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Trial of L-band radar for mapping inundation patterns in the Macquarie Marshes

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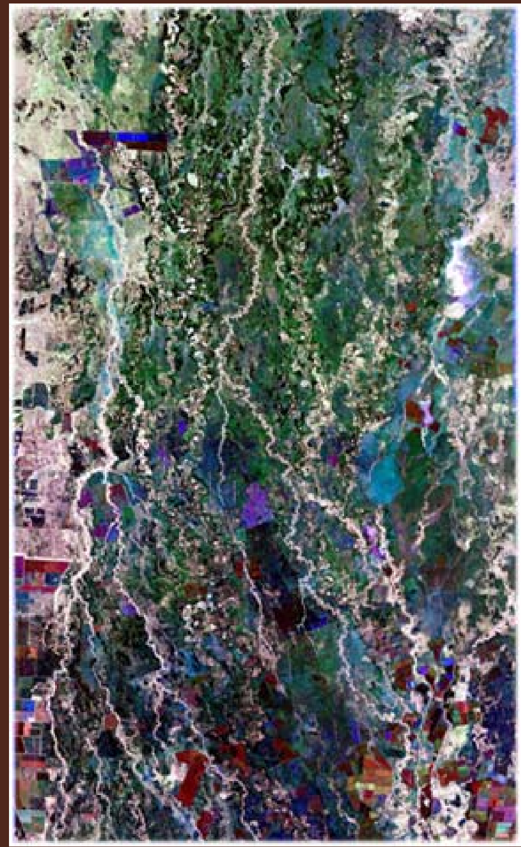
University of New South Wales CRC for Spatial Information[1], Horizon Geoscience Consulting[2], and NSW Department of Environment and Climate Change[3].



HGC
HORIZON GEOSCIENCE CONSULTING

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SYDNEY • AUSTRALIA

Extension Phase Proposal

Deliverables

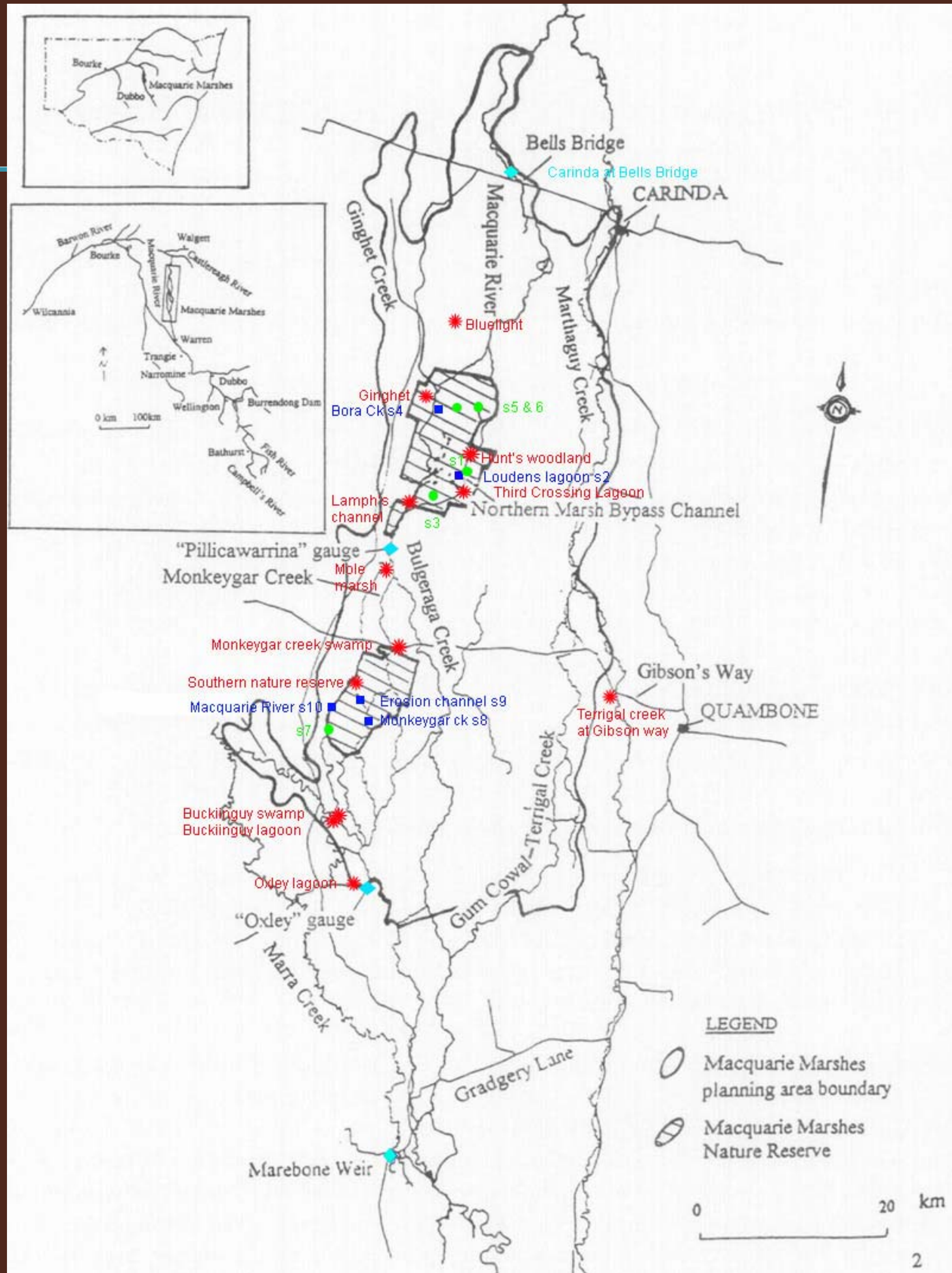
- *Methods for detecting and characterisation vegetation, soil and water class in semi-arid wetland environments.*

- *Development of an operational system using PALSAR data for monitoring wetlands and assessing the effect of environmental flows on vegetation and soil response in semi-arid wetland environments.*

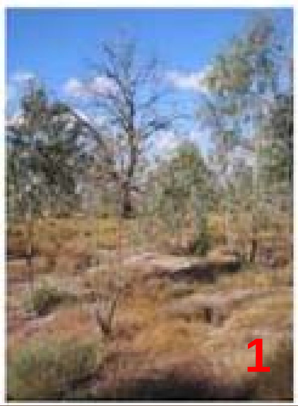
- *Evaluation of Scansar efficiency in detecting and mapping the regional distribution of semi-arid wetland distribution in the MDB.*

