



Preliminary Assessment of Vegetational Response to Flooding in the Okavango Delta, Botswana, using EO-1 Data

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Overview of EO-1 Activities

- **Land cover mapping in Belize (Bill White, PI)**
 - Primary focus of EO-1 funded project
 - One cloud free scene acquired in 2 years (March 7, 2001), no SWIR
 - Mapped land cover in Central Belize (ALI superior to TM)
 - Partial cloud free scene acquired Dec 4, 2001 after Hurricane Iris
 - Mapped land cover change due to Hurricane Iris
 - Still waiting for cloud free data
- **Assessment of vegetational response to flooding in the Okavango Delta**
 - Multi-temporal study of ALI
- **Mapping complex wetlands on Kennedy Space Center from Hyperion**
 - Demonstrate new new algorithms for classification



Characteristics of the Okavango Delta

Fed by floodwaters from Angola highlands

Extremely low topographic relief

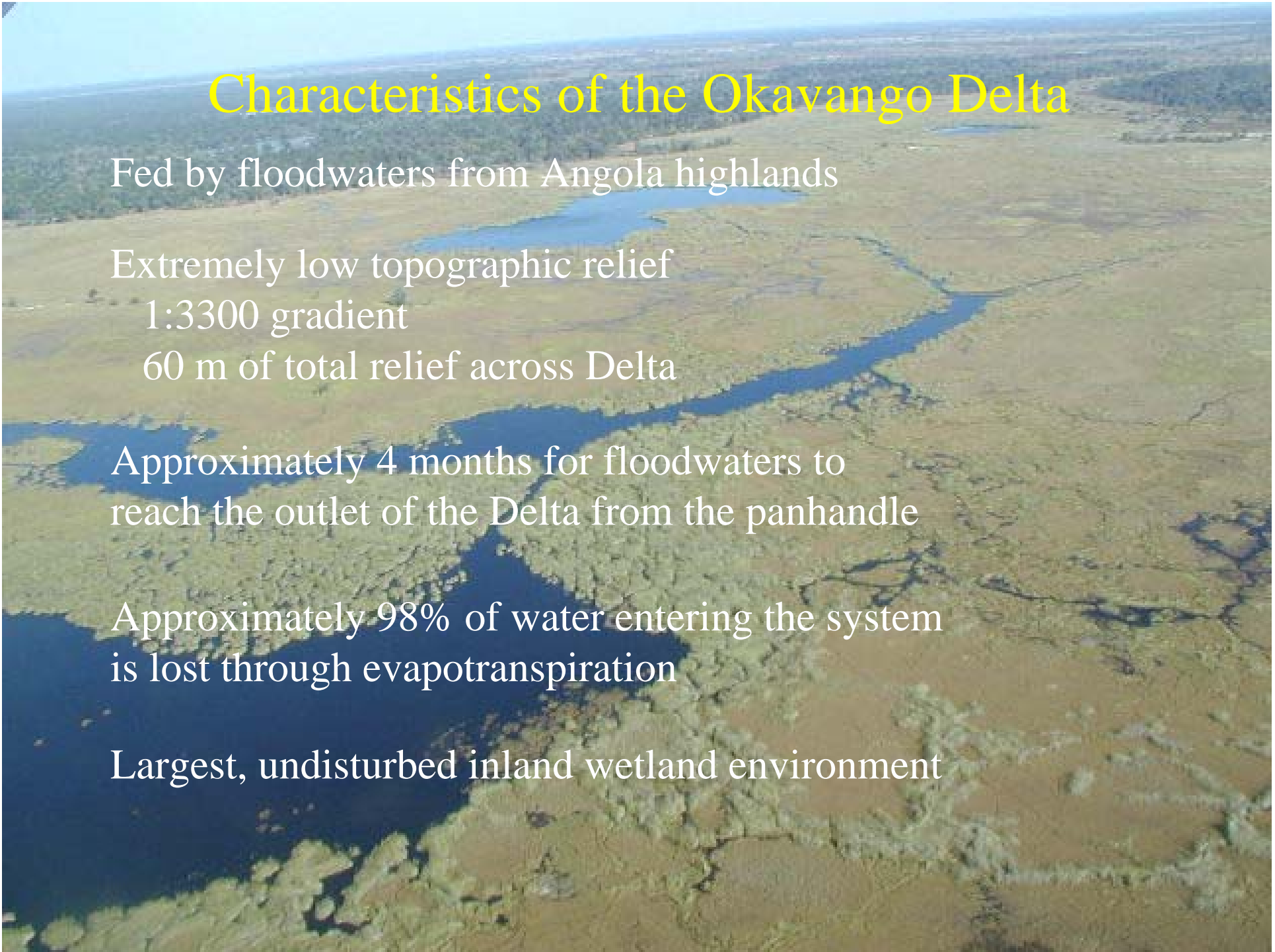
1:3300 gradient

60 m of total relief across Delta

Approximately 4 months for floodwaters to reach the outlet of the Delta from the panhandle

Approximately 98% of water entering the system is lost through evapotranspiration

Largest, undisturbed inland wetland environment



An aerial photograph of a lush, green river valley. The river is braided, with multiple channels and islands of vegetation. The surrounding landscape is dense with trees and shrubs, and the water reflects the sky.

Related Research in the Okavango

Carbon flux studies: Max Planck Institute

Wetland characterization and monitoring: NSF LTER site

Subcontinent atmospheric circulation: deposition of nutrients and anthropogenic emissions (NASA Safari 2000)

Hydrologic studies: low gradient braided rivers
- Source of local water supply for communities

