**27.74**

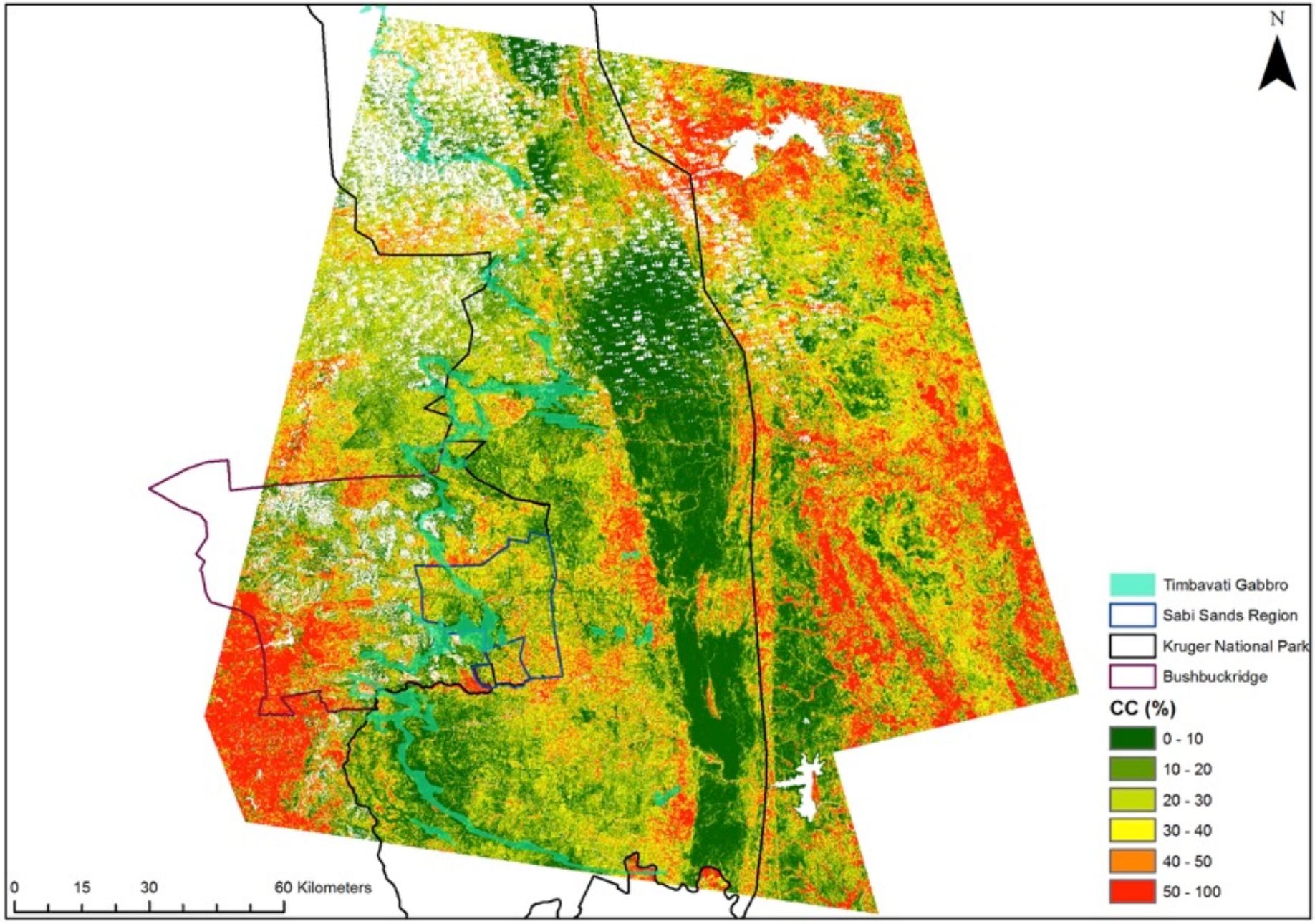


- Best LandSAT-5 model= summer season, multi-seasons improve results further (12%)
- Single L-band SAR dataset outperforms optical
- Combination of L-band SAR datasets with optical summer reflectance still improve accuracy (14%)