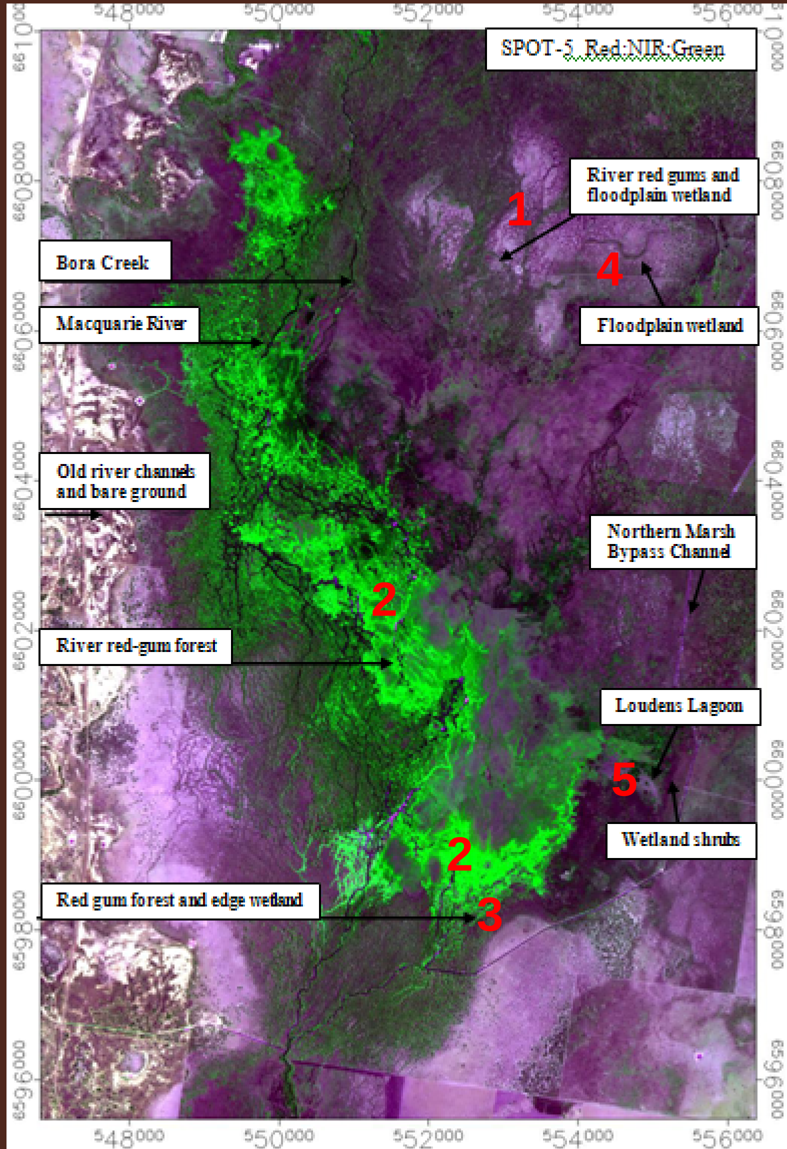
THE MACQUARIE MARSHES

North central NSW, SE Australia

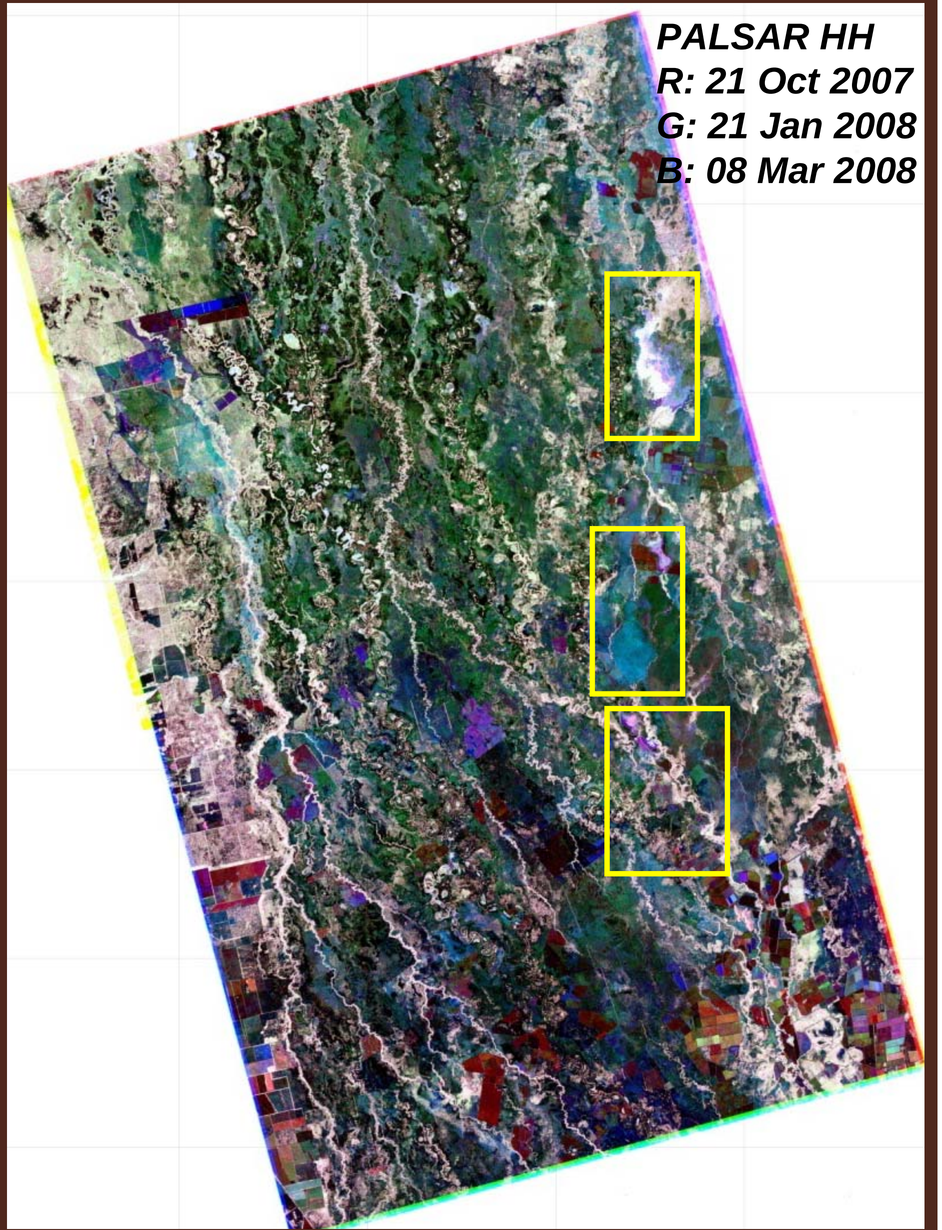


SEMI ARID WETLAND VEGETATION





Project objective: to demonstrate the ability of imaging radar to map and monitor wetland extent and inundation in the Macquarie Marshes



Project datasets

PALSAR:

- Jan07 HH
- Oct07 HH + HV
- Jan08 HH
- Mar08 HH

Terra-X : Mar08 and Apr08

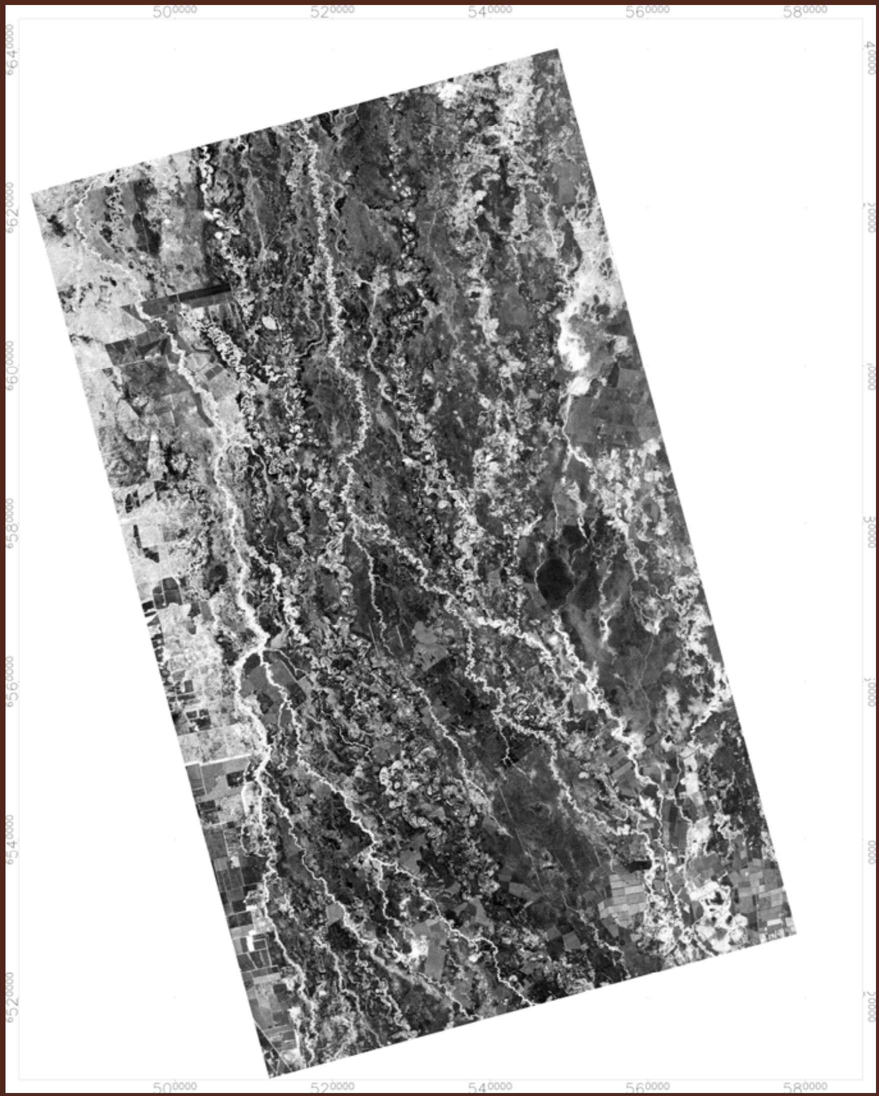
Radarsat: Feb08, Mar08, Apr08

Compartive study (multi-frequency) - discrimination of open water from bare ground and grassland.

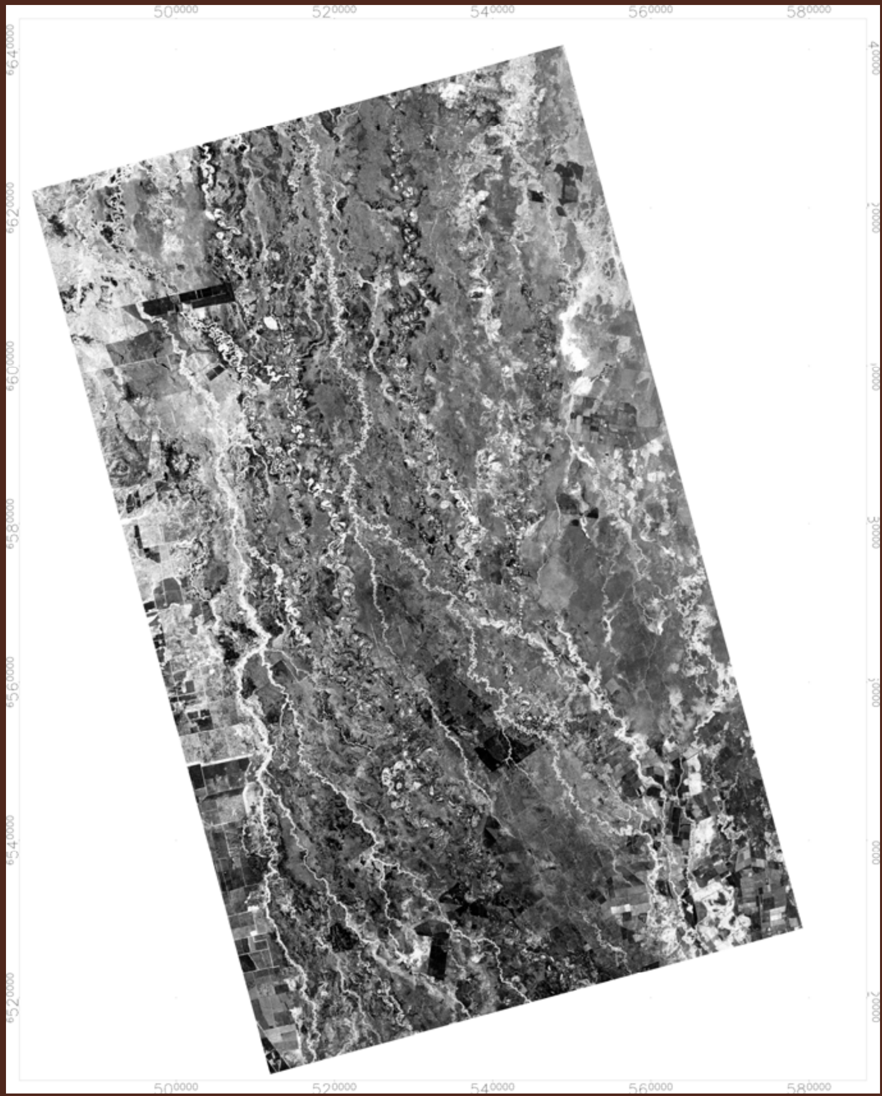
Operational system for monitoring environmental flows in semi-arid wetlands