Fire Ecology

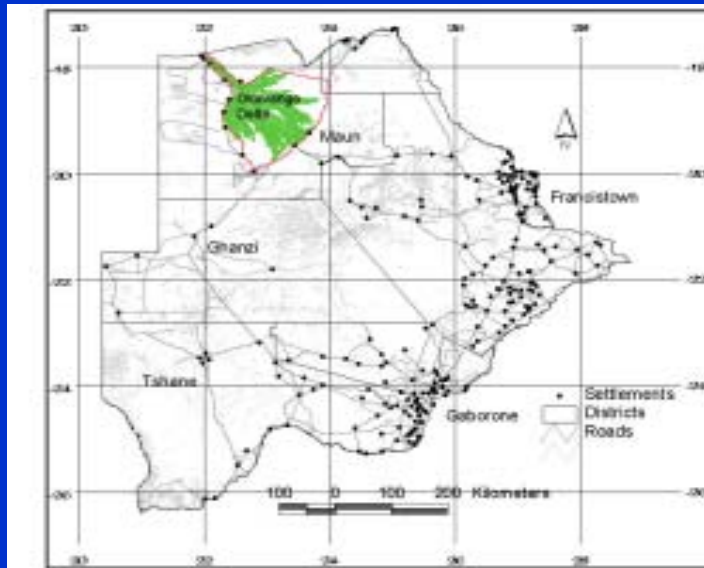
Herbivore and keystone species studies

Objectives

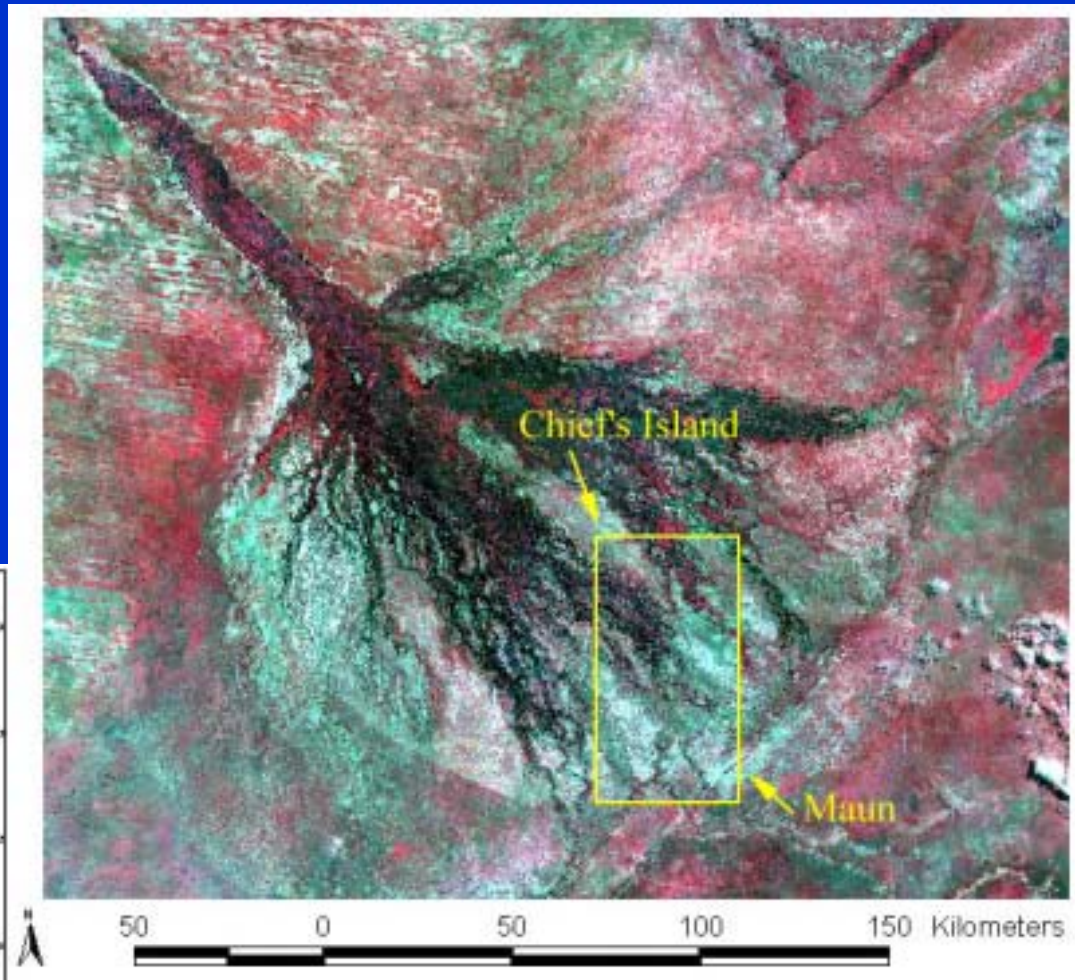
- Investigate the capability of ALI and Hyperion for discriminating spectrally similar land cover classes, including contribution of additional bands
- Evaluate ALI for large scale mapping applications
- Investigate the potential of ALI for mapping annual flooding in the lower Okavango Delta
- Explore the viability of configuring application specific multispectral sensors from hyperspectral sensors for calibration of satellite constellations and creating application dependent “sensors on the fly”

Study Site

ALI/Hyperion study site is located in the distal region of the Delta with Hyperion centered on Chief's Island



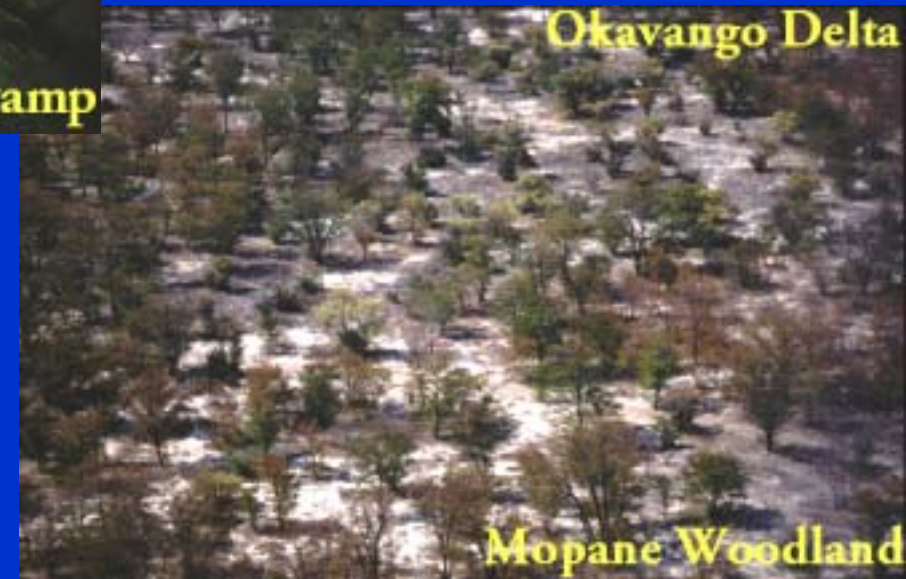
Republic of Botswana



Mapping Vegetation and Characterizing Flooding Via ALI Data



Classification scheme consists of 25 landcover classes selected using IKONOS imagery, high altitude aerial photography, videography, and field campaigns

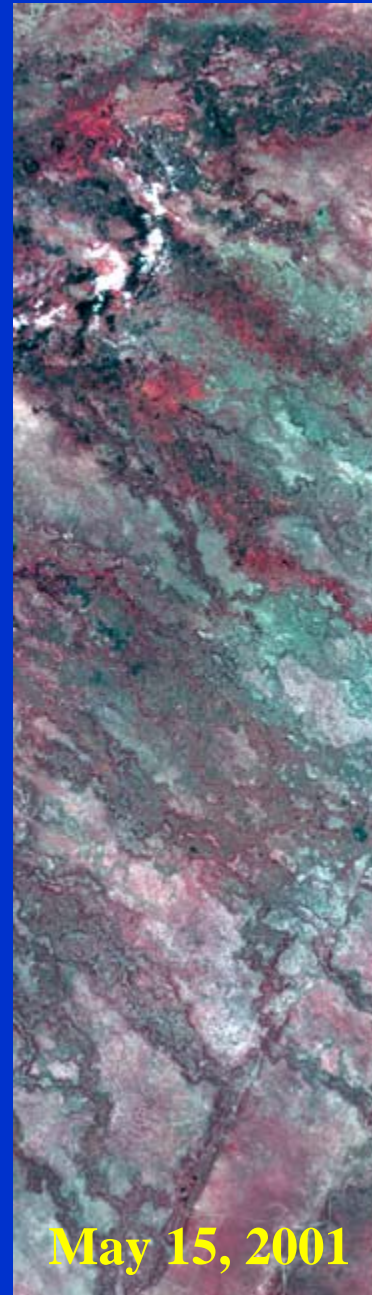




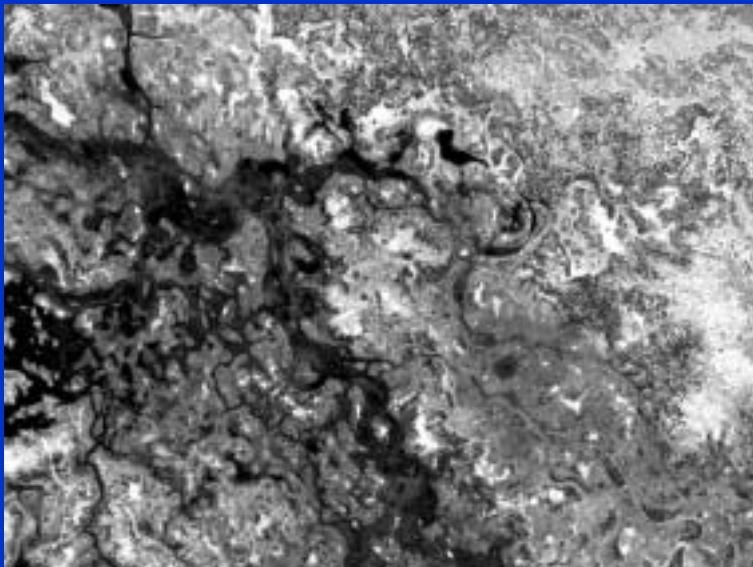
(advancing flood front)

