Change monitoring in near real-time using Landsat and MODIS

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Objectives

Reconstruct the history of Earth in the satellite era

Near real-time monitoring of change (disturbance)

Fusion of Landsat and MODIS

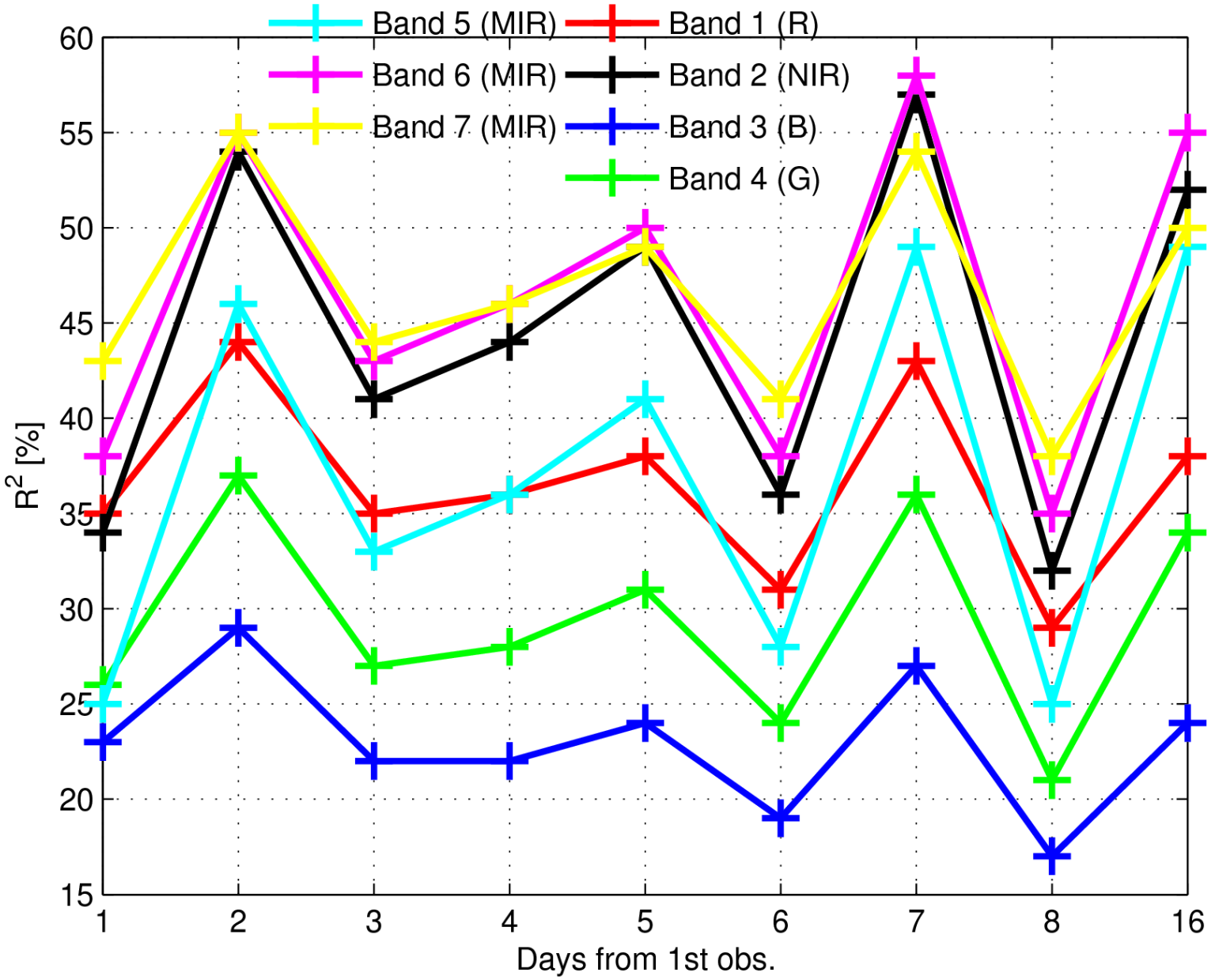
Use time series of Landsat data to predict what the next image should look like (meaning in the absence of change or disturbance) - two years of Landsat imagery used to predict a new unseen year

“predict” at Landsat spatial resolutions daily and then aggregate to MODIS resolutions

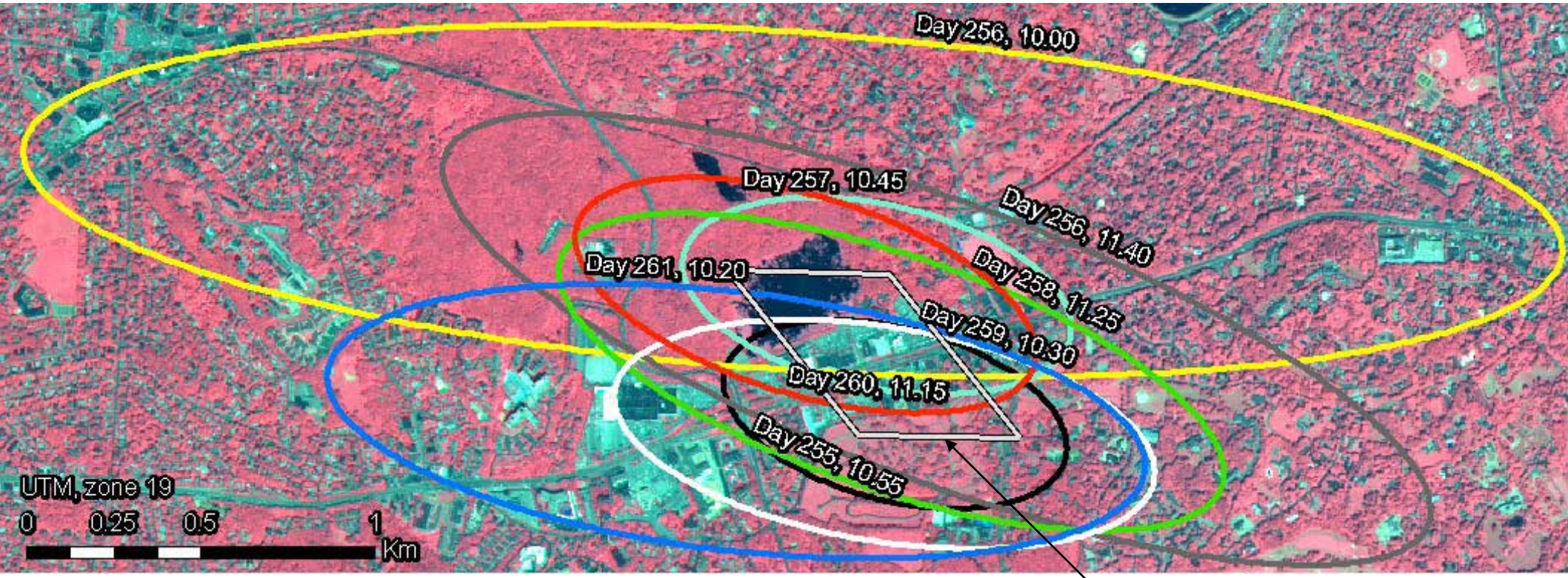
Critical to this approach is the use of MODIS swath data (before it is gridded)

Compare observed MODIS with predicted MODIS to flag change (can be done daily, limited by clouds)