Other data: river gauge records, CTF, field survey & climate data

ALOS PALSAR FBS L-band HH-polarization



21 October, 2007
12.5 m resolution and 38.3° incidence angle
incidence angle



21 January, 2008
12.5 m resolution and 38.3°

Terra-SAR StripMap X-band, HH-polarization

Strip-Map 2 March, 2008

3.75m resolution, 40.6° incidence angle

Strip-Map 4 April, 2008

3.75m resolution, 40.6° incidence angle

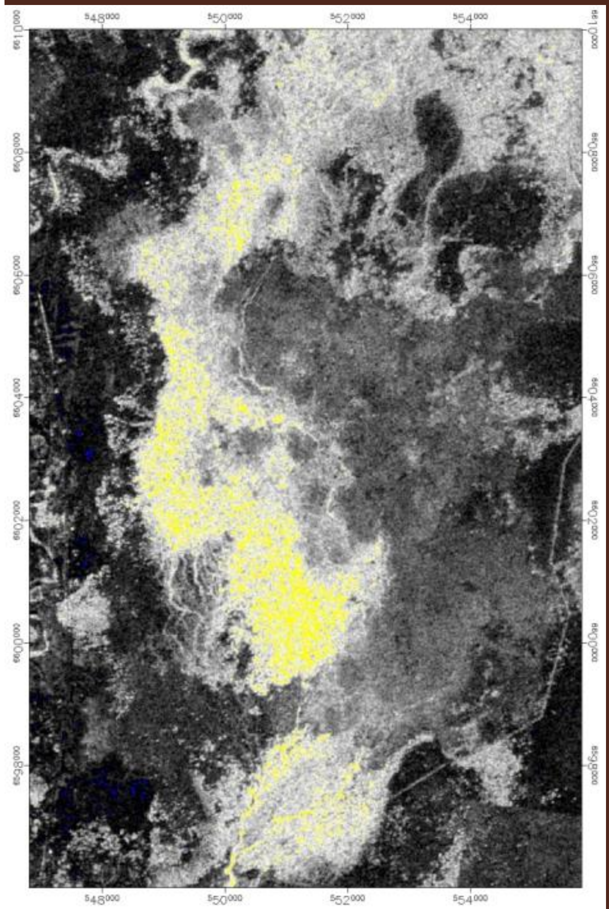
Surface water detection and inundation mapping

Area #1 - visual observation of PALSAR L-HH data to identify areas of surface water:
The Jan08 image was acquired under the wettest conditions and reveals the maximum extent of water in the scene. Open water in ponds and lagoons and wet mud (over flat, scalded areas in western sector) appears black; flooded forest appears **white**. The colour composite confirms the presence of open, ponded water (dark purple) and its separation from wet mud (black). Floodplain areas subject to inundation are also emphasised (**pink-blue**). Flooded forest (**white**) and non-flooded forest (light-pink) is also discriminated.

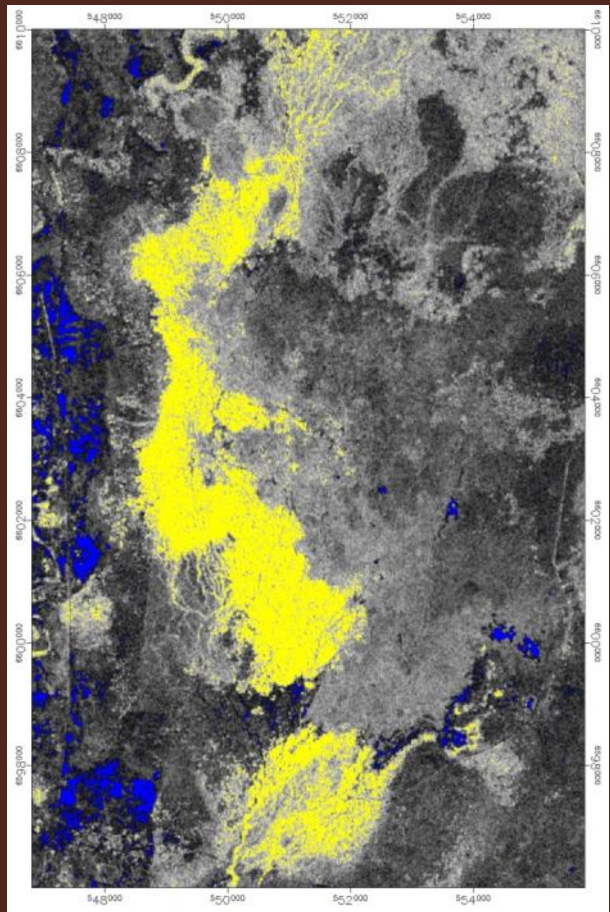
Surface water detection and inundation mapping

Contrast enhancement and thresholding

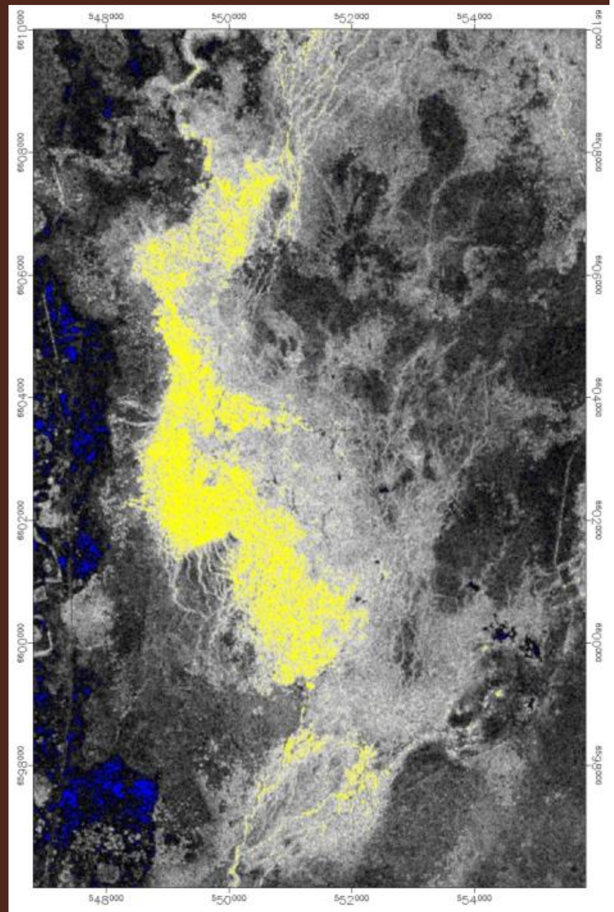
Open water (Blue), Below-canopy water (Yellow)