ALOS

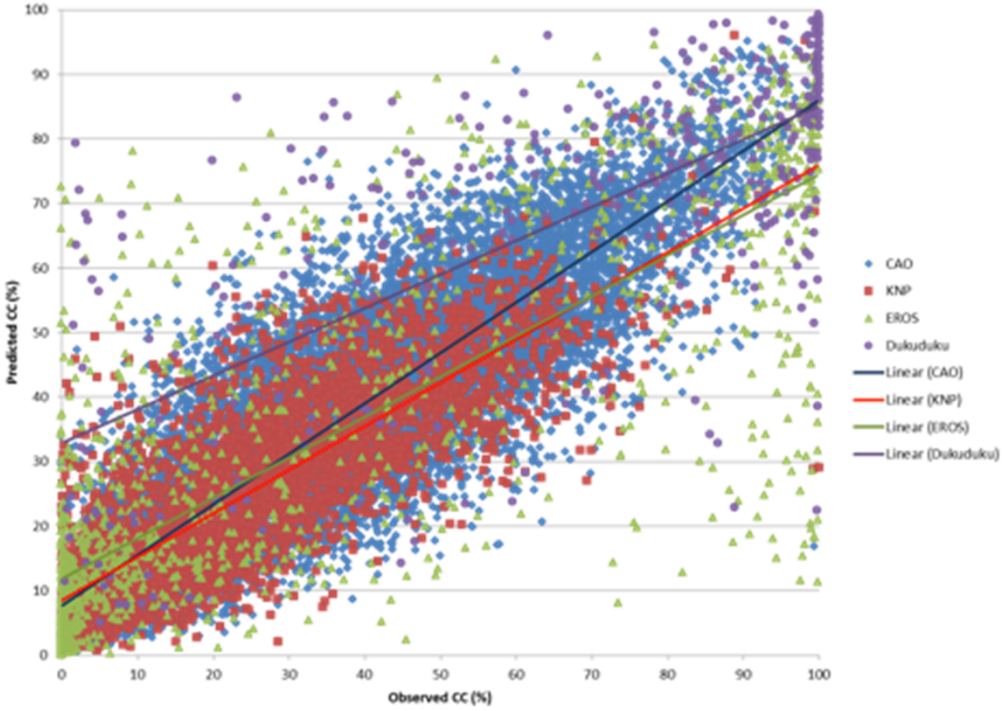
K&C Initiative

An international science collaboration led by JAXA

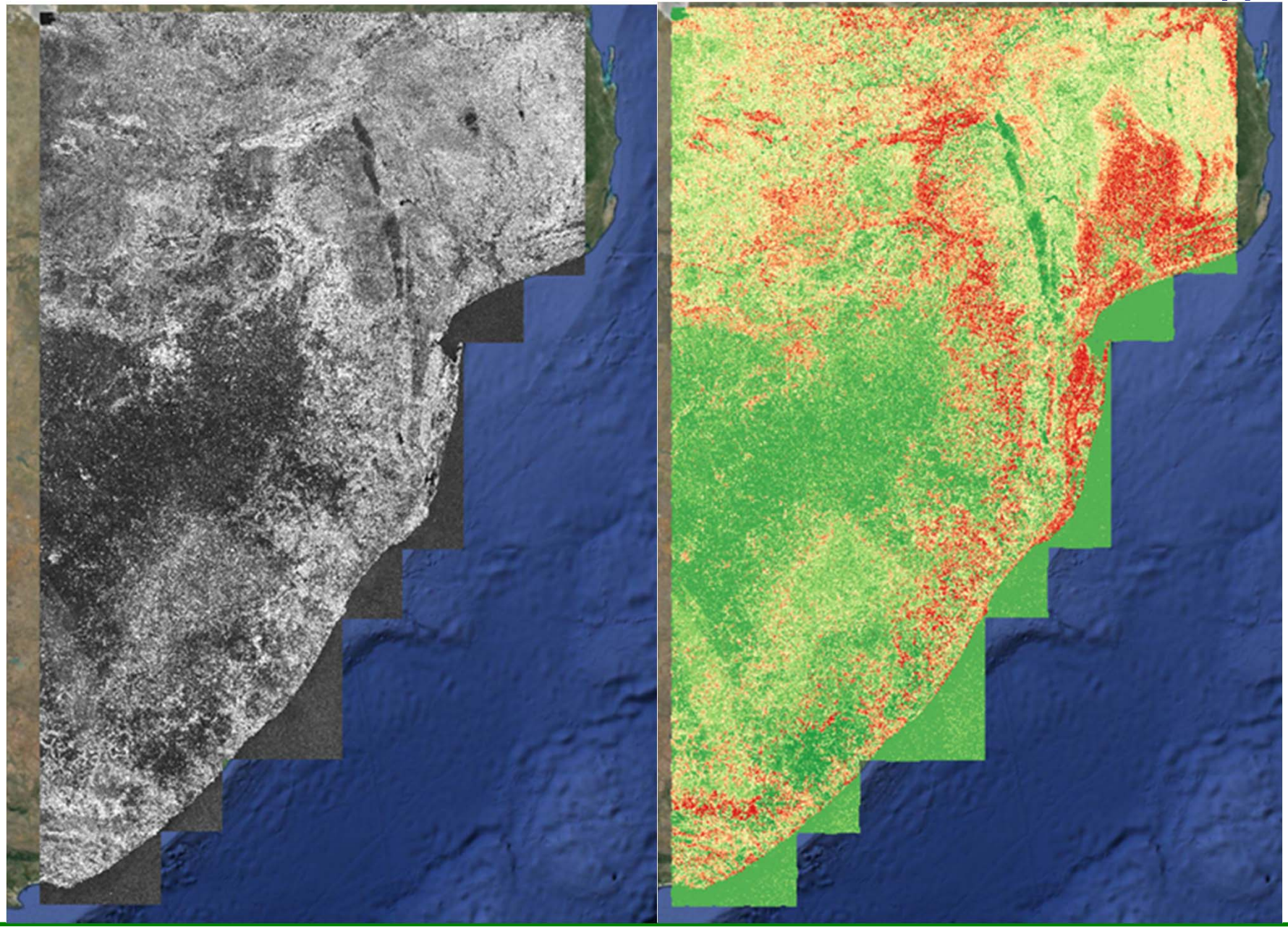


Objective 4: ALOS PALSAR FBD Mosaic datasets for national scale CC mapping

	Backscatter Only (HH+HV)			Backscatter (HH+HV) + Veg class			All Parameters (SAR+Veg+SRTM)			
LiDAR Dataset	*R^2*	*RMSE*	*SEP*	*R^2*	*RMSE*	*SEP*	*R^2*	*RMSE*	*SEP*	*Total # of Obs.*
CAO	0.74	11.41	32.09	0.76	11.01	31.15	0.79	10.40	29.41	24160
Kruger	0.59	11.48	46.02	0.65	10.52	42.07	0.70	9.75	39.00	6512
EROS	0.55	24.04	73.56	0.59	22.88	72.10	0.63	21.74	68.49	2119
Duku Forest	0.38	25.57	37.45	0.45	24.31	35.73	0.55	22.11	32.51	591
CAO+Kruger	0.63	13.52	40.60	0.72	11.80	35.42	0.79	10.27	30.83	30671
CAO+Kruger+EROS	0.61	14.49	43.71	0.70	12.72	38.27	0.76	11.33	34.09	32790
CAO+Kruger+EROS+ Duku	0.60	15.17	44.78	0.70	13.11	38.67	0.76	11.74	34.62	33381