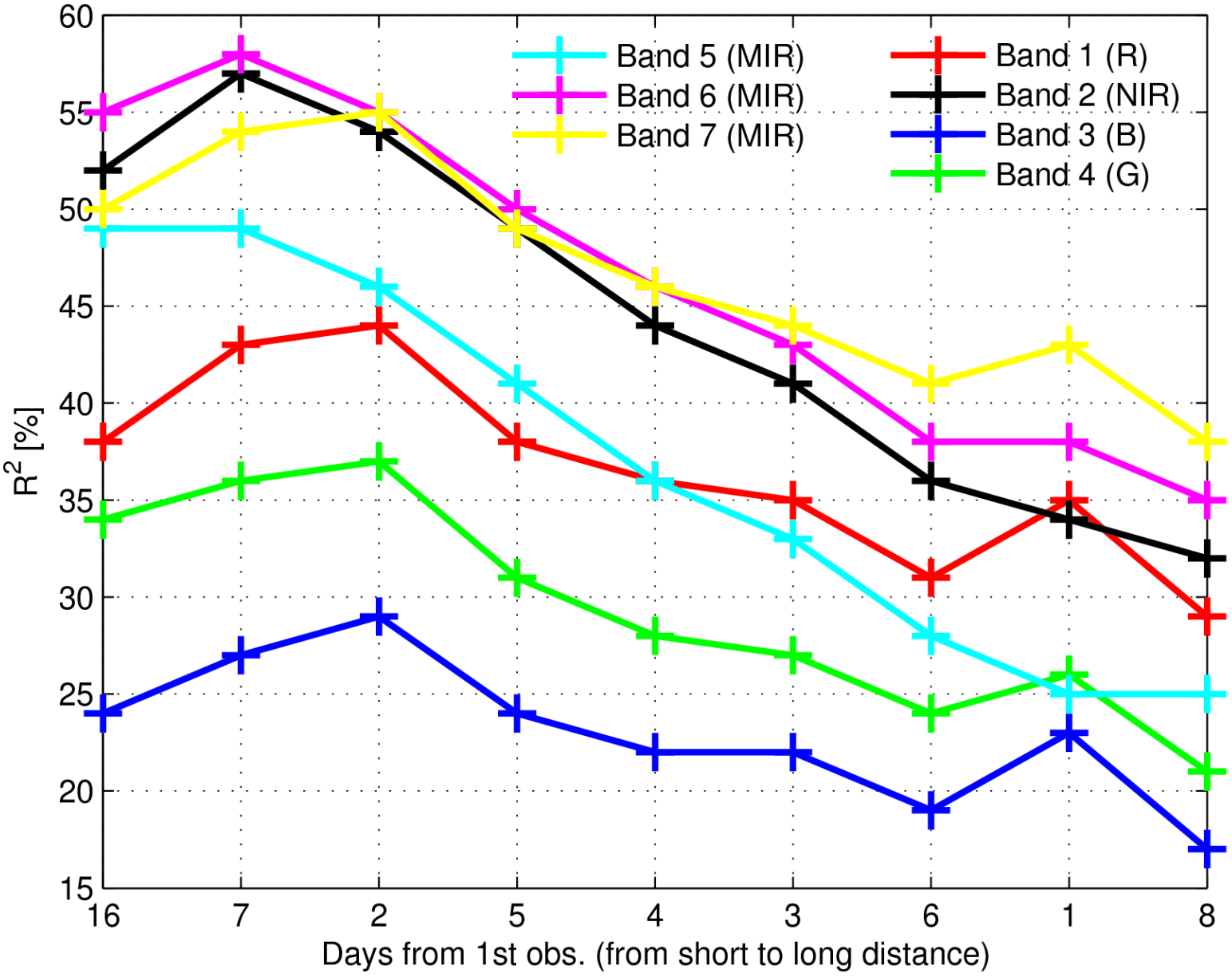
Relationship between consecutive MODIS SR images during 2001



MODIS observation footprints during one week



Sorted by differences in view angles



Time series model for Landsat

$$f(x) = a_0 + \sum_{i=1}^{N} [a_i \cos\left(\frac{2\pi}{iT}\right)x + b_i \sin\left(\frac{2\pi}{iT}\right)x] + a_{N+1} \cos\left(\frac{2\pi}{0.5T}\right)x + b_{N+1} \sin\left(\frac{2\pi}{0.5T}\right)x$$

Where,

x = Julian date

N = number of years

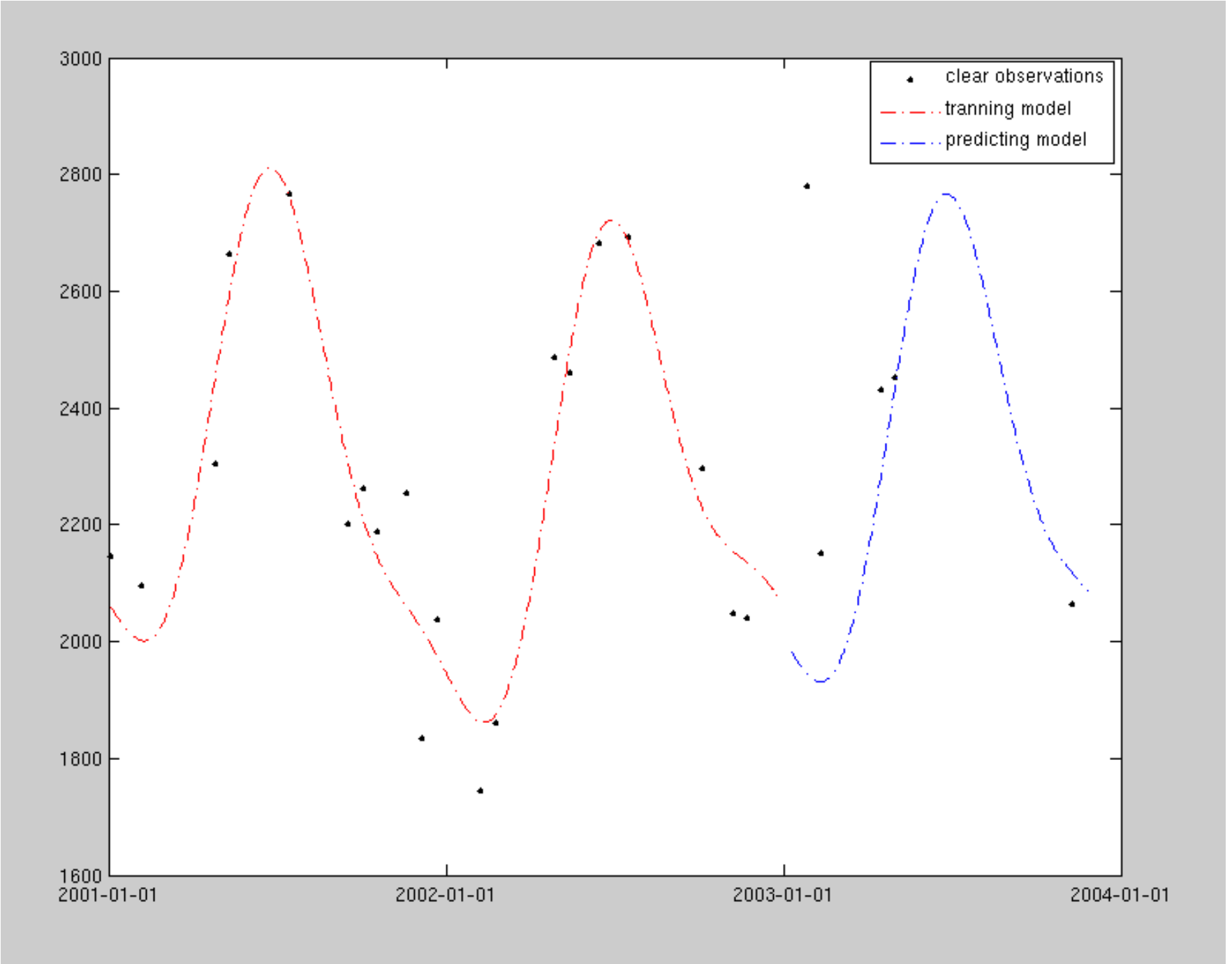
T = number of days per year (=365)