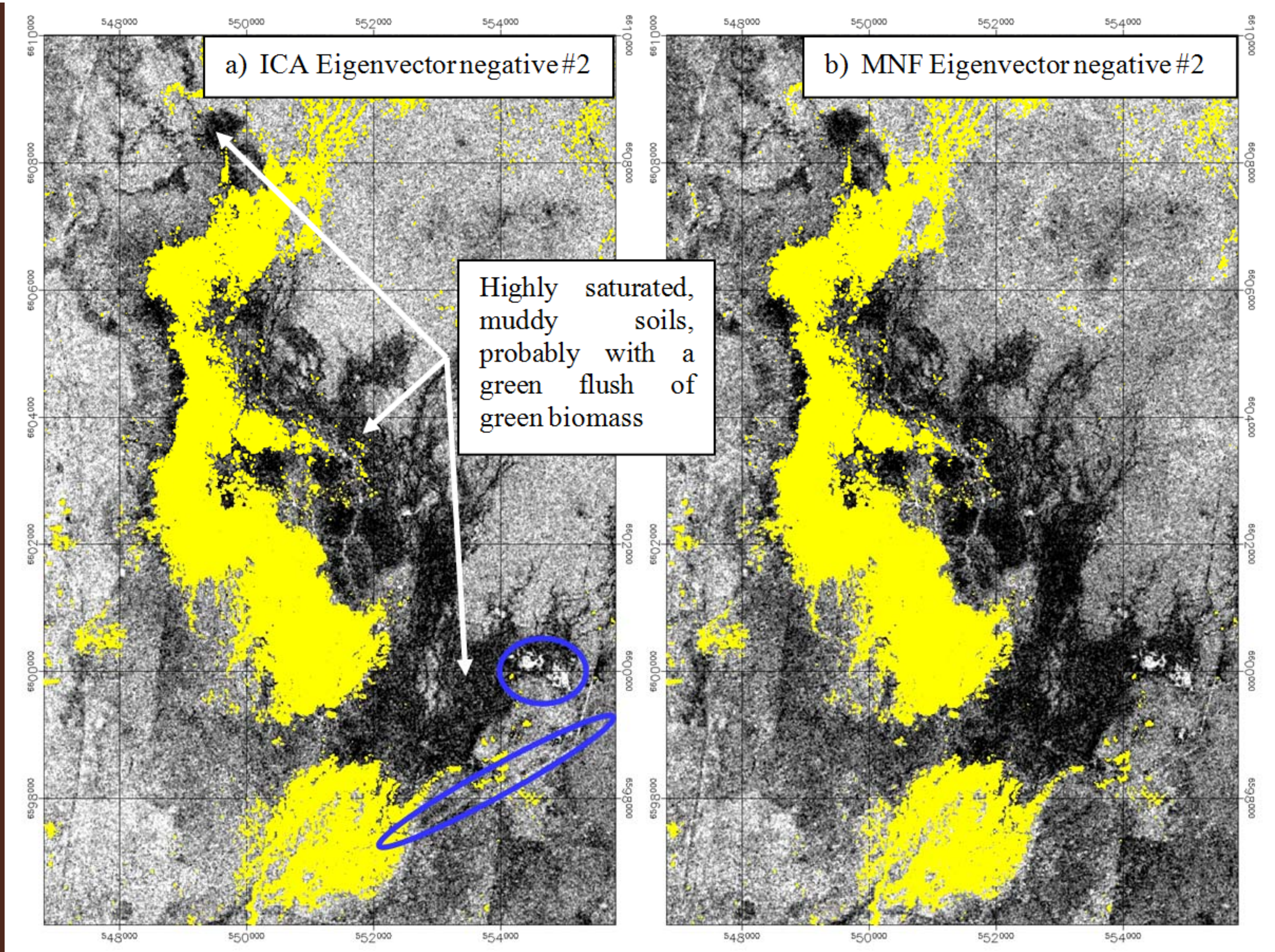
OctHH07



JanHH08



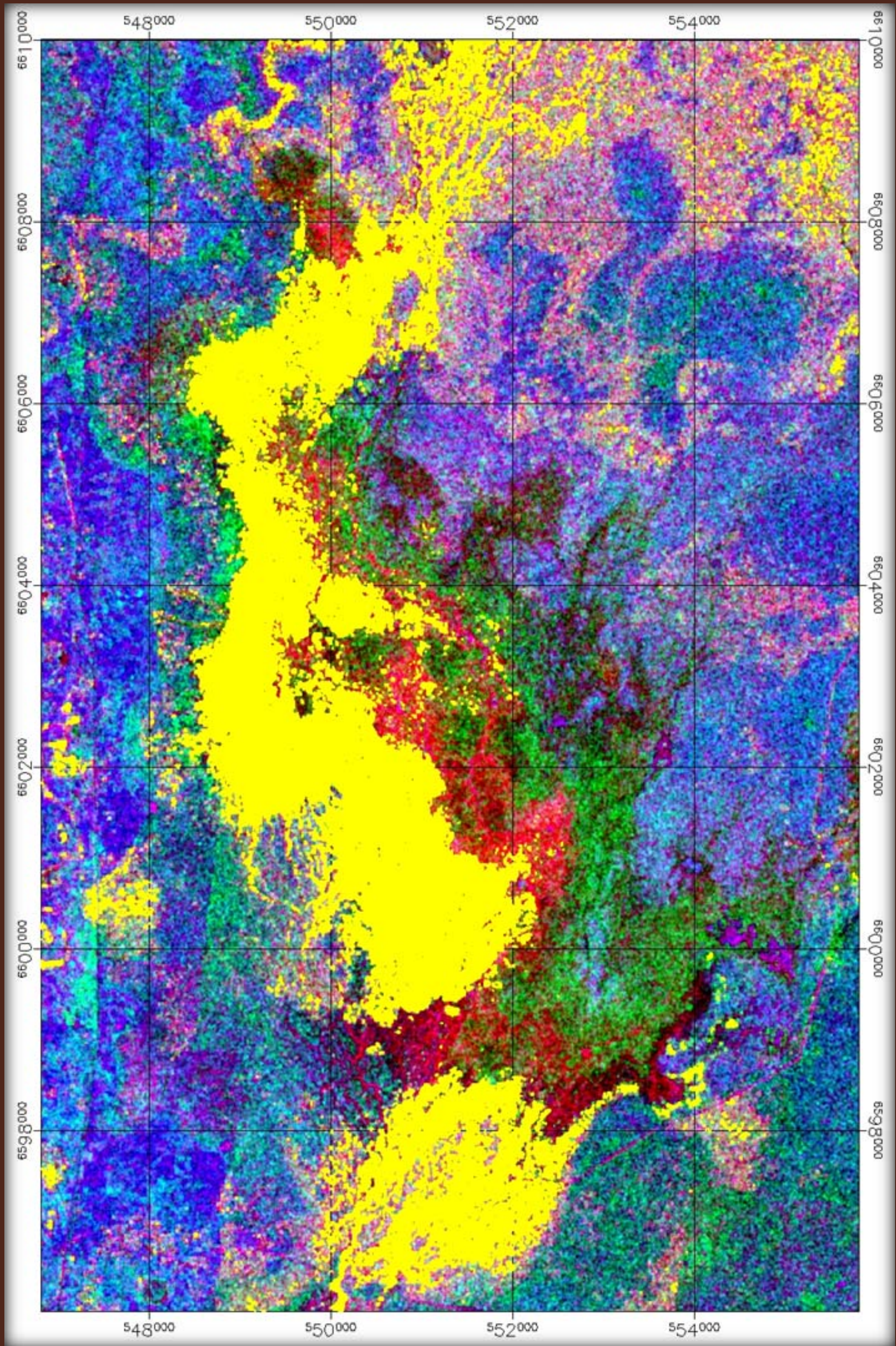
MarHH08



Input bands include Oct07HH, Oct07HV, Jan08HH and Mar08HH.

Areas of open water (white) and highly saturated, muddy soils (black) which may include a flush of green biomass in response to the flooding.

Both eigenvector images have been inverted such that water bodies now appear in white tones and moist soils in dark-grey to black tones.

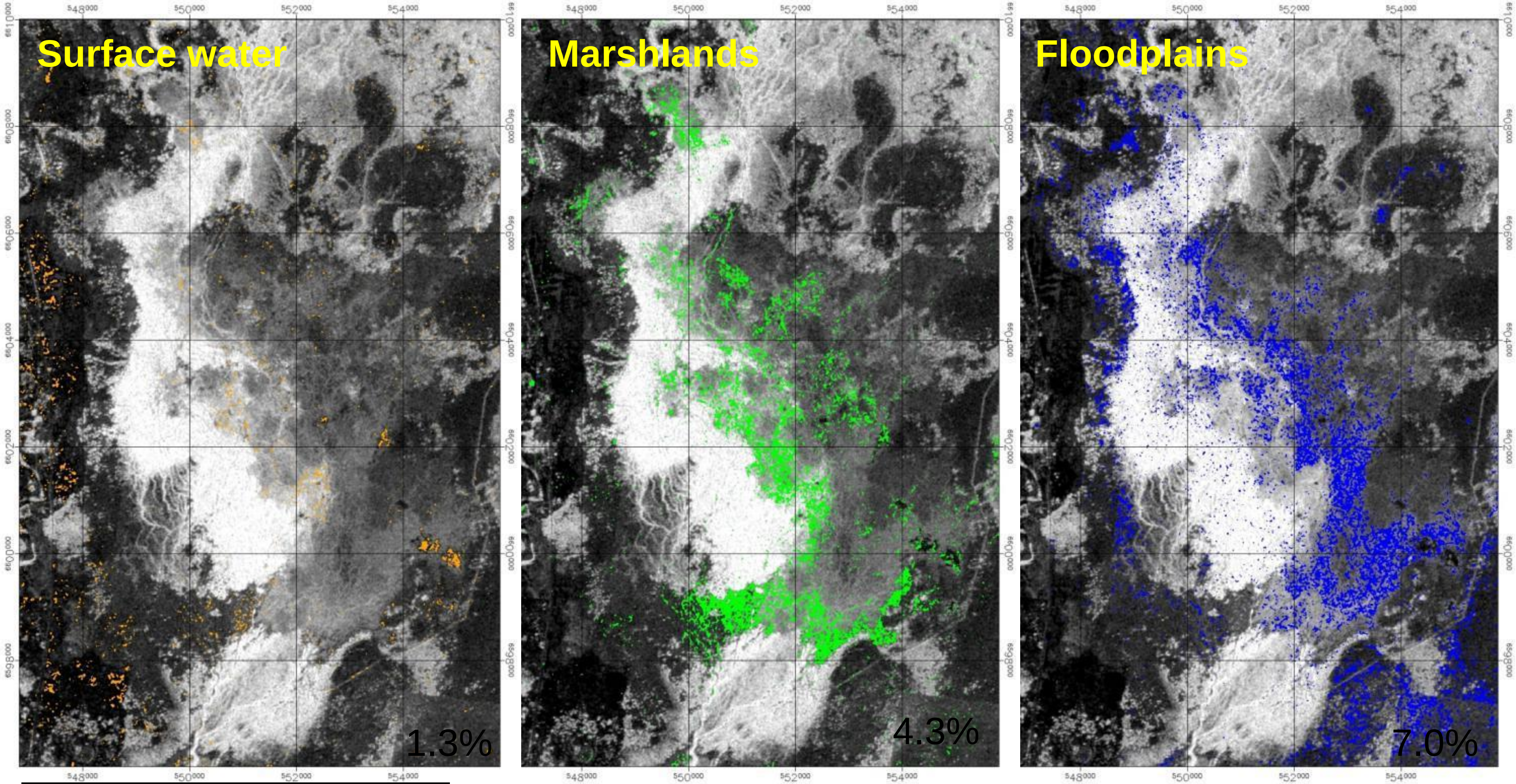


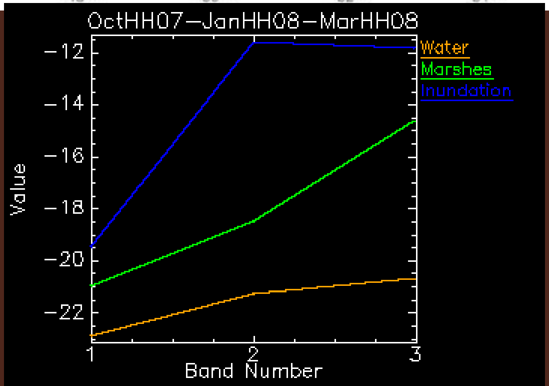
Decorrelation stretch

Area #1 Transform of PALSAR bands Oct07HH, Jan08HH and Mar08HH displayed as Vector #1, #2 and #3 in RGB.

A decorrelation stretch is a simple and effective method to remove high inter-band correlation and increase the range and diversity of colours in a colour composite image.

Flooded red gum forest (**yellow**) has been masked from the image.
There is good discrimination of open water (**purple**), edge wetland or marsh (**red**-magenta), inundated floodplain (**green**), other forest (pink) and surrounding wetland (**blue**).





End-member spectra

Spectral Angle Mapper (SAM) – OctHH07:JanHH08:MarHH08

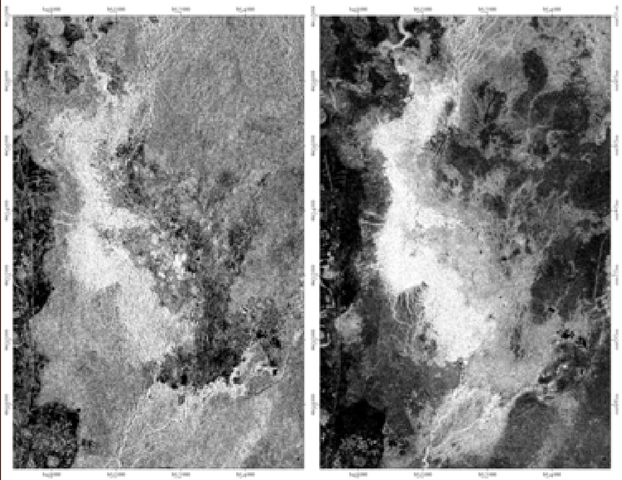
A simple and rapid classification method that determines the L-band HH-polarimetric similarity of selected end-member spectra (average spectra from regions-of-interest representing selected surface types) to spectra of all pixels in the scene. It is essentially a physically based classification technique that determines the spectral similarity between two spectra by calculating the angle between them, treating them as vectors in space with dimensionality equal to the number of bands (3 dates). Smaller angles represent closer matches to the reference spectrum. Areas that satisfy the criterion for 3 cover types, **surface water**, **marshlands adjacent to the red-river gums**, and **floodplains subject to inundation**, are classified. Pixels further away than the specified threshold are not classified. The percentage cover of each class is shown. A median filter has been applied to suppress spuriously classified pixels.