Objective 4: ALOS PALSAR FBD Mosaic datasets for national scale CC mapping

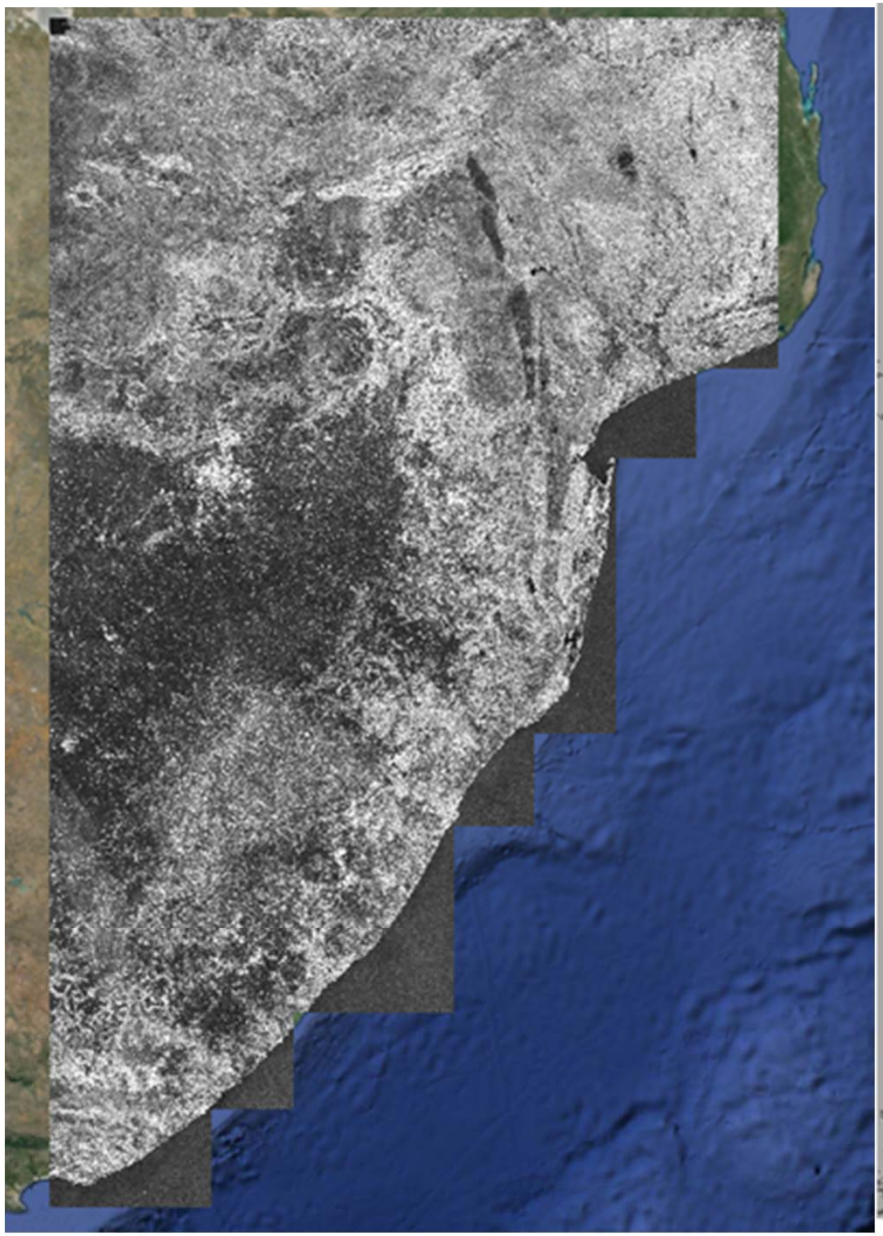


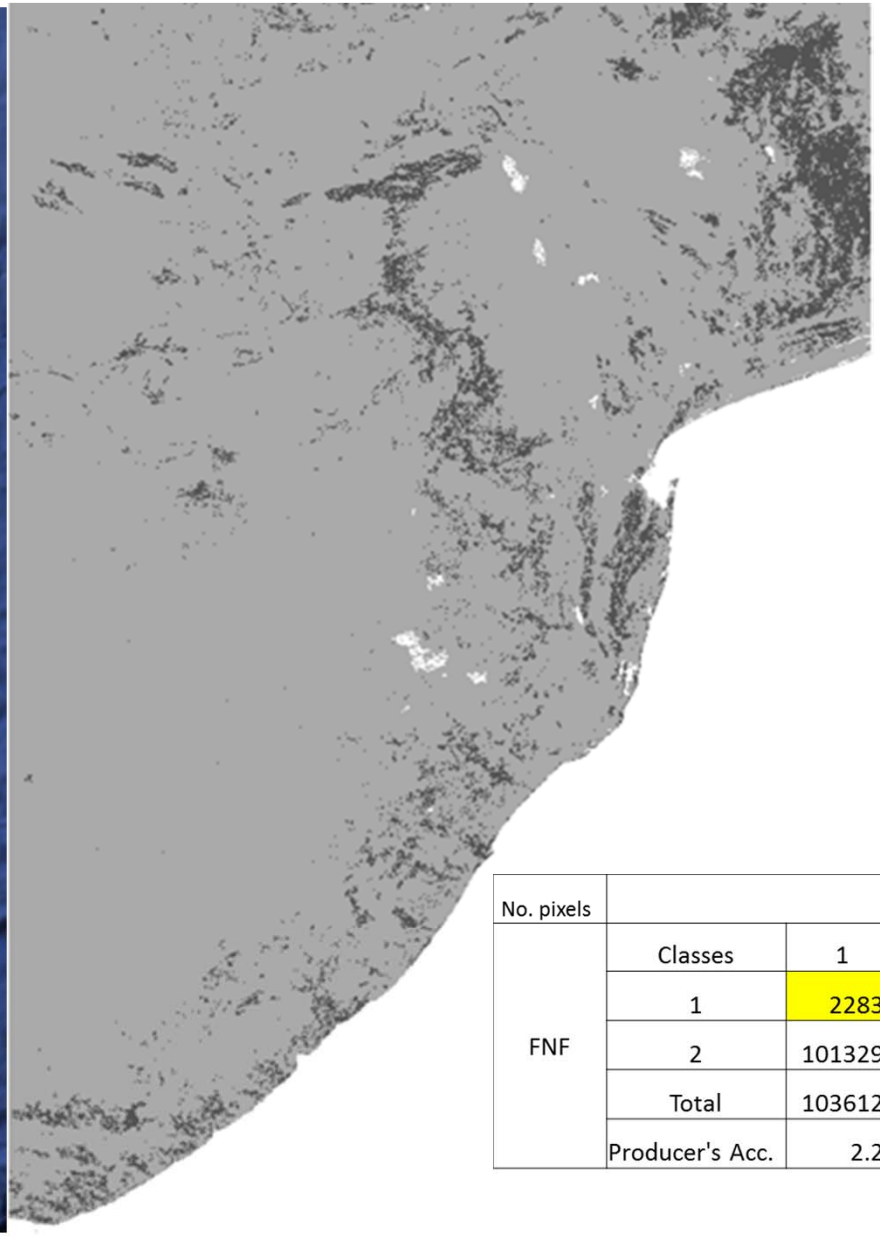
ALOS

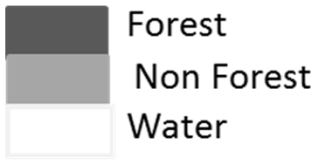
K&C Initiative

An international science collaboration led by JAXA

Objective 5: “Validation” of ALOS PALSAR FNF in South Africa







No. pixels	LiDAR			
FNF	Classes	1	2	Total	User's Acc.
	1	22831	969	23800	95.93
	2	1013292	341522	1354814	25.21
	Total	1036123	342491	1378614	
	Producer's Acc.	2.20	99.72		26.43