a_0 = coefficient for overall reflectance

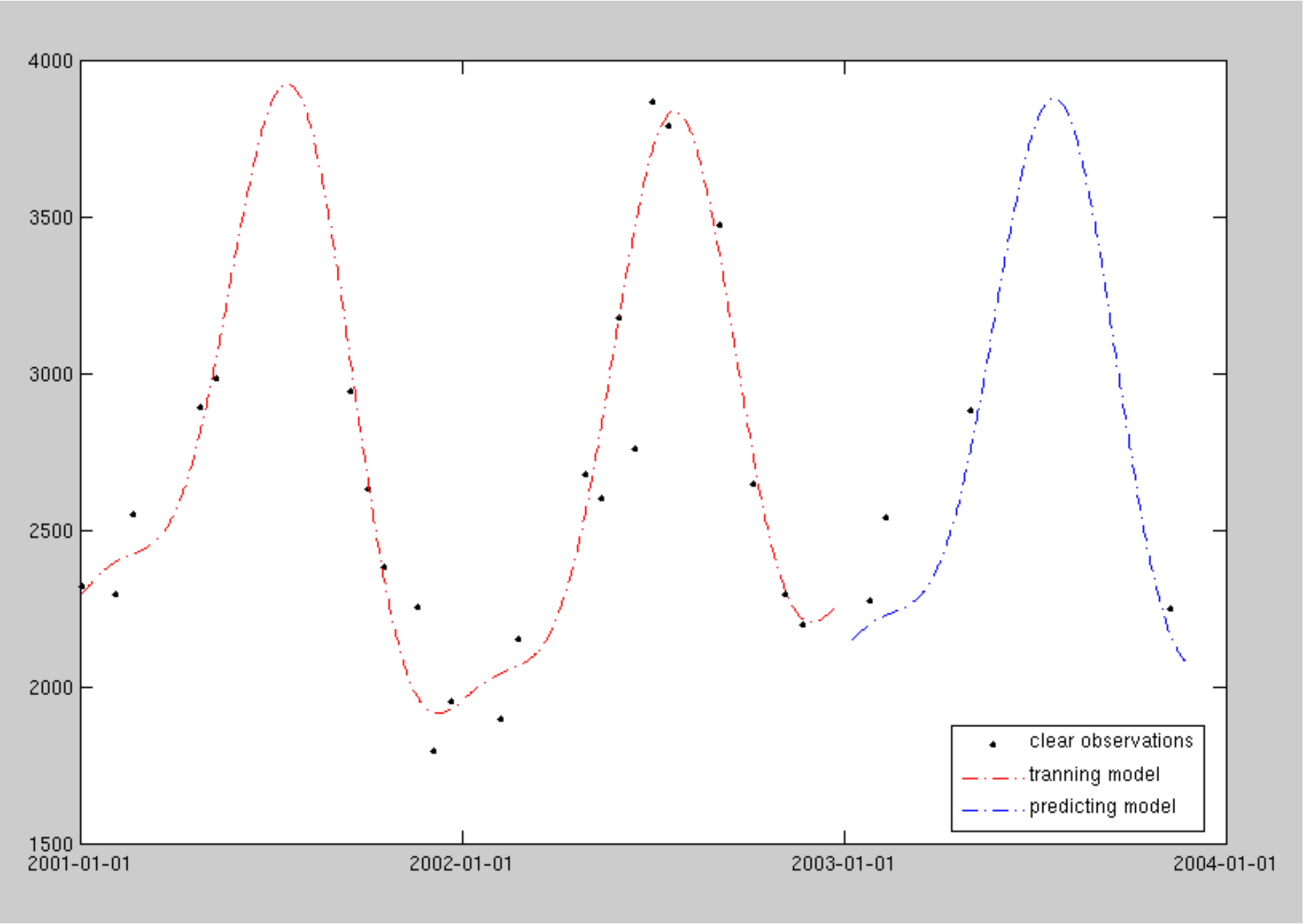
a_i, b_i = coefficients capture the changes over i^{th} year

a_{N+1}, b_{N+1} = coefficients for bimodal change.

Band 4 Surface Reflectance (model training and predicting at 1700, 1700)



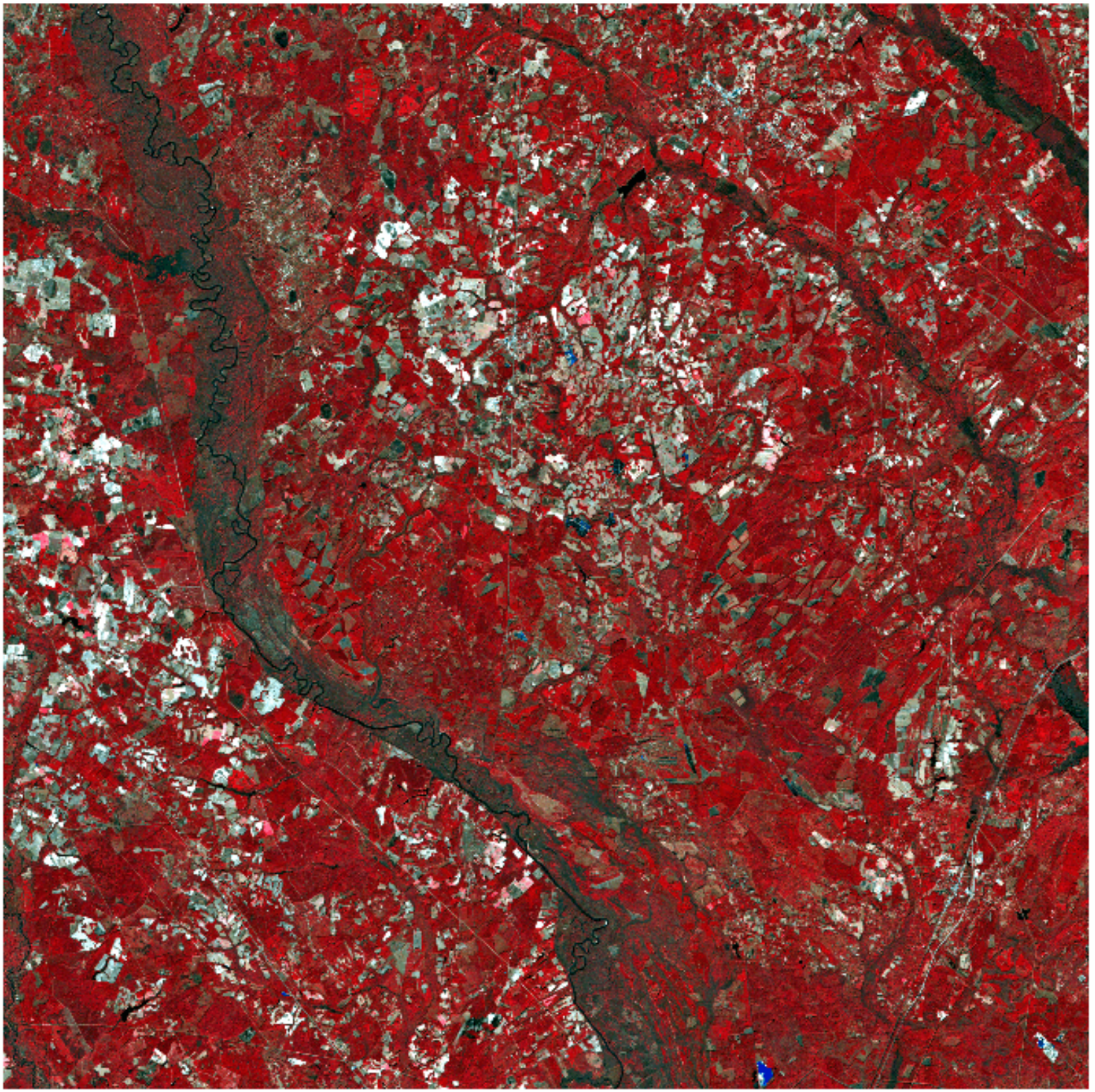
Band 4 Surface Reflectance (model training and predicting at 1700, 1750)