Surface water detection and inundation mapping

Integration of X- and L-band radar data

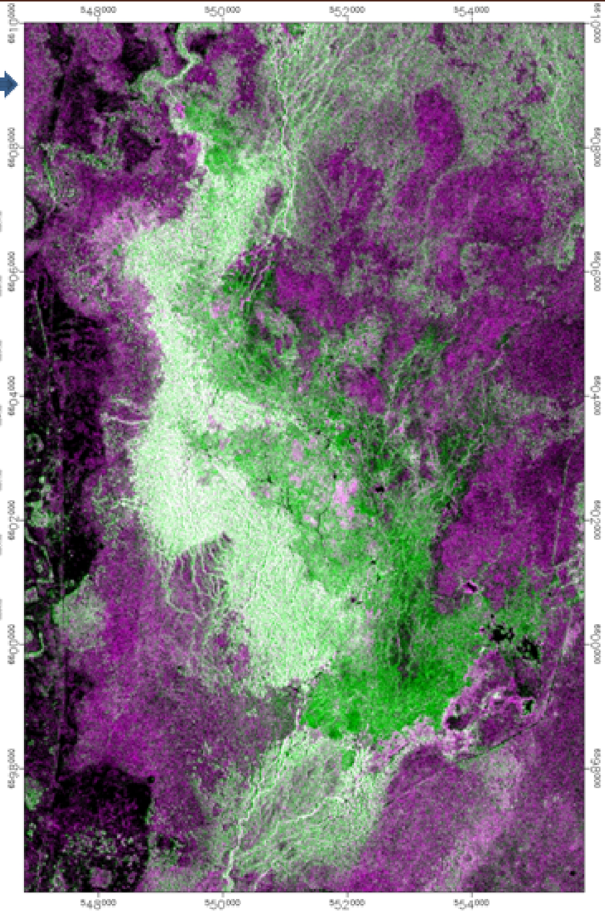
Area #1

R: TS-StripMap	X-HH	02Mar08
G: PALSAR FBS	L-HH	07Mar08
B: TS-StripMap	X-HH	02Mar08



TS-X-HH 02Mar08 PALSAR L-HH 07Mar08

Green and Magenta indicate areas where the backscatter response is dominated by L-band and X-band, respectively.

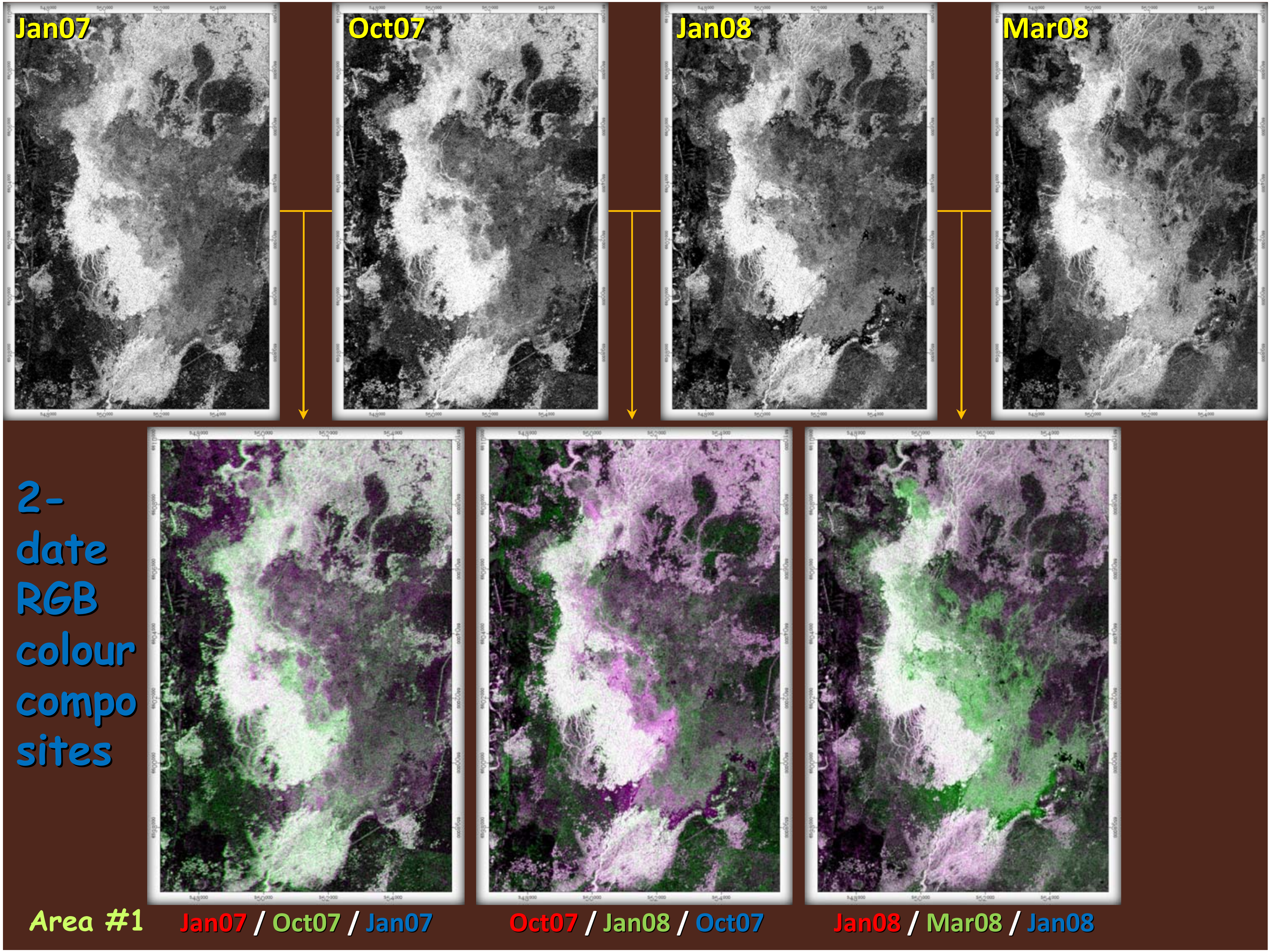


TSX data provide a first return or largely canopy response. Dark areas on the floodplain at X-band reveal areas where the water has overtopped the vegetation in the wetlands.

PALSAR data respond to woody vegetation, particularly where inundated, and provide good discrimination between flooded and non-flooded vegetation.

R:G:B colour composite provides good discrimination of areas subject to inundation. The backscatter over the floodplain wetland is dominated by the PALSAR (green on image) due to L-band 's response to high soil moisture and roughness. Radar backscatter from the surrounding floodplain area is dominated by TSX (purple on image). The low shrubs and grasses of the floodplain provide many opportunities for volume scattering at X-band. Patches are observed in the edge wetland where the response is also dominated by the TSX . These are most likely areas of very high backscatter as a result of ponded water with aquatic vegetation.

Change detection


Jan07
Oct07
Jan08
Mar08
2-date RGB colour composites
Area #1
Jan07 / Oct07 / Jan07
Oct07 / Jan08 / Oct07
Jan08 / Mar08 / Jan08

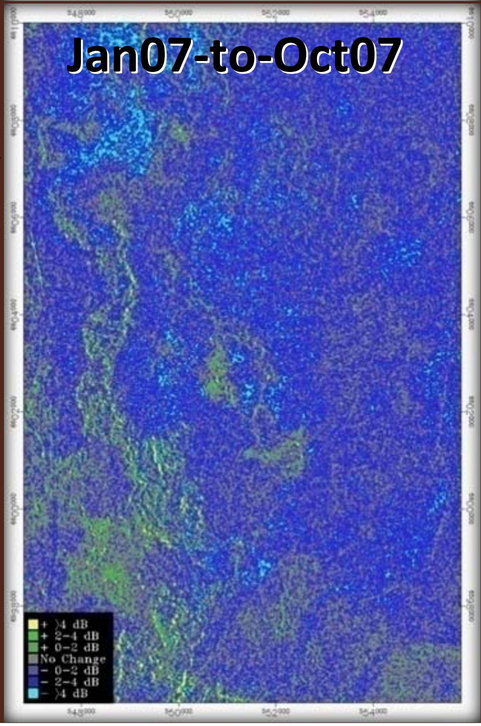
Band difference

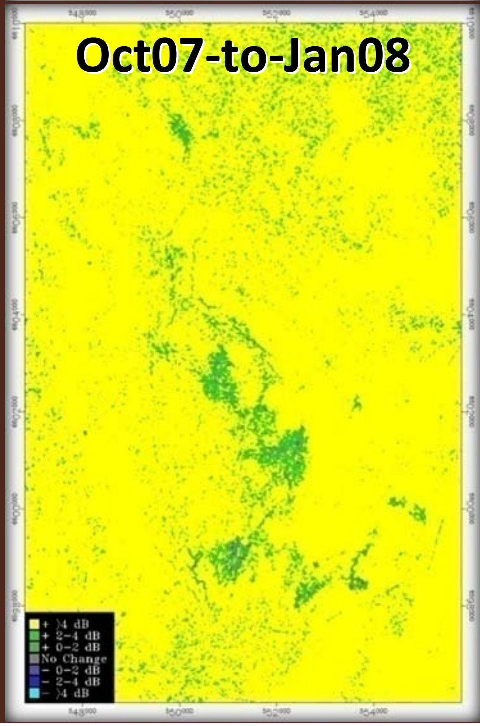
Black and white areas represent extreme change while mid-grey equates to no change.

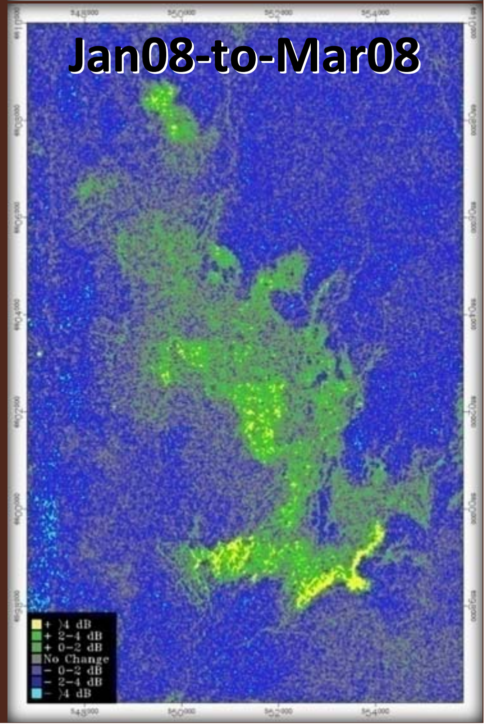
Area #1
PALSAR HH

Change detection

The resulting Difference Map classification image is colour-coded to indicate the magnitude of the change between the two images. Positive changes displayed in shades of Green, grading from gray for no change to Yellow for largest positive change. Negative changes display in shades of Blue, grading from gray for no change to Cyan for the largest negative change. Each level represents a change of 2dB.