ALI Imagery History

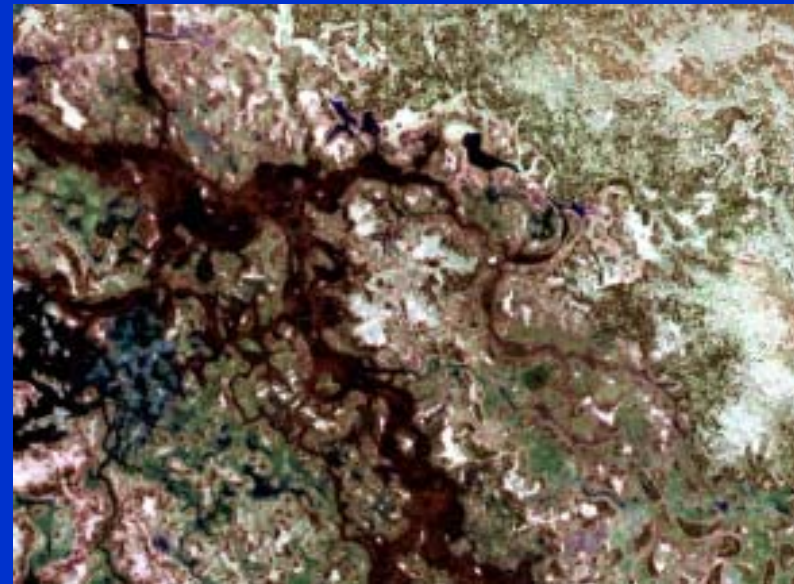
- 8 cloud free ALI images acquired over Chief's Island during 2001 flooding season (April- Sept)
- 8 cloud free ALI images acquired over Chief's Island during 2002 flooding season (May – October)
- 2003 – Data will be requested from EDC as funds allow



ALI Panchromatic and Multispectral Data Over the Okavango Delta



EO-1 Panchromatic
(Mapping trona islands and fire
scars and delineating ground truth
boundaries)

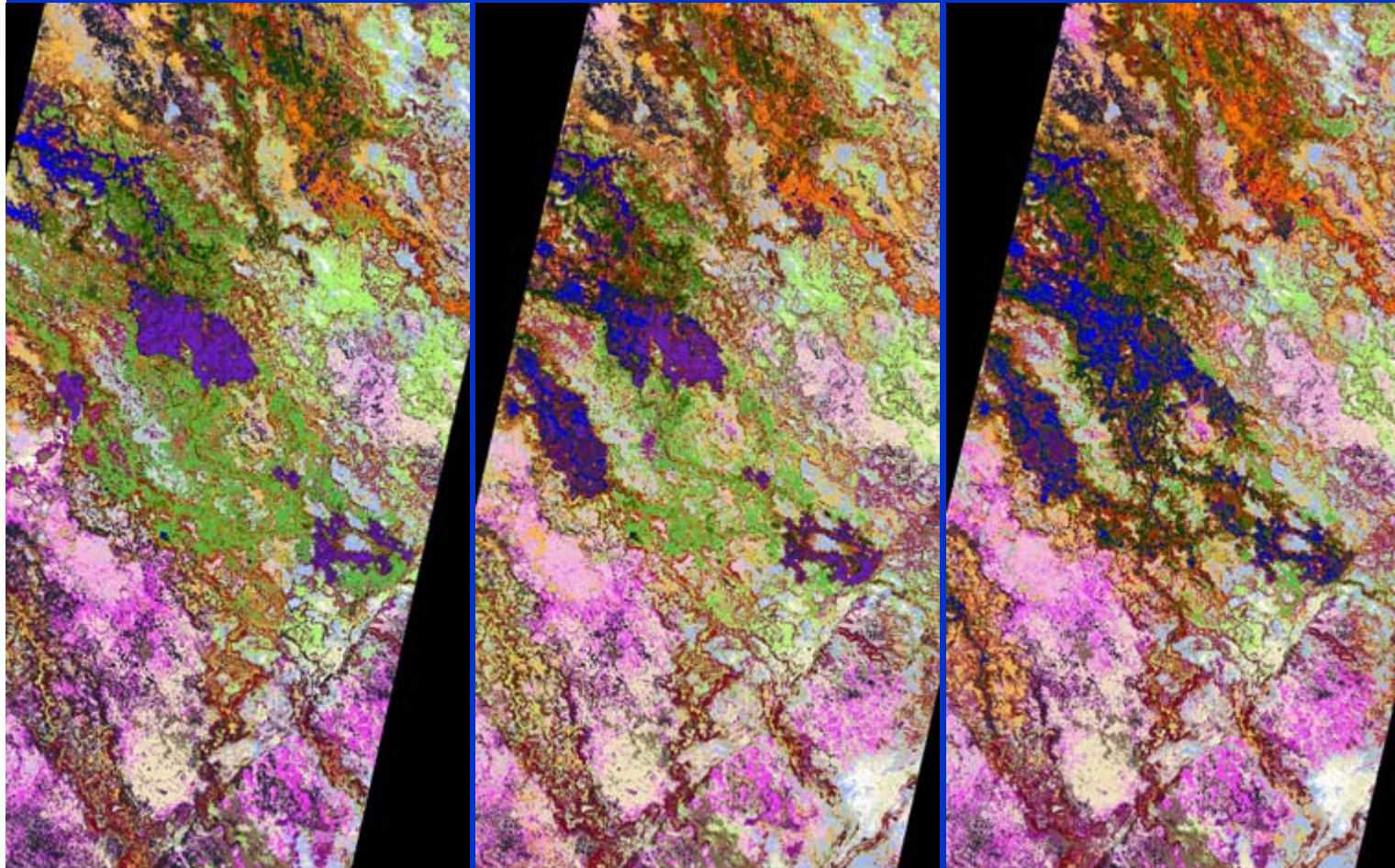


EO-1 Multispectral
(Mapping land cover
classes and progression
of flooding)

Processing and Analysis of ALI

- Destripe, align bands, mosaic SCA strips, convert to reflectances
- Classification
 - Bayesian Pairwise Classifier with feature selection to evaluate utility of new bands for classification and multi-temporal classification (Crawford et. al, 1999)
 - Improved discrimination and interpretability
 - Best Bases Bayesian Pairwise Classifier for analysis of Hyperion (Kumar et. al, 2002)
 - Curse of dimensionality and interband correlation necessitate reduction of input space
 - Bayesian Hierarchical Classifier to evaluate the impact of class aggregation and reduce computation time (Kumar et. al, 2000)

2001 ALI Imagery Classified Sequence



May 31, 2001

June 16, 2001

July 11, 2001

- Water
- Aquatic vegetation
- Firescar 1
- Firescar 2
- Backswamp
- Floodplain 1
- Floodplain 2
- Floodplain 3
- Reeds
- North Riparian
- South Riparian
- Acacia Mix
- Woodland Mix
- Acacia Woodlands
- Acacia Shrublands
- Acacia Grasslands
- Short Mopane
- Dense Mopane
- Mopane/Peccheul/Grass Mix
- Peccheul/Grass Mix
- Island Interior Grasses
- Dry Grasses
- Exposed soil