Study area

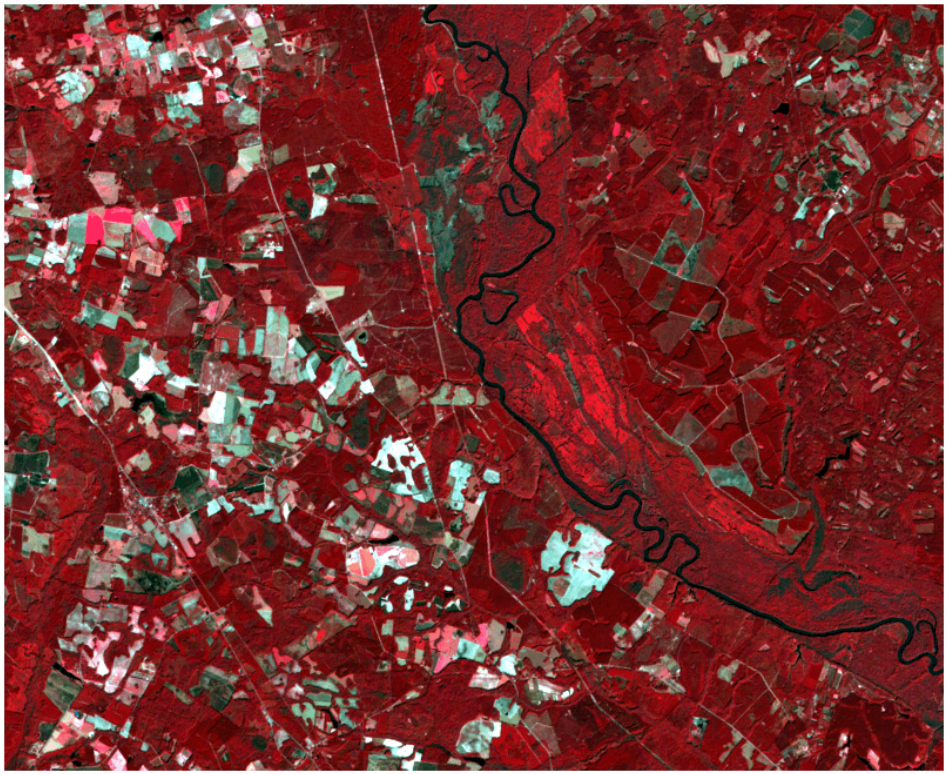
- 2000 x 2000 pixels (30 m), in Georgia
- Heavy cloud and cloud shadow contamination (11.28 clear ETM observations per year on average)