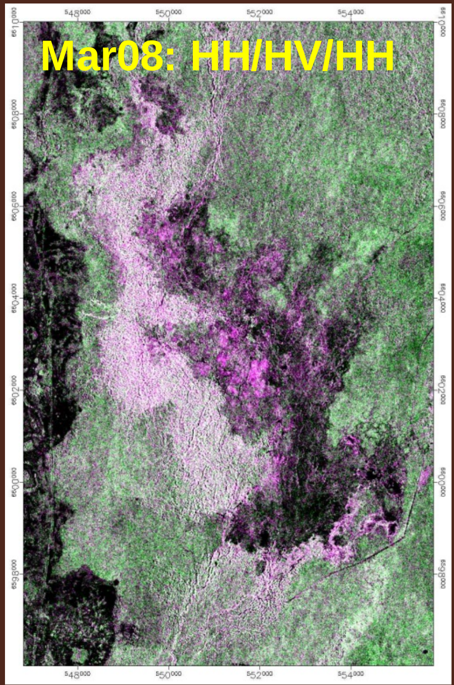


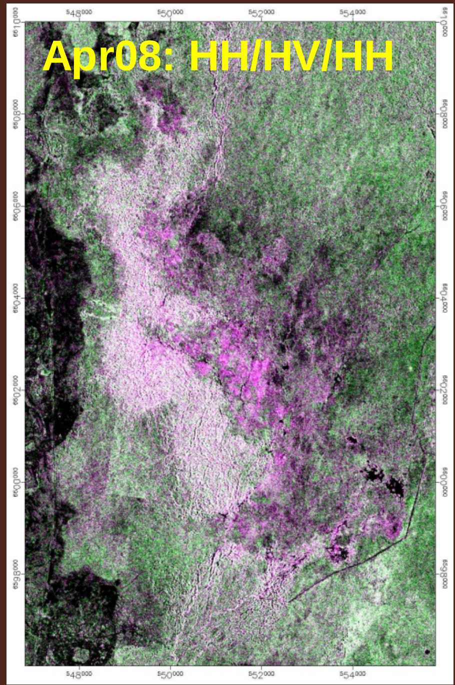


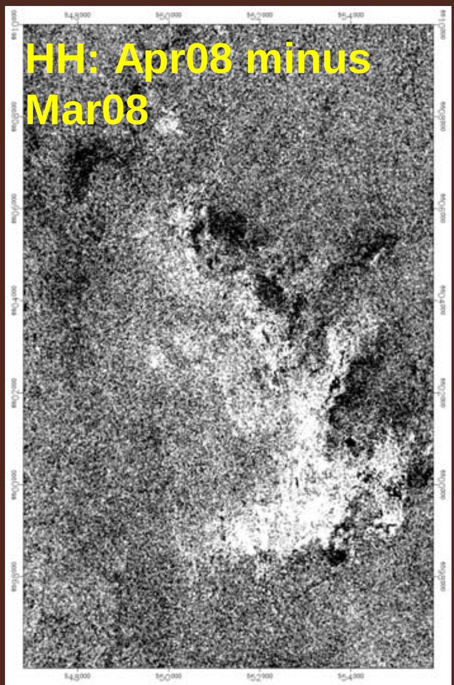


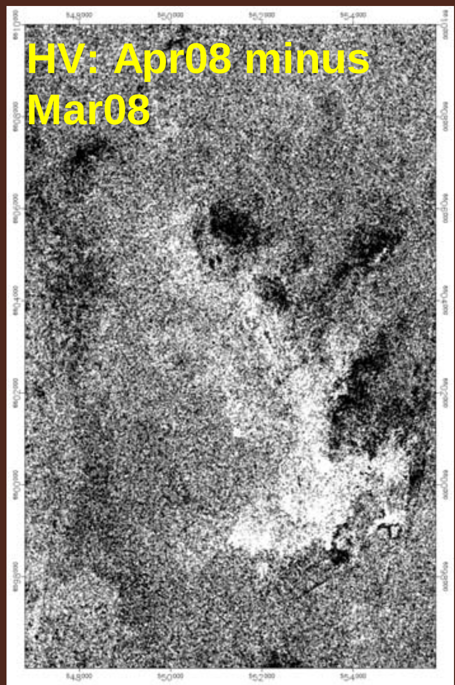
Change detection TerraSAR-X

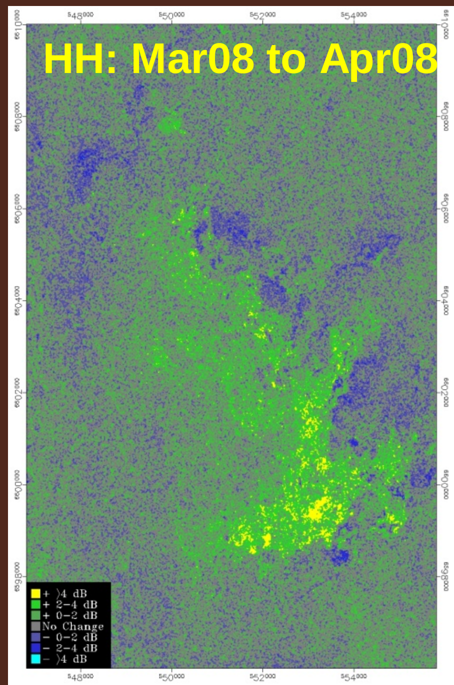
X-HH backscatter is responding to changing soil moisture levels as a result of flooding in Dec07. Patches of bare ground have become smooth, wet mud, and small ponded areas have formed. Both surfaces induce specular scattering and hence appear dark on the imagery.
Edge wetland shows an increase in backscatter, higher at HH due to high soil moisture and a flush in vegetation growth.