ALOS K&C Initiative led by JAXA

dation of ALO

ALOS PALSAR FNF

AR FNF

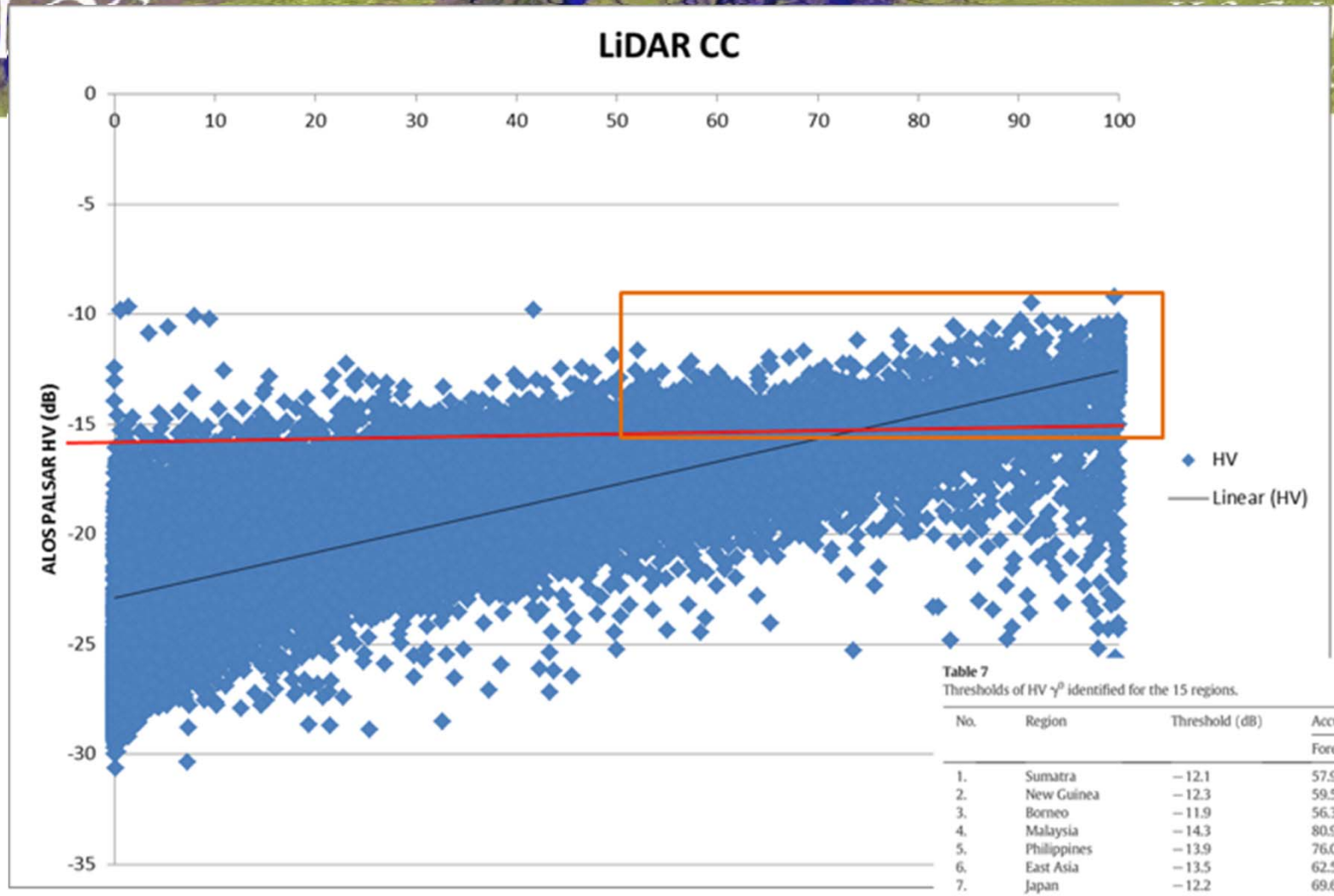


Table 7
Thresholds of HV γ^0 identified for the 15 regions.