Classification Accuracies: May-July 2001

	Producer	User	Producers	Users	Producers	Users
n riparian	67.57	39.68	61.01	62.58	62.43	75
s riparian	50.25	68.28	83.33	77.35	91.28	92.99
short mopane	84.18	91.98	81.33	84.38	67.84	91.67
mopane (dense)	83.84	47.7	65.56	78.15	74.26	75.54
acacia mix	94.15	88.5	86.49	88.89	100	96.25
woodland mix	100	82.76	50	49.31	87.59	92.7
acacia woodlands	35.67	57.01	68.75	51.64	87.41	60.39
acacia shrublands	41.53	32.48	88.52	76.6	67.74	70.59
acacia grasslands	19.54	49.28	86.5	88.68	87.42	82.25
mopane/pecheul/grasses	91.33	84.04	88.14	64.2	90.91	65.84
grass/pecheul	93.2	97.16	85.8	95.39	93.96	85.5
dry grasses	77.86	43.43	85.43	82.17	47.06	66.67
island interior	82.5	98.8	77.63	92.91	56.41	86.27
exposed soil	83.87	72.22	93.88	87.34	96.23	69.86
reeds1	93.57	95.24	91.02	96.82	100	95.6
backswamp	90.71	88.36	82.76	92.31	72.41	96.33
floodplain1	42.68	84.34	77.44	87.59	68.02	67.24
floodplain2	76.61	92.23	70.49	94.16	85.64	95.27
floodplain3	42.28	44.83	86.6	66.67	76.35	67.39
water	91.79	98.9	91.49	100	99.55	100
aquatic veg	83.21	93.97	95.57	88.3	93.42	100
firescar1	60.53	100	88	92.31		
firescar2	96.91	72.35	88.03	91.24	93.16	89.85
Overall	73.06%		81.40%		82.24%	

- Results of 10 classifications, randomly sampled training/test data
- Good discrimination, except for mixed classes

Feature Selection Experiments (subset)

class pairs	expt1	expt2	expt3	expt4	expt5
1 2	1p 3 5p	1p 3 5p 7	1p 3 5p	1p 3 5p	1p 3 1 5p
1 3	5p	5p	5p	5p	5p
1 4	5 2	5 2 1p 7	5 2	5 5p 4p	1p
1 5	1p 2	1p 2	1p 2	1p 2	1p
1 6	5 3	5p 4p 3	5 3 1p	5p 4p 3	5 3
1 7	5 2 4 7 1p	5 2 4 5p 4p	5 2 4 5p 4p	5 2 4 5p 7	5 4p 5p
1 8	5 3	1p	5 3	5 3 7	7
1 9	5 7	5p	5p	5p	2
1 10	5p	5p	5p	5p	1p
1 11	1p 5p	1p	1p 5p	5p	5p
1 12	5	5p	5p	5p	7
1 13	5	5	5	2	2
1 14	3	3	3	3	3
1 15	5p 1 2 4	5p 1 2 4	5p 1 2 4	5p 1	5p 1 2
1 16	4	4	4	4	4 4p
1 17	4 3 5	4 3	4 3 5	4 3 5	4 3 5
1 18	5 7	5 7	5 7	5 5p	5
1 19	3	3	3	3	3
1 20	4p	4p	4p	5p	5p
1 21	5p 7 4 5	1 5p 4	1 4p	5p 7 4	5p 7 4 5
1 23	7 5p	7 3 4	7 5	7 5	7
2 3	4p	5p	5p	5p	5p
2 4	3	3	3	3	3
2 5	1p	1p	1p	1p	1p
2 6	5 2 7 4 5p	5 2 7 1	5 5p 4p	5p 4p 7	5 7 2
2 7	3 1p 4 5p 3	1p 4 5p 4p 1	3 1p 4	3 1p 4 5p 4p 1	3 4 1p 5p 4p
2 8	3 4	3 4	3	3 4	3 4
2 9	2	2	2	3	3
2 10	2	5p	2	5p	2
2 11	5p	5p	5p	5p	5p
2 12	5	5	3	5	3
2 13	3	2	2	2	2 5
2 14	3	3	3	3	3
2 15	4p 4	4p 4 1p 2	4p 4 1p 5p	4p 4 1p 2	4p 4 1p 2
2 16	4	4	4	4	4

- Forward selection greedy algorithm using classification accuracies
- Number of required bands for pairwise discrimination is $\ll 9$
- New bands are often selected preferentially

Summary of Feature Selection Experiments

Total Features Selected

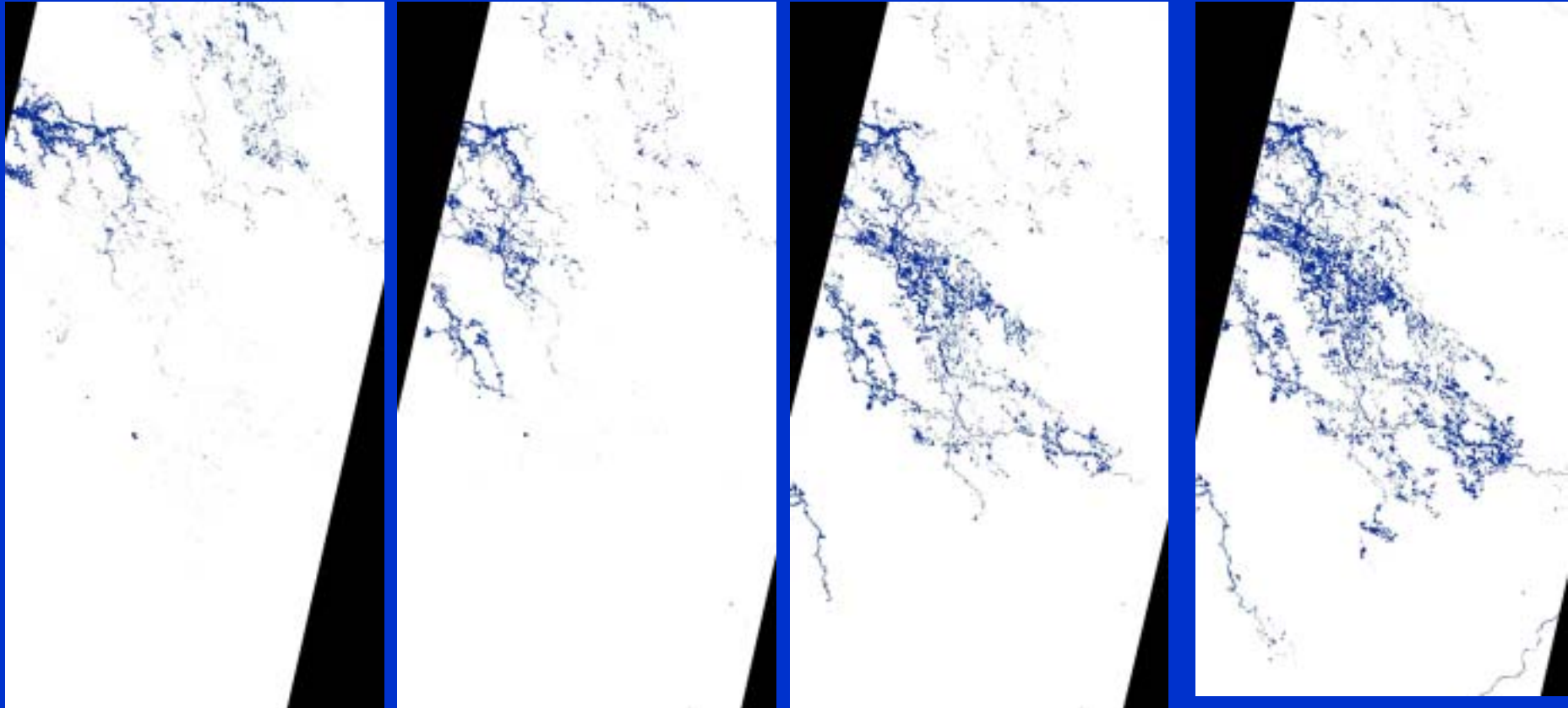
Band	expt1	expt2	expt3	expt4	expt5	Total	total/number of class pairs
1p	56	55	53	50	54	268	1.160173
1	21	27	25	29	27	129	0.558442
2	30	36	39	25	32	162	0.701299
3	70	65	55	77	59	326	1.411255
4	47	46	42	37	39	211	0.91342
4p	35	40	37	41	40	193	0.835498
5p	41	40	42	44	47	214	0.926407
5	26	21	22	21	23	113	0.489177
7	36	46	37	37	38	194	0.839827
	362	376	352	361	359	1810	1.5671