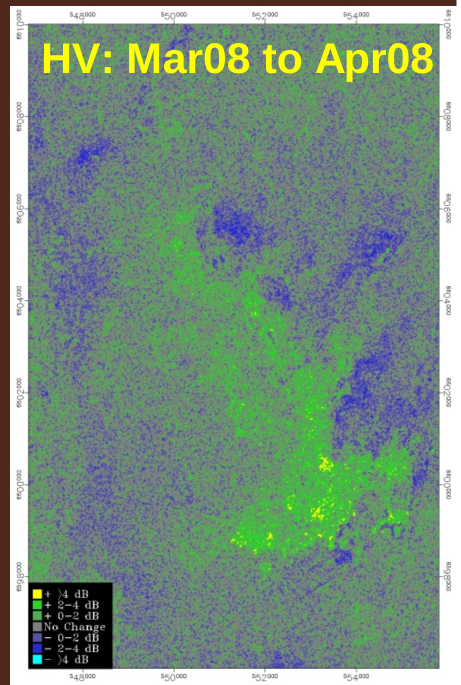










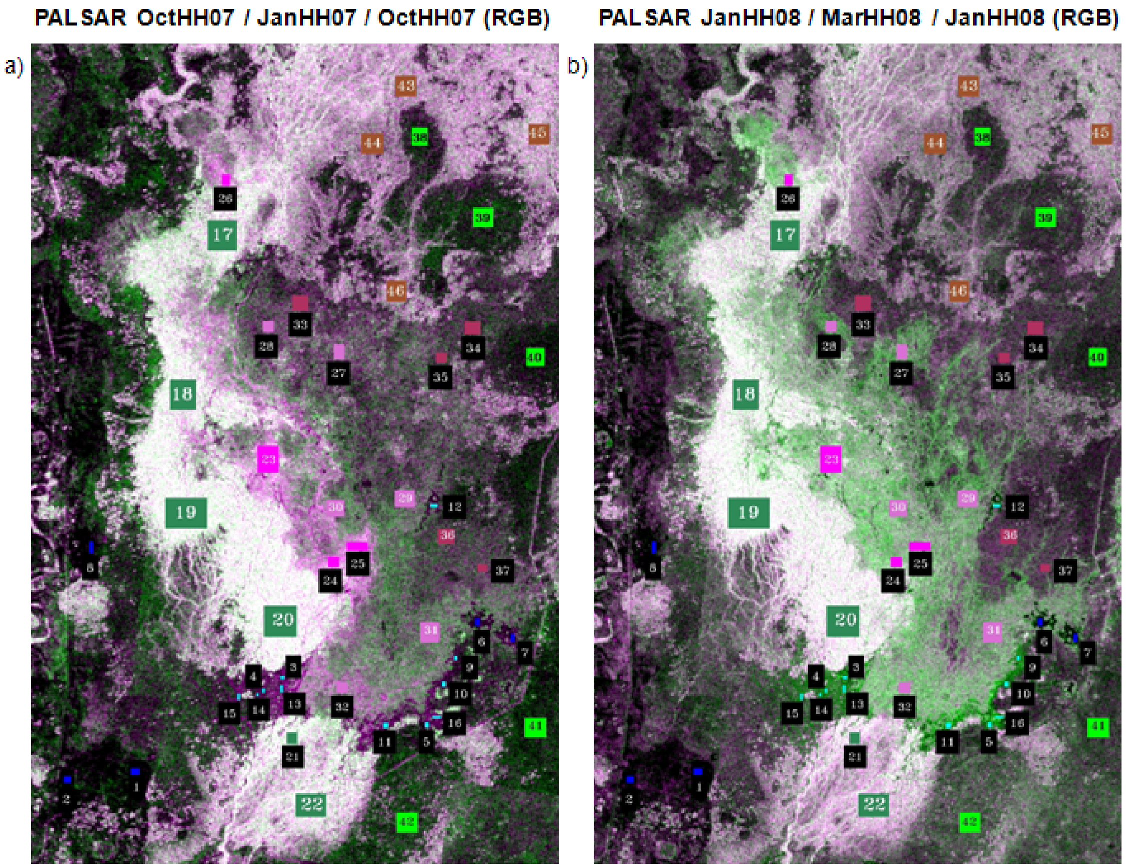


Delineation of wetland communities

Delineation of wetland communities

Spectral separability between cover classes

Area #1



X-band Terra-SAR

C-band Radarsat-1

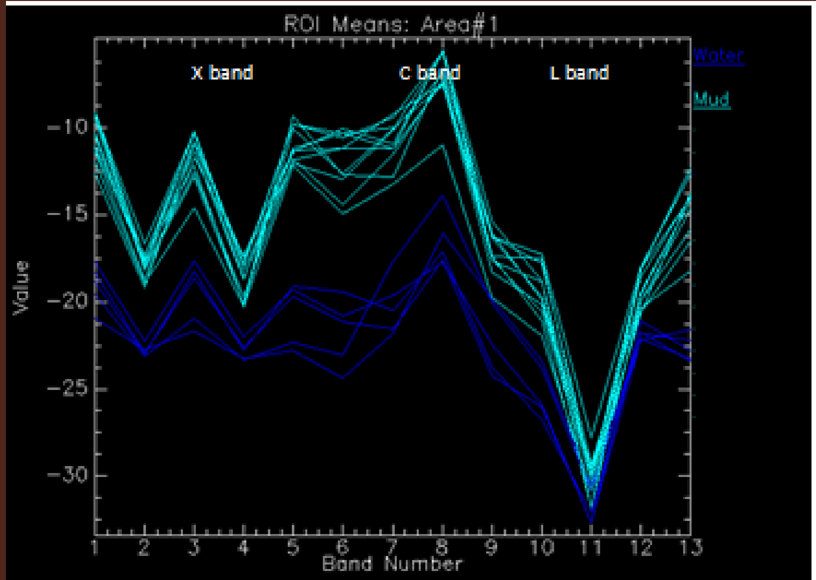
L-band ALOS-PALSAR

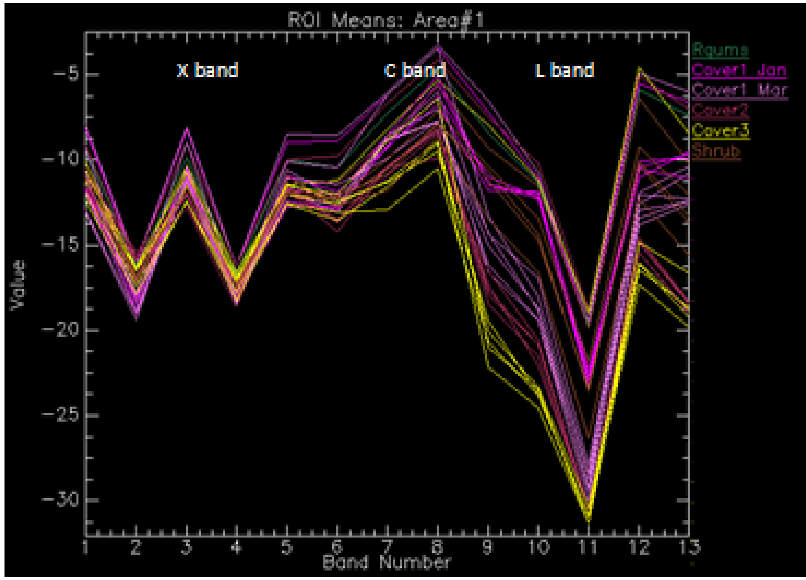
ROI #	Surface cover	Estimated wetness	Detailed site description
1, 2, 6 – 8	Water	Wet in Jan08 and Mar08	Ponded, open water
3 – 5, 9 – 16	Mud	Wet in Jan08	Water or wet mud
17 – 20	Forest	Wet in Jan07, Oct07, Jan08 and Mar08	River red gums
21 – 22	Forest	Wet in Oct07, Jan08 and Mar08	River red gums
23 – 26	Open forest	Wet in Jan08 and Mar08	Sparse juvenile – young River red gums & wetland shrubs
27 – 32	Open forest	Wet in Jan08 and Mar08	Sparse juvenile – young River red gums & wetland shrubs
33 – 37	Shrubs	Wet in Jan08	Wetland shrubs & grasses
38 – 42	Shrubs	Wet in Jan08	Wetland shrubs & grasses
43 – 46	Forest	Wet in Jan08	River red gums & wetland shrubs

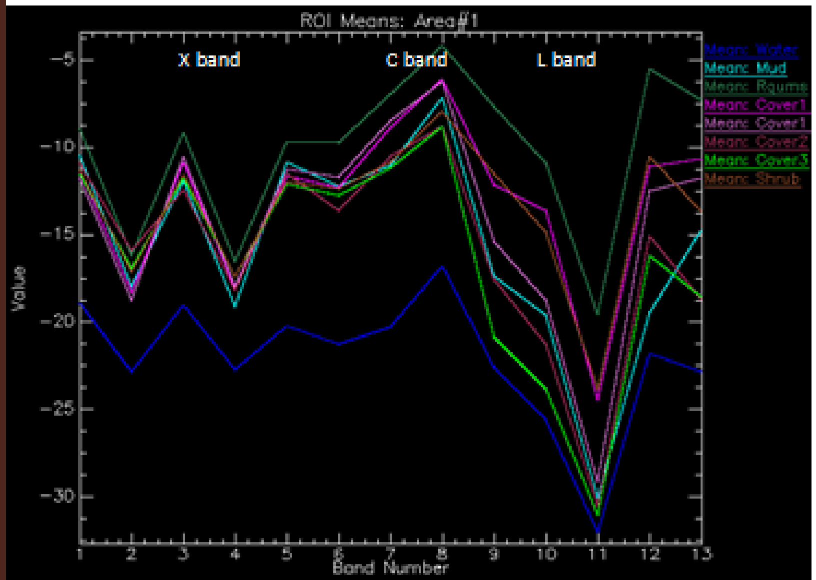
ROIs for different cover classes identified on PALSAR imagery:
a) Oct07:Jan07:Oct07; and
b) Jan08:Mar08:Jan08.

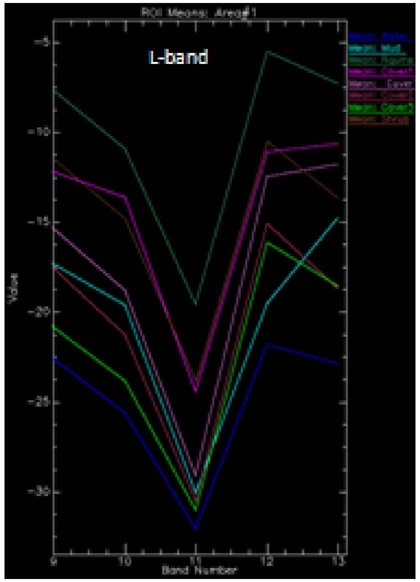
46 ROIs in total, representative of the dominant wetland vegetation and surface cover

Radar spectra of wetland cover classes









Radar spectra for ROI's for each cover class
TL – Water and Mud
TR – vegetation classes
Bottom – mean spectra for each cover class

Bands

1. TSX StirpMap HH Mar08
2. TSX StripMap HV Mar 08
3. TSX StripMap HH Apr 08
4. TSX StripMap HV Apr08
5. TSX ScanSAR HH Mar08
6. TSX ScanSAR HH Apr08
7. Radarsat HH Feb08
8. Radarsat HH Mar08
9. PALSAR HH Jan07
10. PALSAR HH Oct07
11. PALSAR HV Oct07
12. PALSAR HH Jan08
13. PALSAR HH Mar08

Delineation of wetland communities

Pair separation: least-to-most

PALSAR Oct07 HHHV, Jan08 HH and Mar08 HH

Cover2 and Cover3	0.86091280
Cover1 and Cover1 Mar	0.93103708
Cover1 Jan and Shrub	0.99866084
Rgums and Cover1 Jan	1.48350942
Cover1 Mar and Shrub	1.54459046
Rgums and Shrub	1.60906854
Cover2 and Shrub	1.81467935
Water and Mud	1.84897197
Water and Cover3	1.86261779
Mud and Cover3	1.87628350
Mud and Cover1 Jan	1.87754546
Cover1 Mar and Cover3	1.87883994
Mud and Cover2	1.89244011
Mud and Cover1 Mar	1.90478837
Cover1 Mar and Cover2	1.92188775
Cover1 Jan and Cover3	1.94861968
Cover3 and Shrub -	1.95281853
Cover1 Jan and Cover2	1.96141156
Rgums and Cover1 Mar	1.96928921
Mud and Shrub	1.97136449
Water and Cover2	1.99067615
Water and Shrub	1.99930970
Water and Cover1 Jan	1.99982266
Mud and Rgums	1.99990883
Water and Cover1 Mar	1.99997995
Rgums and Cover2	1.99999545
Rgums and Cover3	1.99999893
Water and Rgums	2.00000000

Radarsat C-HH 25Feb and 20March 2008

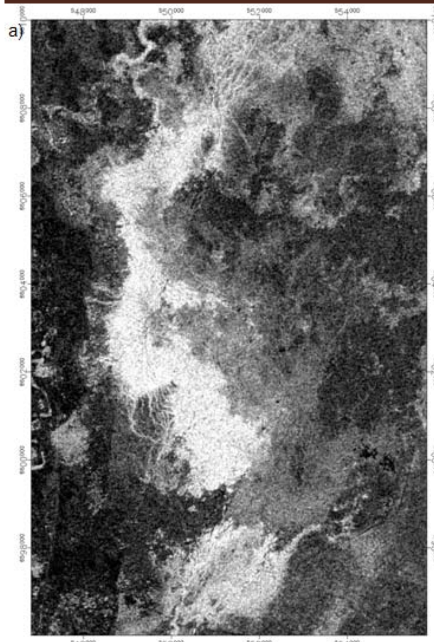
Cover1 Jan and Cover1 Mar	0.02091268
Cover2 and Cover3	0.02763956
Cover2 and Shrub	0.05069727
Cover3 and Shrub	0.05127454
Mud and Shrub	0.06184305
Mud and Cover3	0.10880794
Mud and Cover1 Mar	0.11336449
Mud and Cover1 Jan	0.12449420
Mud and Cover2	0.17182107
Cover1 Mar and Shrub	0.20490970
Cover1 Jan and Shrub	0.21625582
Rgums and Cover1 Mar	0.23787841
Rgums and Cover1 Jan	0.25011389
Cover1 Mar and Cover3	0.28706091
Cover1 Mar and Cover2	0.32467776
Cover1 Jan and Cover3	0.33979363
Cover1 Jan and Cover2	0.36659233
Mud and Rgums	0.53689267
Rgums and Shrub	0.80443555
Rgums and Cover3	0.92583331
Rgums and Cover2	1.02045745
Water and Cover3	1.46869846
Water and Mud	1.57293494
Water and Cover2	1.61338809
Water and Shrub	1.65052439
Water and Cover1 Mar	1.76898114
Water and Cover1 Jan	1.82643767
Water and Rgums	1.94410996