2001/1/4 Landsat SR imagery



Show animations

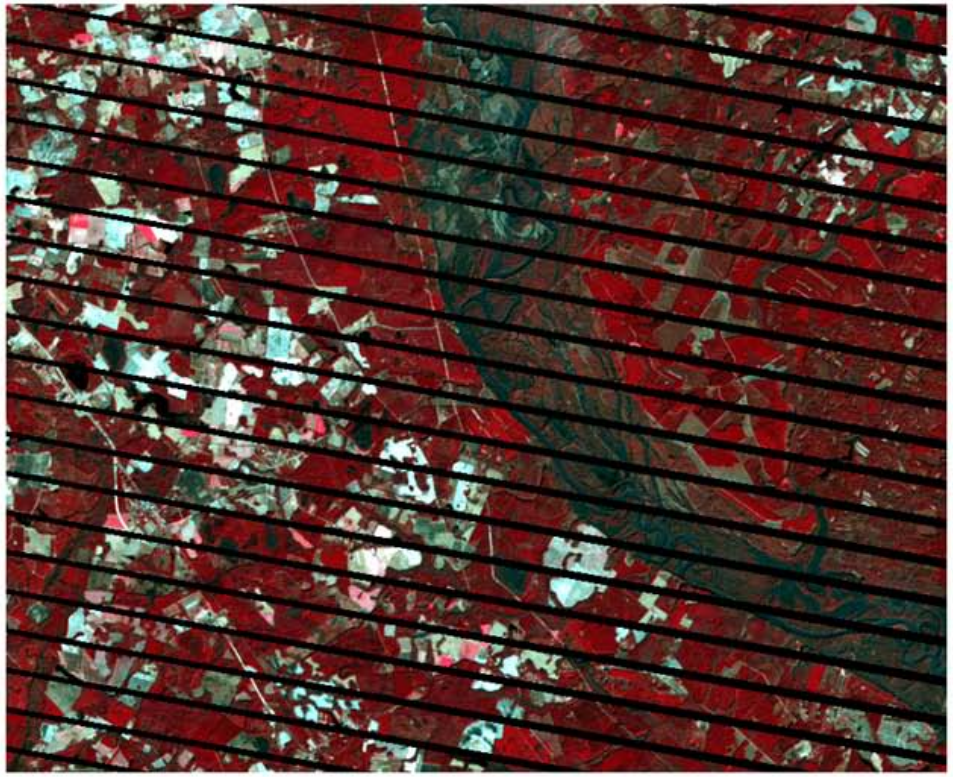
Landsat forest clearing during 2003



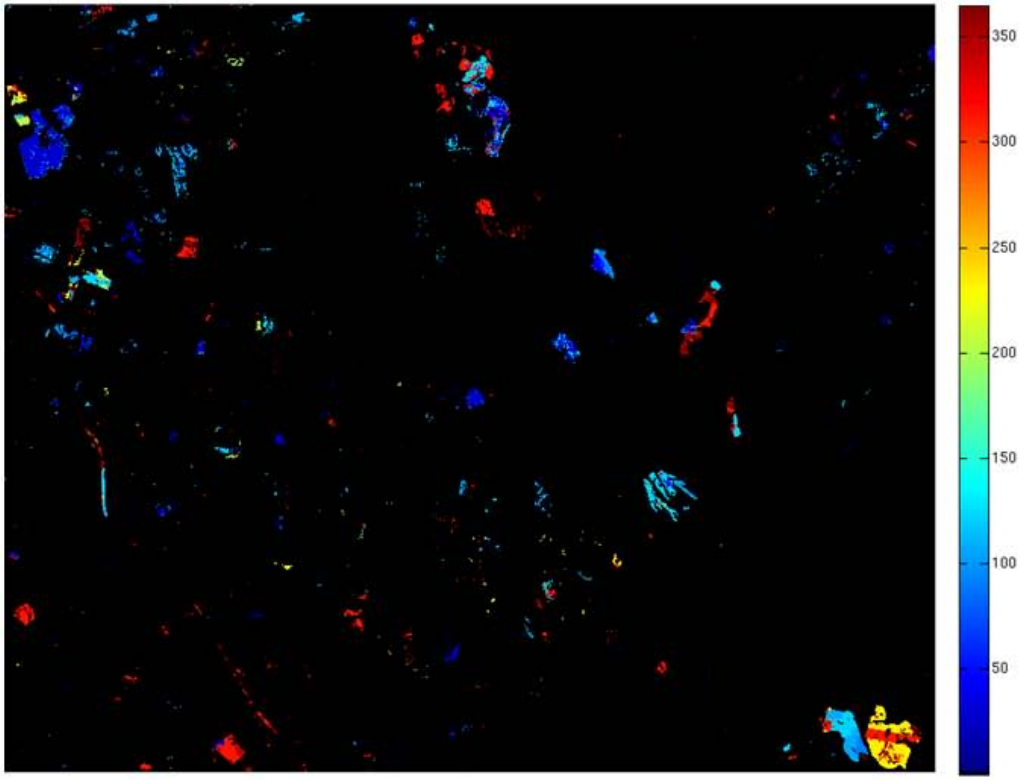
2002/11/23 Landsat SR

2002/11/23 deforestation

Final forest clearing within 2003

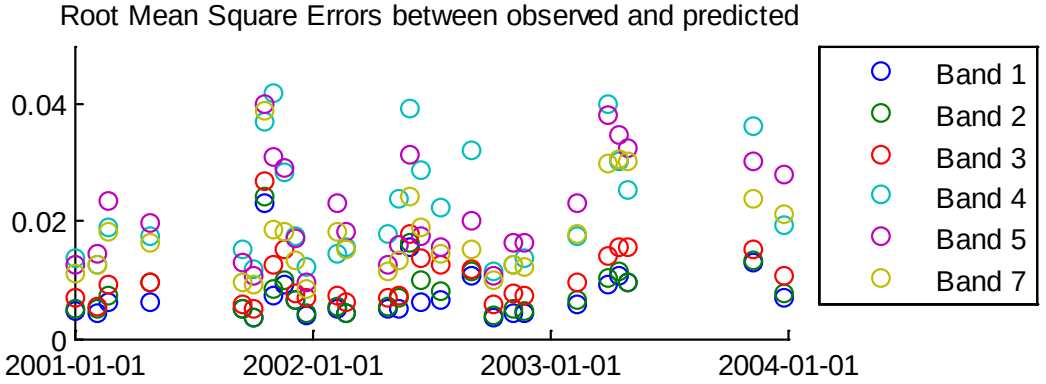