First Feature Selected

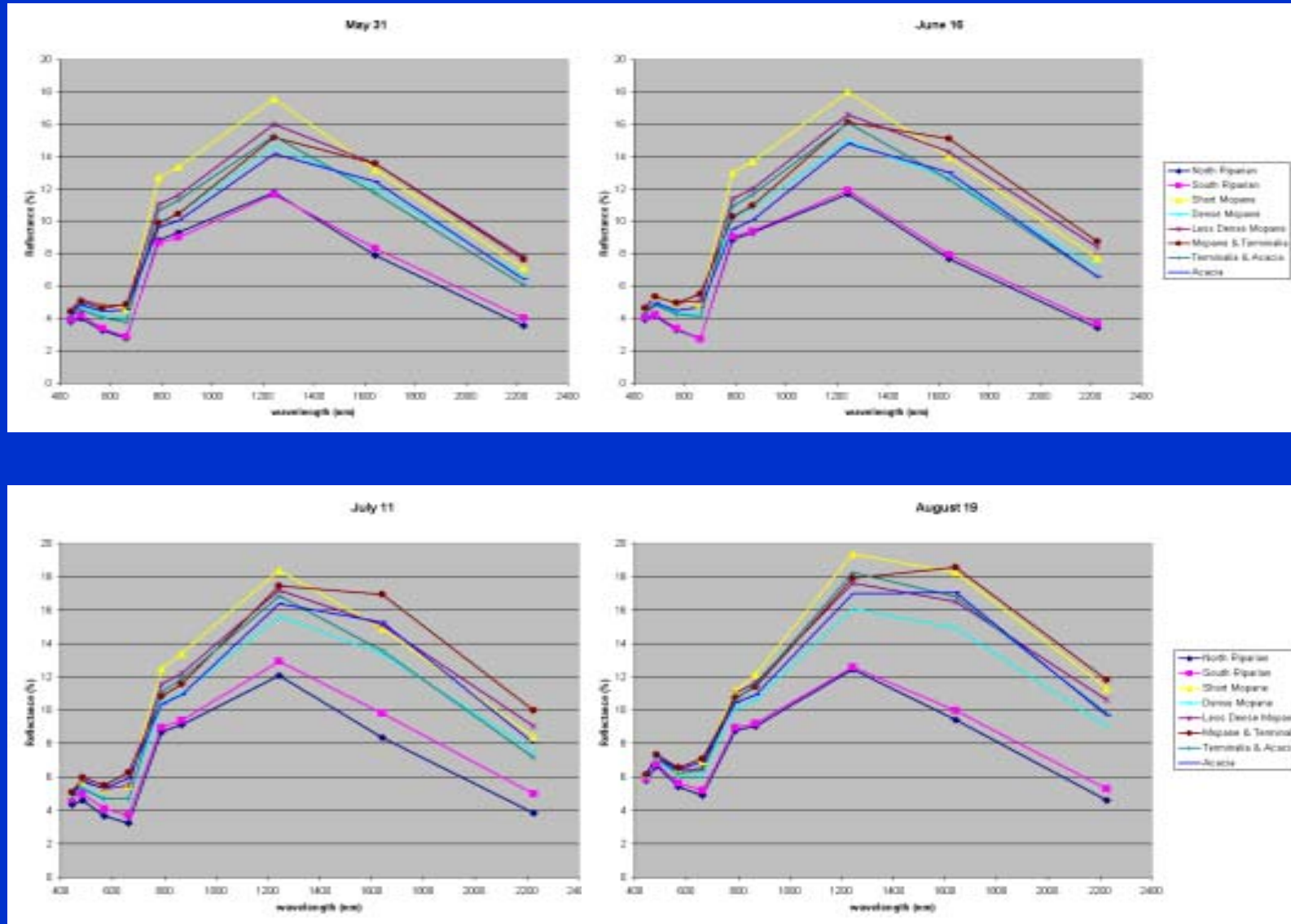
Band	expt1	expt2	expt3	expt4	expt5
1p	43	38	39	38	40
1	11	11	13	15	17
2	18	22	27	16	19
3	39	36	30	44	31
4	35	30	32	29	29
4p	27	30	25	27	27
5p	17	19	22	24	21
5	18	12	15	12	15
7	23	33	28	26	32

- New bands appear to provide preferentially selected information for some classifiers

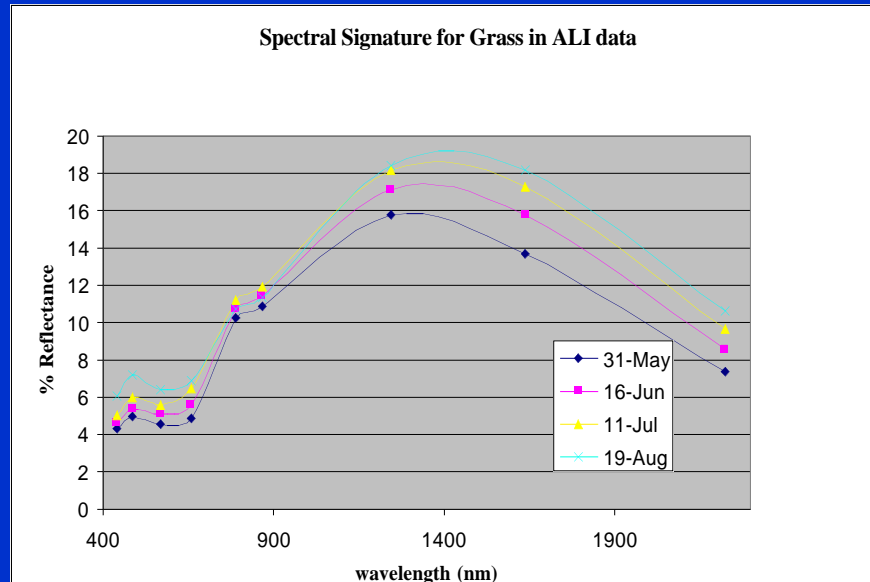
2001 ALI Flood Sequence: Preliminary Study of Riparian ET



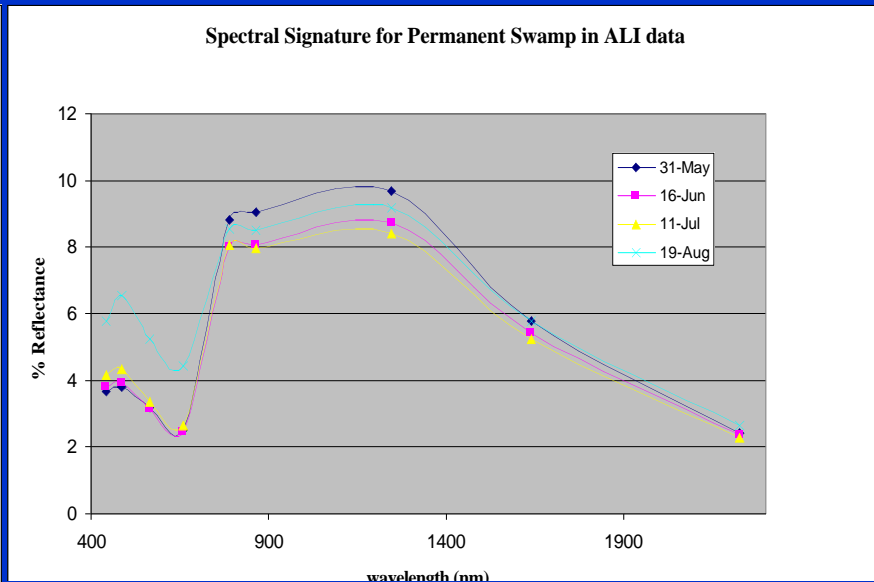
Spectral Signatures for Woodland Classes, 2001