Terra-X StripMap HH+HV 2March 2008

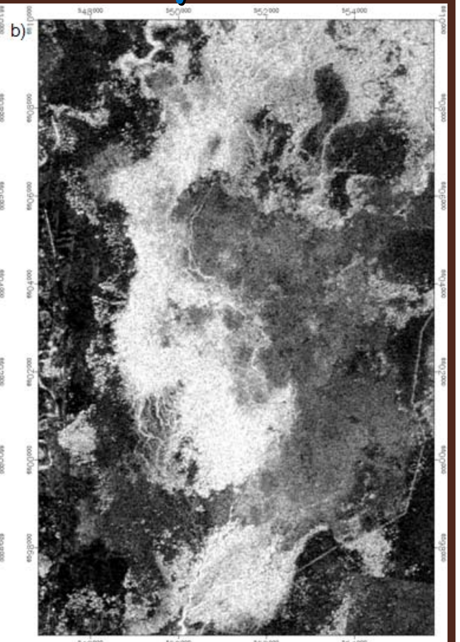
Cover3 and Shrub	0.01991971
Mud and Cover1 Jan	0.06847982
Cover1 and Cover1 Mar	0.07551740
Mud and Cover1 Mar	0.13578311
Cover2 and Cover3	0.16110290
Cover1 Jan and Shrub	0.21279707
Cover2and Shrub	0.22122928
Mud and Shrub	0.28682247
Cover1 Jan and Cover3	0.30402188
Mud and Rgums -	0.32609357
Mud and Cover3	0.40760145
Cover1 Mar and Shrub	0.45339780
Rgums and Shrub	0.46177694
Rgums and Cover2	0.50727863
Rgums and Cover3	0.53816755
Cover1 Mar and Cover3	0.55322620
Rgums and Cover1 Jan	0.55809957
Cover1 Jan and Cover2	0.67474428
Mud and Cover2	0.67986993
Rgums and Cover1 Mar	0.70284812
Cover1 Mar and Cover2	0.96985169
Water and Cover1 Mar	1.57771810
Water and Cover1 Jan	1.79145443
Water and Mud	1.81715242
Water and Shrub	1.92149698
Water and Cover3	1.92245072
Water and Rgums	1.94500660
Water and Cover2	1.97443708

Spectral separation using Jeffries-Matusita and Transformed Divergence separability measures. These values range from 0 to 2.0 and indicate how well the selected ROI pairs are statistically separate. Values >1.9 indicate that ROI pairs have good separability.

Canonical Variate Analysis – CVA

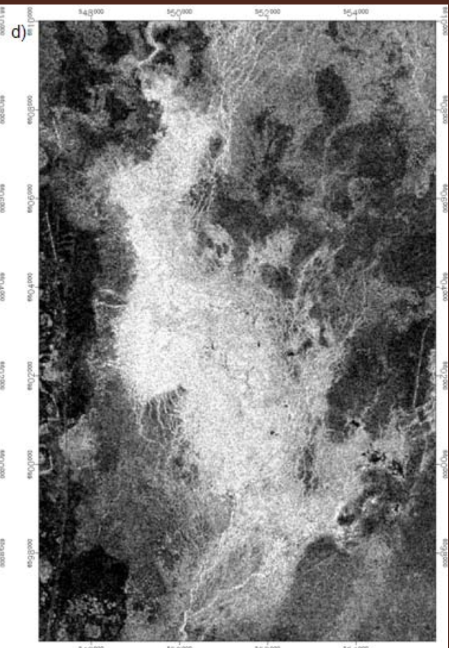


CV1: 76% (-2.7*B1+3.6*B2+B3+2.1*B4)



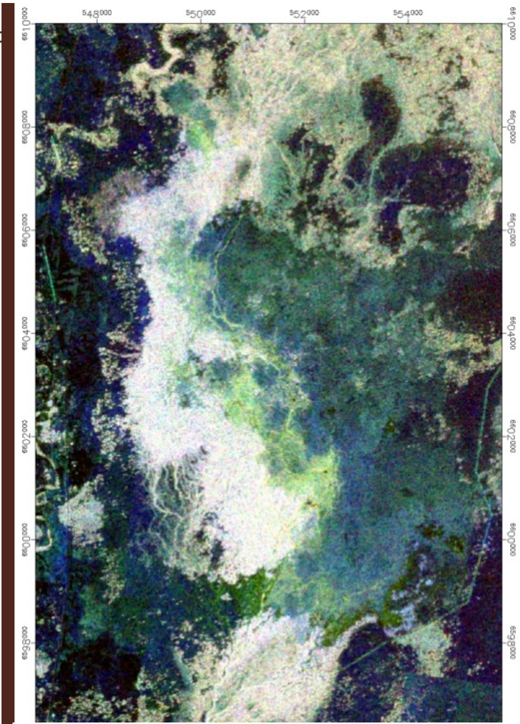
CV2: 18% (3*B1+B2+8.4*B3-2.5*B4)

CV3: 3.3% (11.8*B1+6.2*B2-14.8*B3+B4)



CV4: 2.7% (B1-1.6*B2-2*B3+7.6*B4)

CV2: CV1:CV3 (RGB)



Oct07HH / Oct07HV / Jan08HH (RGB)

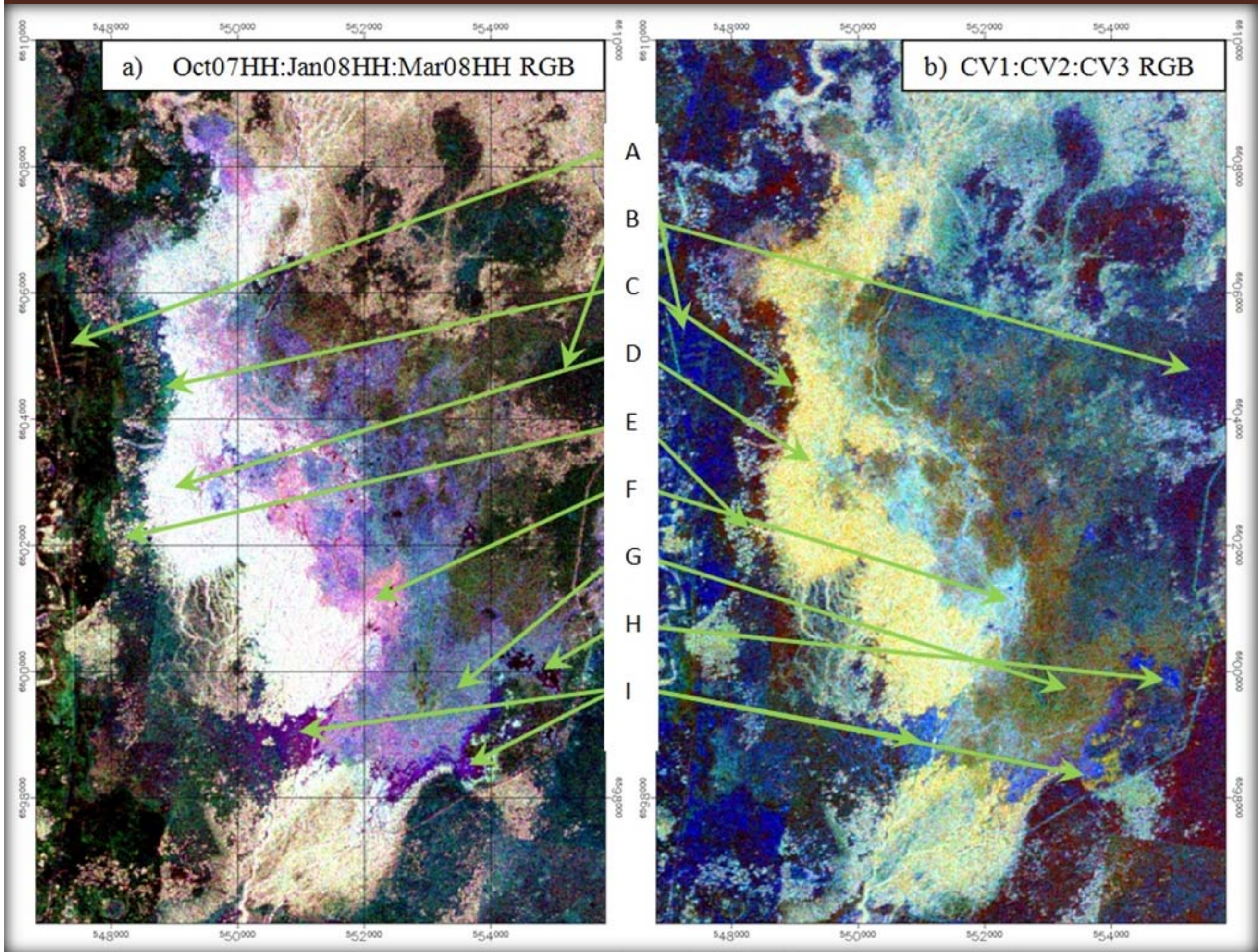
All-bands subset analysis

No. bands	Image dates and polarisation	Percent of contained information
4	Oct07 HH:Oct07 HV:Jan08 HH:Mar08 HH	100 %
3	Oct07 HH:Oct07 HV:Jan08 HH	91.7%
	Oct07 HH:Oct07 HV:Mar08 HH	88.3%
	Oct07 HV:Jan08 HH:Mar08 HH	86.6%
	Oct07 HH:Jan08 HH:Mar08 HH	73.8%
2	Oct07 HH:Oct07 HV	79.7%
	Oct07 HV:Jan08 HH	78.4%
	Oct07 HV:Mar08 HH	60.1%
	Oct07 HH:Jan08 HH	59.5%
1	Oct07 HV	52.7%
	Oct07 HH	29.1%
	Jan08 HH	26.8%
	Mar08 HH	22.4%

Delineation of wetland communities

Canonical Variate Analysis of PALSAR data

Area #1



Wetland classes identified in the CVA image include:

A Bare or sparsely vegetated ground and old river channels

B Floodplain shrub and grassland

C Narrow strip of potentially inundated ground

D Red gum forest

E Scattered patches of red gums

F Edge wetland

G Potentially inundated floodplain wetland

H Open water

I Water with aquatic vegetation cover

General conclusions

The study has demonstrated the ability of imaging radar to map and monitor changes in wetland hydrology and discriminate between different wetland cover types. Following the release of environmental water into the Macquarie Marshes, and acquisition of a suitable time series of L-band ALOS PALSAR data, the following outcomes can be achieved:

- The presence of and changes in surface water and soil moisture content;
- The generation of spatial map data of inundation extent over the period of image acquisition;
- The monitoring of flood extents and changing wetland dynamics over the timeframe of image acquisition;
- The discrimination of wetland cover classes using time-series analysis;
- Monitoring of changes in wetland condition using change detection techniques; and
- The generation of spatial map data of wetland community extent.

Additionally, the acquisition of multi-frequency SAR data (e.g., ALOS PALSAR and TerraSAR-X) may achieve the following:

- Improved discrimination of wetland cover types based on short- and longer-wavelength radar response to vegetation structure, moisture content and surface roughness.

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Thank you

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