No.	Region	Threshold (dB)	Accuracy (%)	
			Forest	Non-forest
1.	Sumatra	−12.1	57.92	57.61
2.	New Guinea	−12.3	59.51	61.31
3.	Borneo	−11.9	56.35	56.02
4.	Malaysia	−14.3	80.92	79.85
5.	Philippines	−13.9	76.01	76.24
6.	East Asia	−13.5	62.54	61.57
7.	Japan	−12.2	69.62	69.91
8.	India	−15.1	95.20	94.88
9.	Europe	−14.8	82.19	82.29
10.	Australia	−20.1	91.69	92.00
11.	Amazon	−14.4	70.28	70.46
12.	Chile	−15.5	95.20	95.32
13.	Africa	−15.6	92.80	93.23
14.	North America	−14.2	76.92	76.96
15.	Central America	−14.1	83.20	82.73

- FNF under-represents the distribution of (open) forest as defined (≥10%) but does capture, to some extent, limited dense closed forest extents
- Threshold closer -20 dB, biome driven vs continent driven?
- Can PALSAR matches the FAO definition?

Deliverables – Papers and reports

1. Published

- Conference presentations and papers
  - *Naidoo L, Mathieu R et al. Advanced modelling of savannah woody cover using multi-frequency (X-, C- and L-band) synthetic aperture radar datasets. IGARSS 2011, IEEE, July 13-18 2011, Quebec, Canada.*
  - *Urbazaev M, Schmullius C et al. Woody cover mapping with RADAR and airborne LiDAR in the Great Kruger National Park region. IGARSS 2011, IEEE, July 13-18 2011, Quebec, Canada.*
  - *Mathieu R, Naidoo L et al. LIDAR and ALOS PALSAR integration for national scale woody fractional cover mapping in South Africa. 10th AARSE conference, 27 – 31 October 2014, Johannesburg, SA.*
  - *Naidoo L, Mathieu R et al. Assessment of the performance of global forest products in South Africa: establishing the benchmark. 10th AARSE conference, 27 – 31 October 2014, Johannesburg, SA.*
  - *Naidoo L, Mathieu R et al. Woody fractional cover modelling in savannahs using multi-frequency SAR and optical integrated data approaches. 10th AARSE conference, 27 – 31 October 2014, Johannesburg, SA.*

2. Submitted/in preparation

- *Journal Paper*
  - *Naidoo L, Mathieu R, et al. Savannah woody structure modelling and mapping using integrated multi-frequency (X-, C- and L-band) Synthetic Aperture Radar (SAR) remote sensing datasets. ISPRS J of Photogrammetry and Remote Sensing (2015).*
  - *Urbazaev M, Thiel C et al. Mapping of fractional woody cover using ALOS PALSAR L-band backscatter in the Kruger National Park region, SA. In review Remote Sensing of Environment (2015).*
  - *Naidoo L, Mathieu et al. Integration of Optical and L-band Synthetic Aperture Radar (SAR) datasets for the regional assessment of woody fractional cover in the Greater Kruger National Park region. In review JAG (2015)*

Deliverables –

Data sets and Thematic products (mosaics, classification maps etc.)

1. Completed and Delivered to JAXA

- *Field and very high res LiDAR and optical-derived canopy cover data*

Phase 4

1. Higher focus on biomass and height
2. Investigate more advanced SAR processing (interferometry, polarimetry)
3. Move toward operationalization of national and regional products in SA and region (SASSCAL)
4. Contribute to improve the ALOS FNF product in southern African environment