ALI Reflectances During 2001 Flooding Event

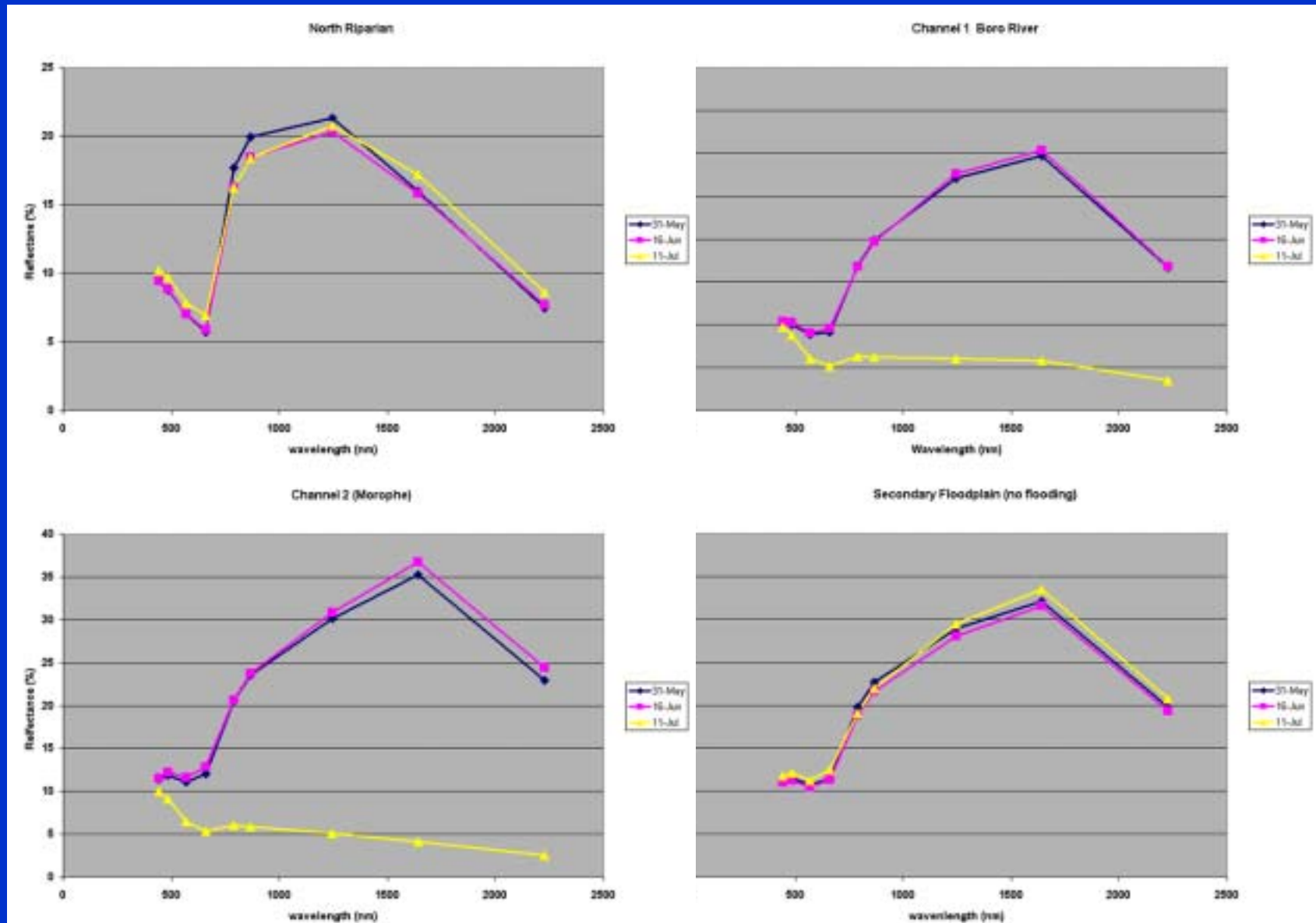


Vegetation senescence progressing through the dry season indicated by higher reflectances with the most significant separation occurring in the mid-infrared region



Permanent swamp predominantly in north. The peak reflectances for permanent swamp occur on May 31, as the peak water level in the northern portion of the scene occurred in June and July.

Vegetational Response to 2001 Flooding Event



Multitemporal Classification of Dryland Classes

	Producers	Users
n riparian	59.12	81.03
s riparian	88.69	78.84
short mopane	59.64	75.57
mopane (dense	54.44	76.56
acacia mix	77.03	83.82
woodland mix	79.14	83.77
acacia woodla	57.04	69.23
acacia shrubl	63.75	67.55
acacia grassl	77.87	87.16
mopane/pecheu	79.66	63.09
grass/pecheul	76.92	92.2
dry grasses	68.21	86.55
island interi	83.55	97.69
exposed soil	70.75	70.75
Overall	0.71%	

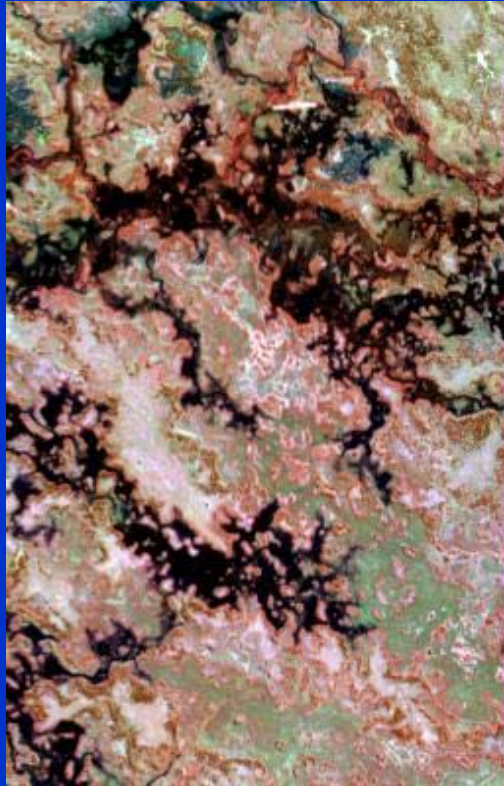
- Masked floodplain classes
- Improved discrimination between woodland classes
- Possibly affected by slight misregistration errors
- Subject of ongoing study, including algorithm development