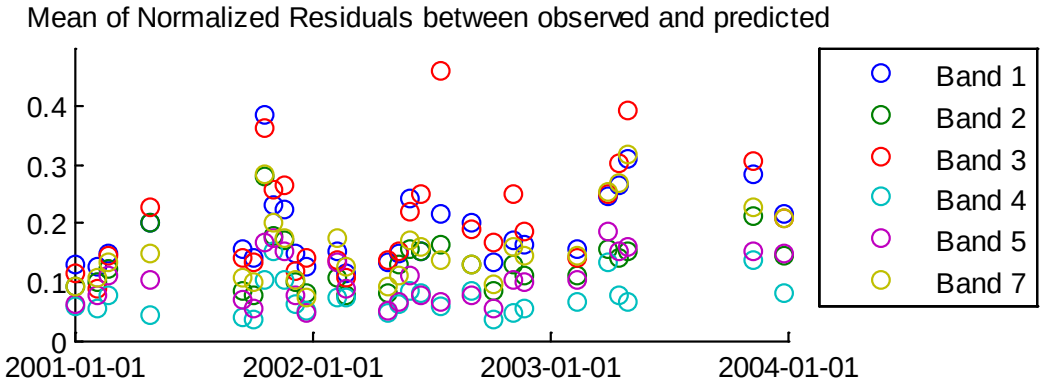
2003/12/28 Landsat SR



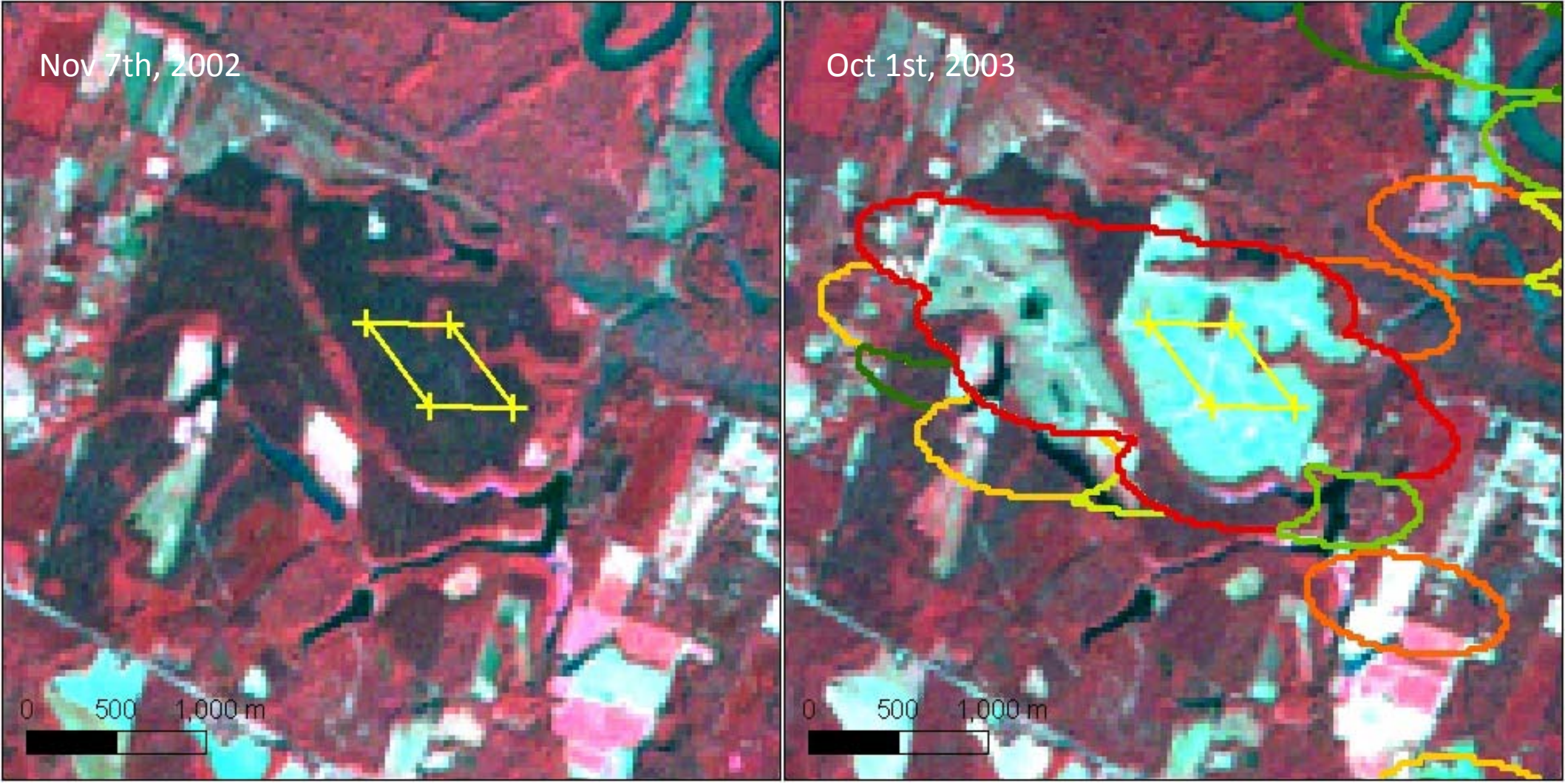
2003/12/28 deforestation

Accuracy assessment of predicted images





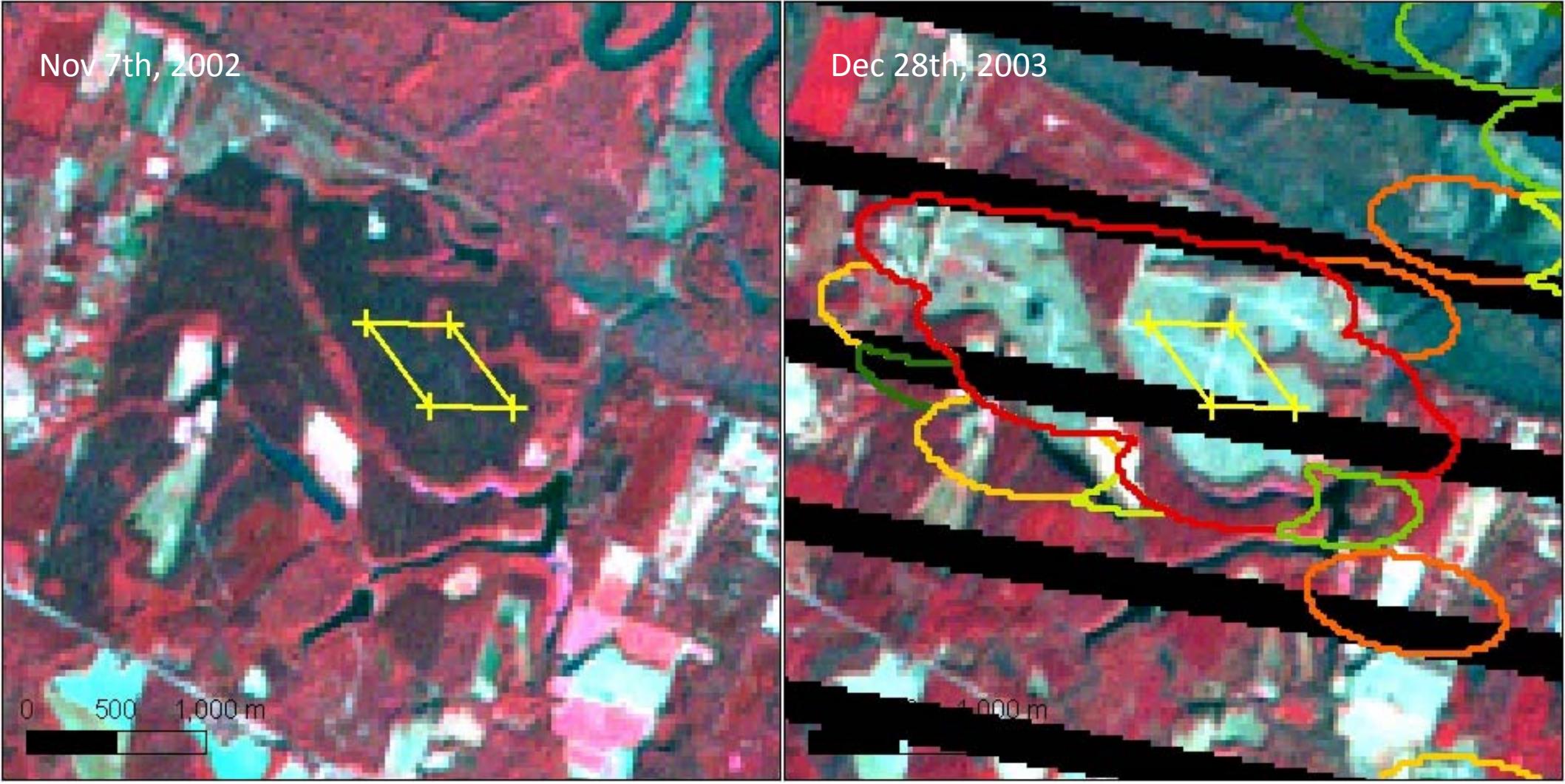
Landsat SR Band	Ref/DN	Mean RMSE
Band 2	0.003	0.0082
Band 4	0.004	0.0224
Band 7	0.0038	0.0176