Classification Accuracies: ALI vs ETM+

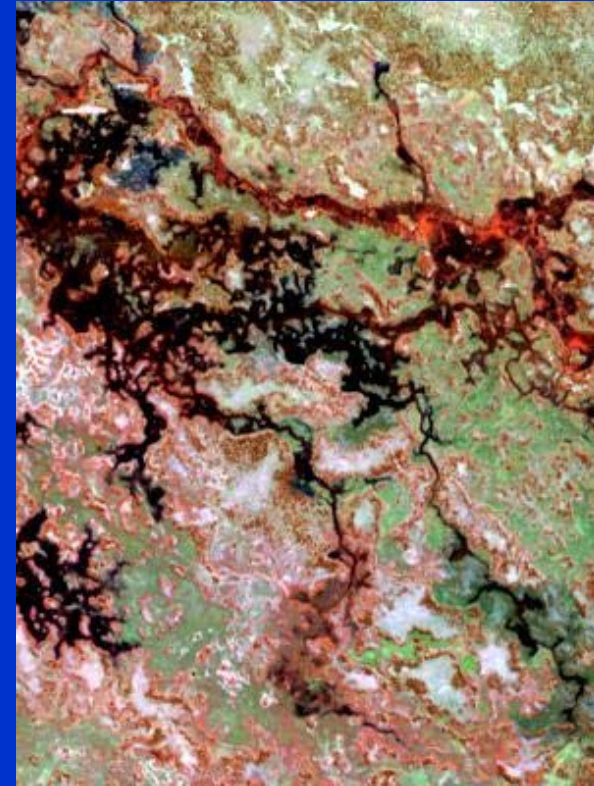
	AUG 12 ETM+		AUG 19 ALI	
	Producers	Users	Producers	Users
n riparian	43.06	44.33	65.07	61.82
s riparian	71.5	53.28	80.31	58.94
short mopane	50.7	76.22	59.07	90.71
mopane (dense)	65.82	50.42	49.45	59.65
acacia mix	99.16	73.75	100.00	91.54
woodland mix	70.91	78.79	90.91	94.34
acacia woodlands	43.71	27.5	19.21	17.90
acacia shrublands	27.47	42.02	47.25	55.48
acacia grasslands	65.71	68.66	75.00	92.11
mopane/pecheul/mix	92.47	75.84	98.63	62.61
grass/pecheul	91.61	84.52	99.35	89.53
dry grasses	42.28	61.17	61.07	61.90
island interiors	40.36	61.64	56.95	96.21
exposed soil	84.05	73.86	81.47	79.41
reeds1	77.58	81.53	91.52	94.97
backswamp	62.79	90	75.19	97.98
floodplain1	64.89	61.59	96.18	75.90
floodplain3	33.14	34.94	48.57	34.27
water	99.63	99.26	100.00	100.00
aquatic veg	93.23	98.9	94.27	100.00
firescar2	96	97.96	98.67	97.05
Overall	68.30%		0.76%	

Note: Problems with SCA 4 of ALI affected results

Sensor Comparison: May 31, 2001 Imagery



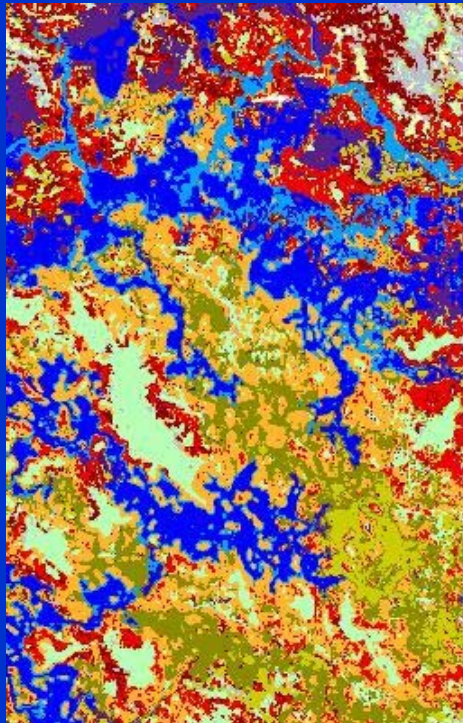
Hyperion



ALI

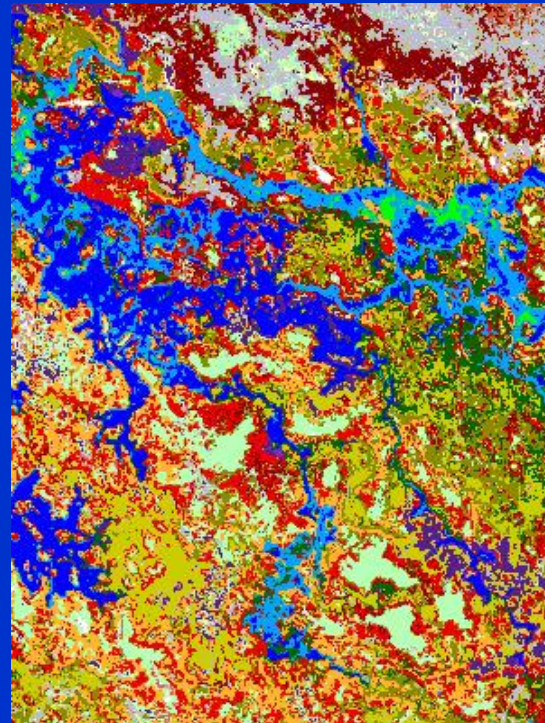
- Bands aggregated using 17 land cover classes defined in ALI
- 14 land cover classes defined in Hyperion imagery
(coverage difference)

ALI/Hyperion Comparison: May 31, 2001



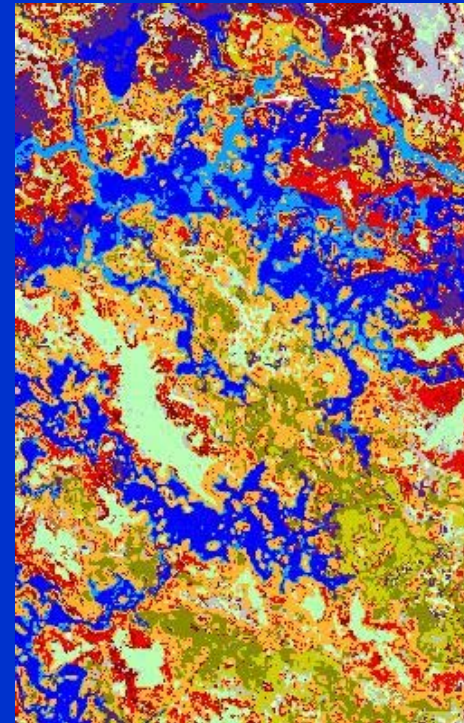
Hyperion

Overall Accuracy: 72.89%



ALI

Overall Accuracy: 85.15%



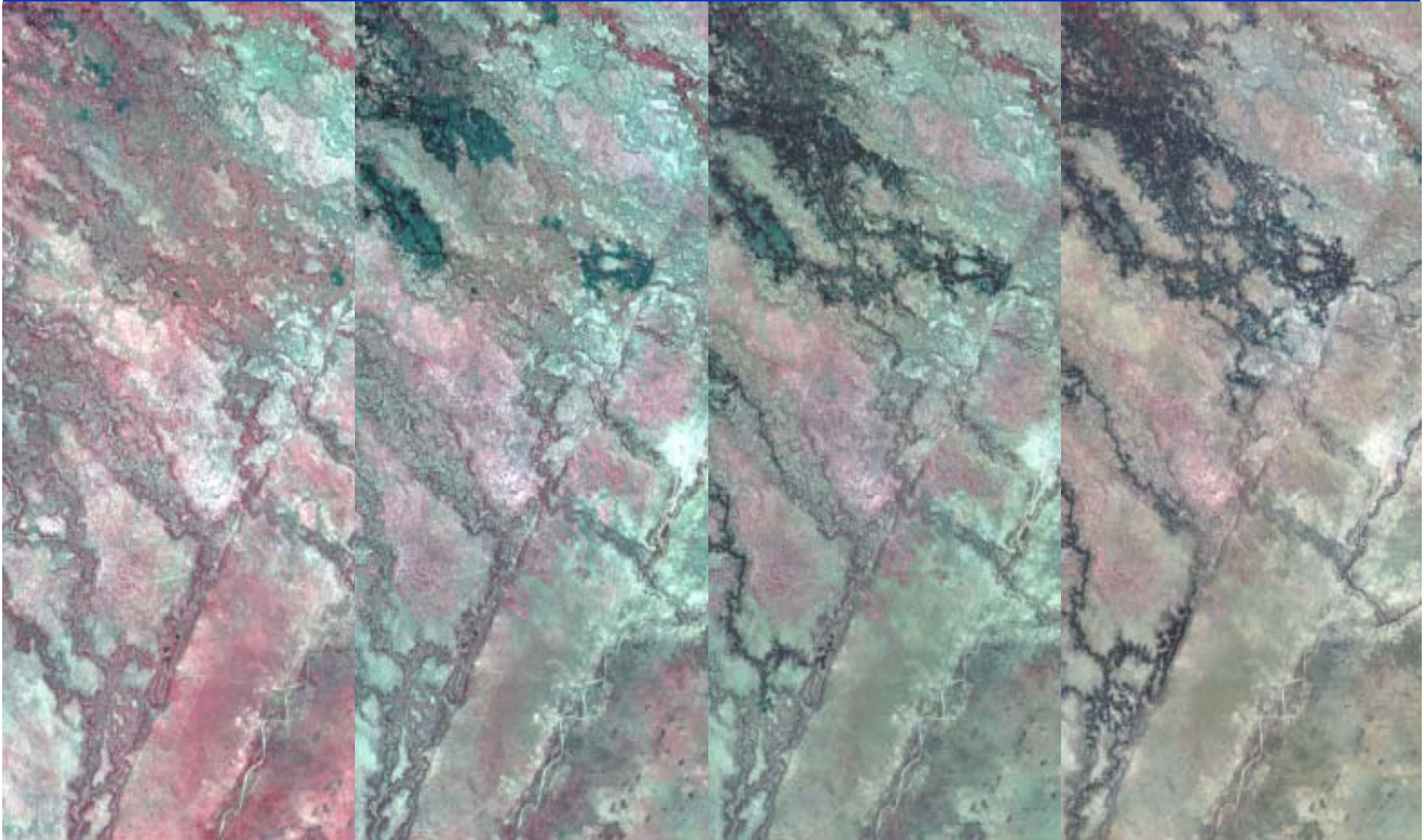
Synthesized ALI

Overall Accuracy: 74.69%



- Hyperion classification extremely sensitive to adequate destripping
- Spectral contribution of Hyperion may not be adequately exploited due to spatial complexity of this landscape
- “On the fly” configuration of application specific sensors for mapping is viable

2001 Flood History of Chief's Island



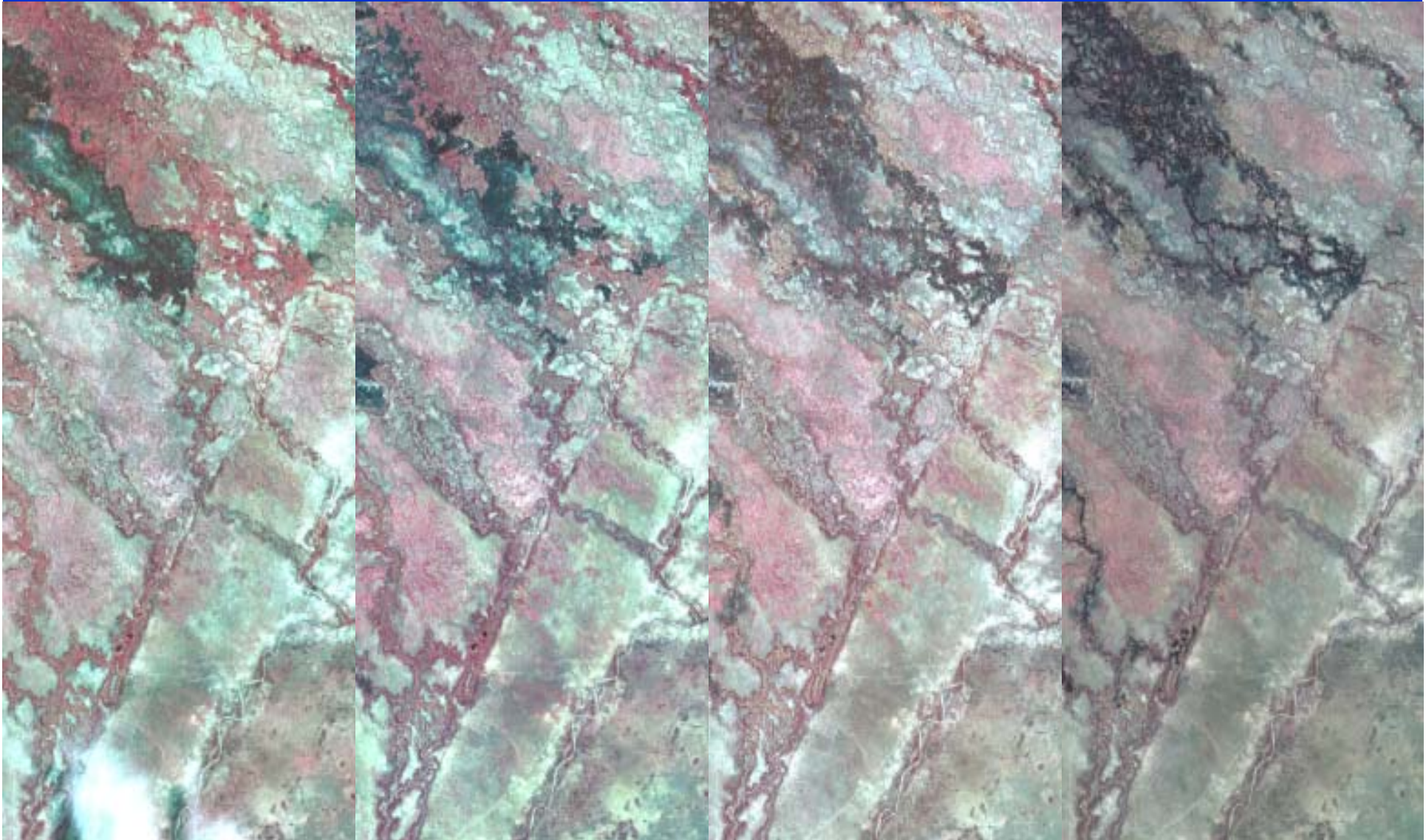
May 15, 2001

June 9, 2001

July 11, 2001

August 19, 2001
Peak flooding

2002 Flood History of Chief's Island



April 9, 2002

May 11, 2002

June 19, 2002

July 21, 2002

2001-2002 Flood History



July 11, 2001



Increased flooding
near Chief's Island
in 2002 compared to
2001.

Marophe Channel
not flooded in 2002

July 21, 2002

What Next with EO-1?

General

- Continued research on better exploitation of hyperspectral information in Hyperion
- Incorporation of texture measures from ALI Pan band
- Improvements to multitemporal classification algorithm

Studies of the Okavango

- Acquire and analyze data from 2002 flood season
- Validate land cover mapping results via 2003 field campaign
- Initiate collaborative fire ecology study with U of Munich
- Incorporate EO-1 results into an upscaling modeling effort with MODIS

Conclusions

- EO-1 ALI is an effective prototype for Landsat Continuity Mission in land cover mapping applications
 - In general, resulted in higher classification accuracies and required fewer bands for discrimination than Landsat ETM+ (Higher SNR, pushbroom design, additional bands)
 - Bands 4p, 5p are useful for discriminating woodland classes
 - ALI superior for mapping feature boundaries and texture (Pan band)
 - Adequate band-to-band alignment and mosaicking can be accomplished with appropriate LOS maps and good ephemeris information over a range of pointing

Conclusions, cont'd

- Hyperion

- With proper processing, Hyperion data can be used effectively for land cover mapping, synthesis to multispectral data.
- Atmospheric correction advantageous relative to standard multispectral sensors
- Spatial resolution of 30m inadequate to exploit Hyperion in many
- land cover mapping applications

Acknowledgements

- **NASA EO-1 Program**
 - Steve Ungar, support of field campaign
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