Location of the MODIS
500 m "change" pixel

"Strength" of forest clearing flag

1
2
3
4
5
6

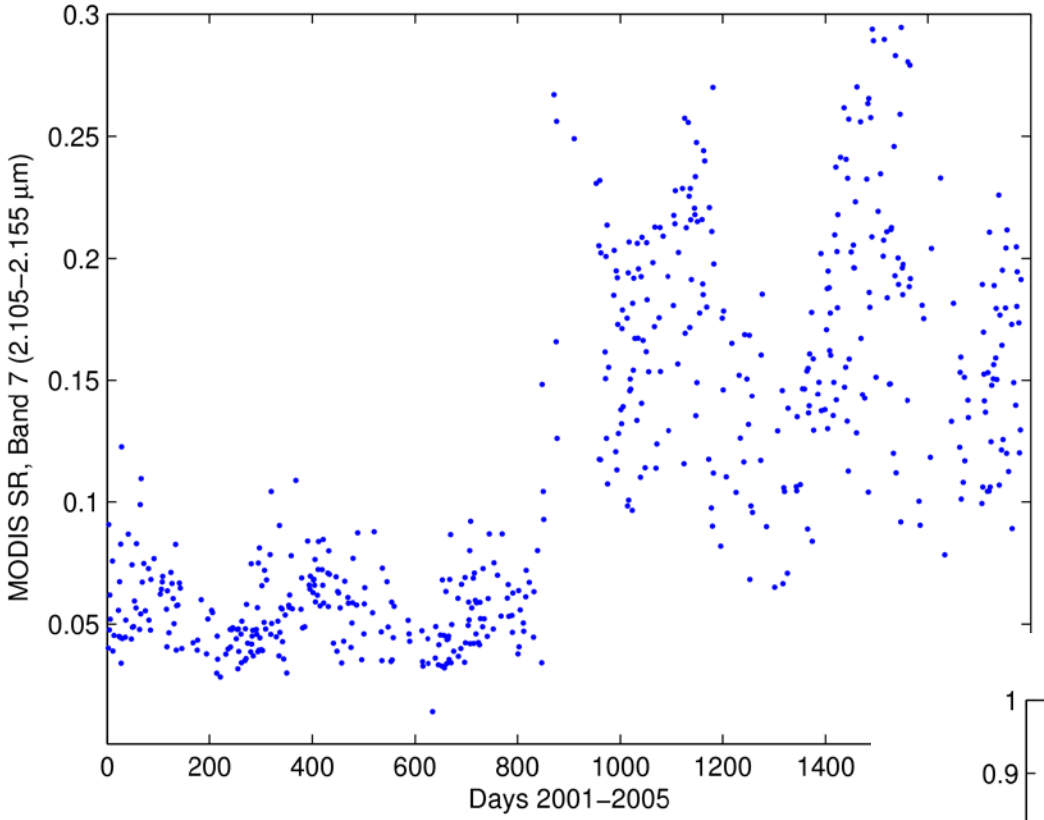


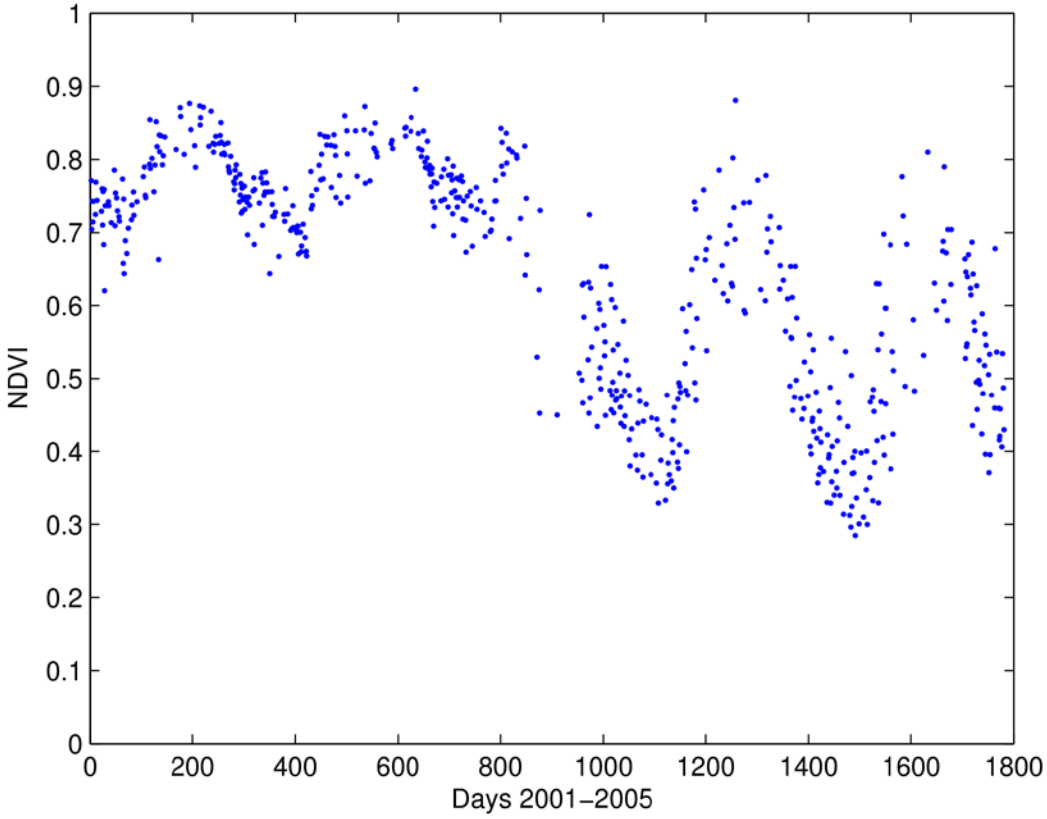
Location of the MODIS
500 m "change" pixel

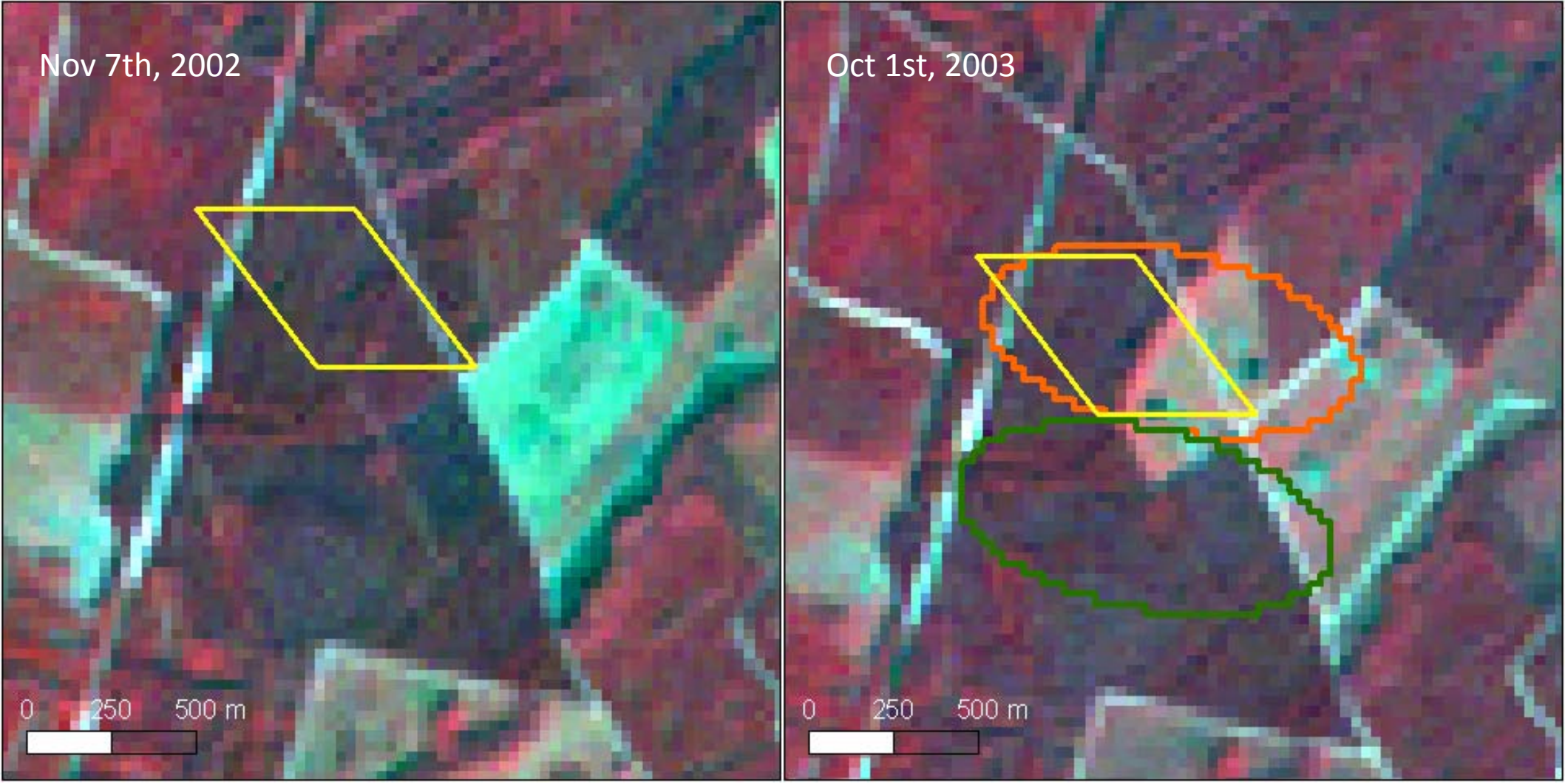
"Strength" of forest clearing flag

1
2
3
4
5
6

7. R1791 C350


MODIS SR, Band 7 (2.105–2.155 µm)
0.3
0.25
0.2
0.15
0.1
0.05
0
200
400
600
800
1000
1200
1400
Days 2001–2005

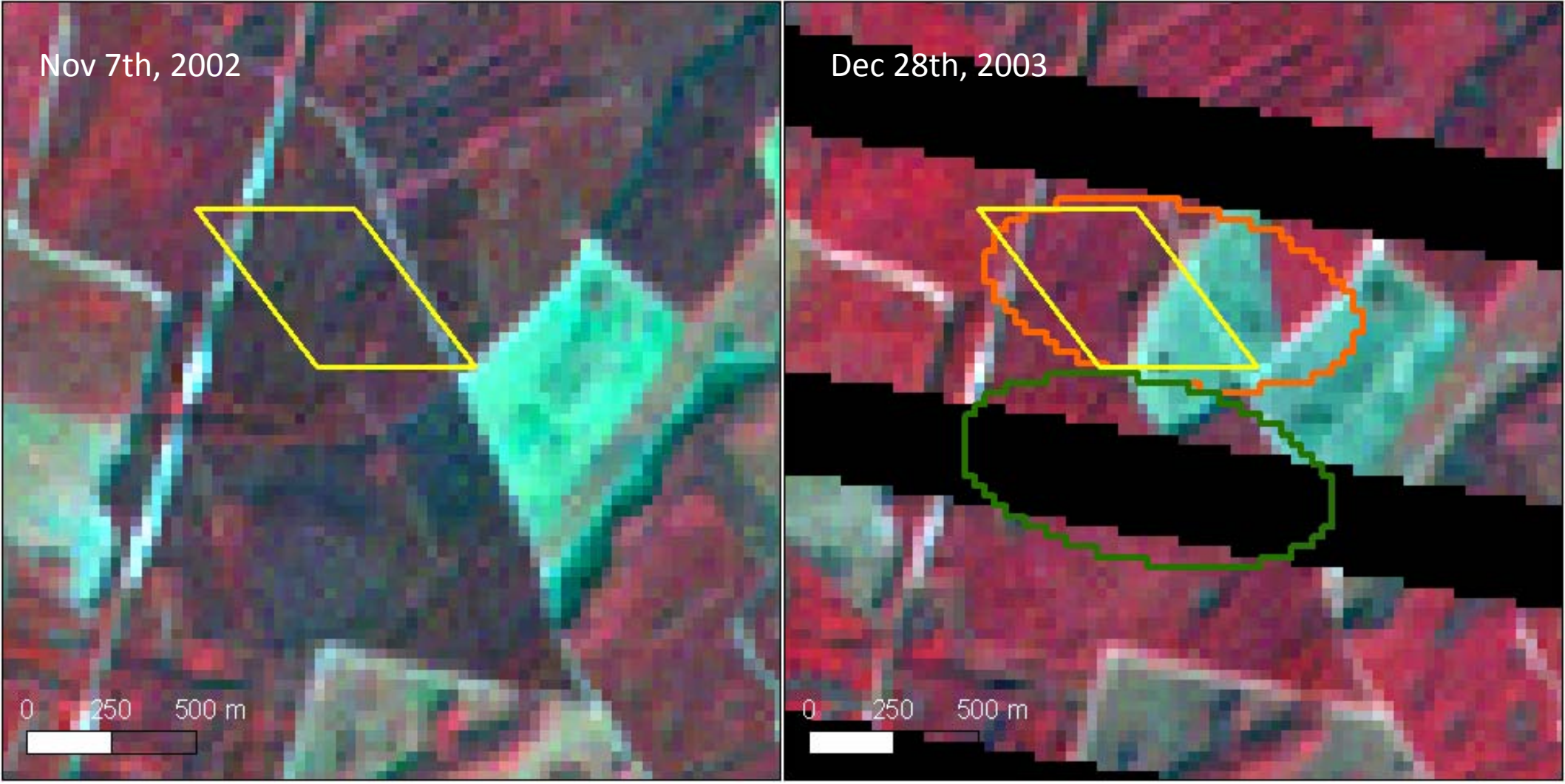

NDVI
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
1400
1600
1800
Days 2001–2005



Location of the MODIS
500 m "change" pixel

"Strength" of forest clearing flag

1
2
3
4
5
6

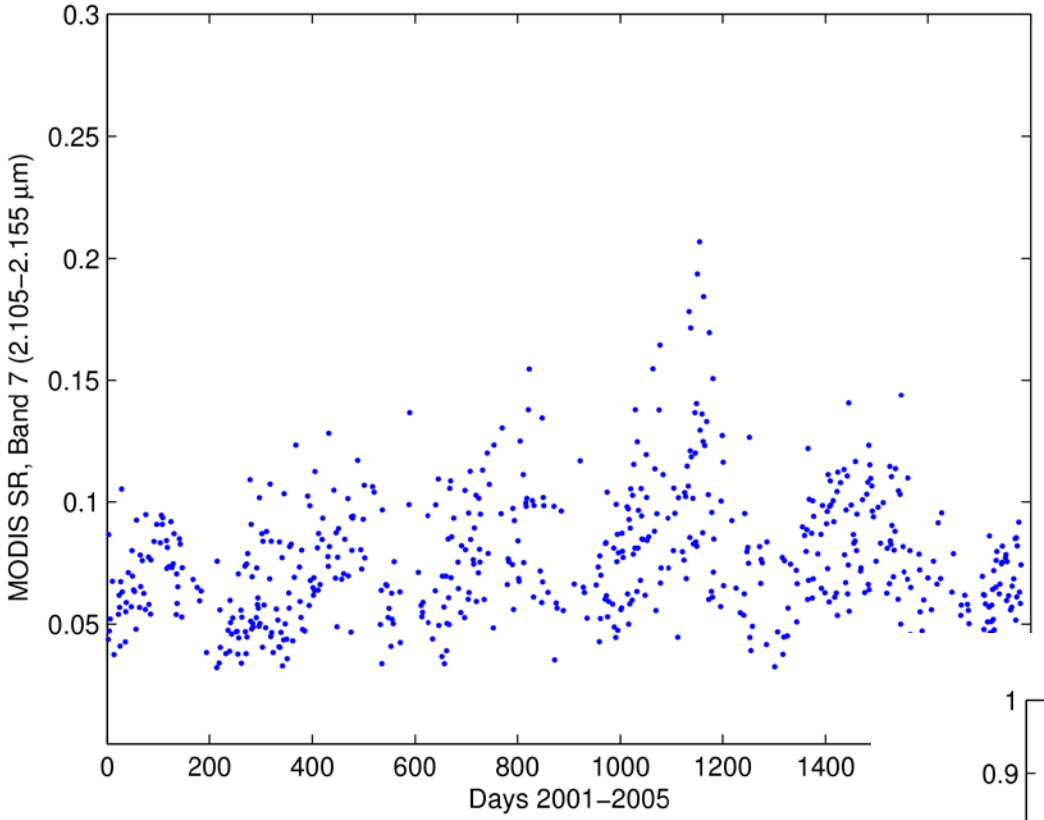


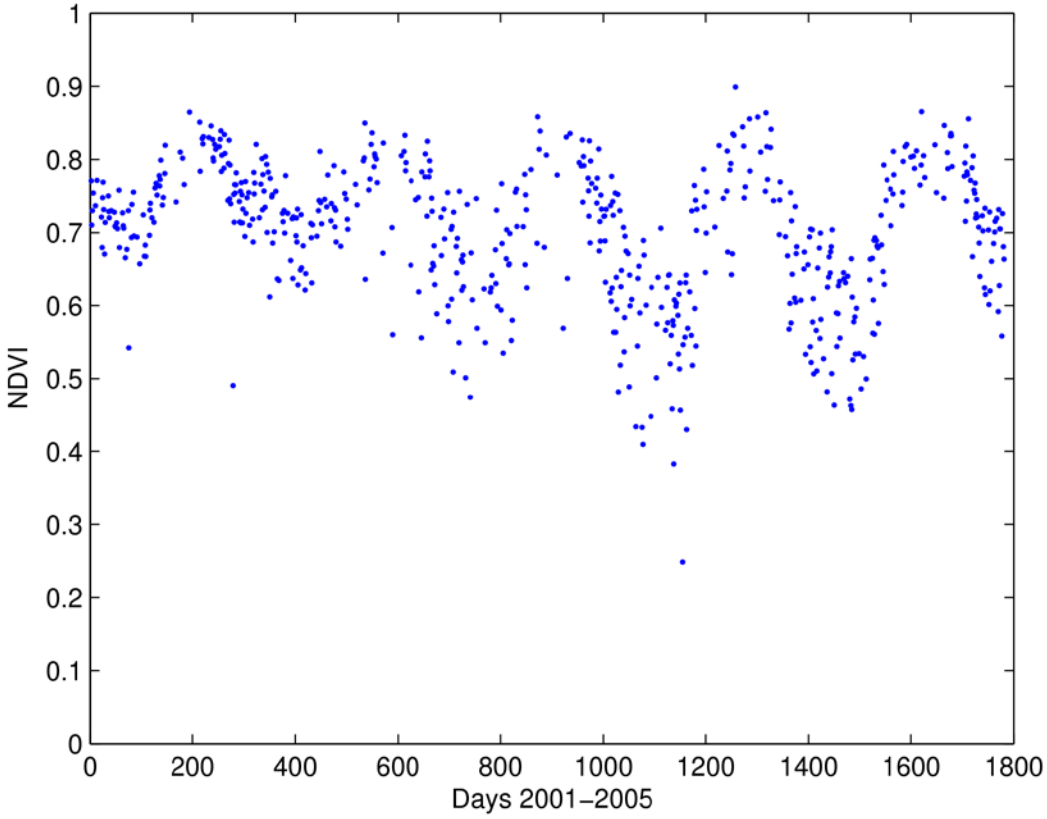
Location of the MODIS
500 m "change" pixel

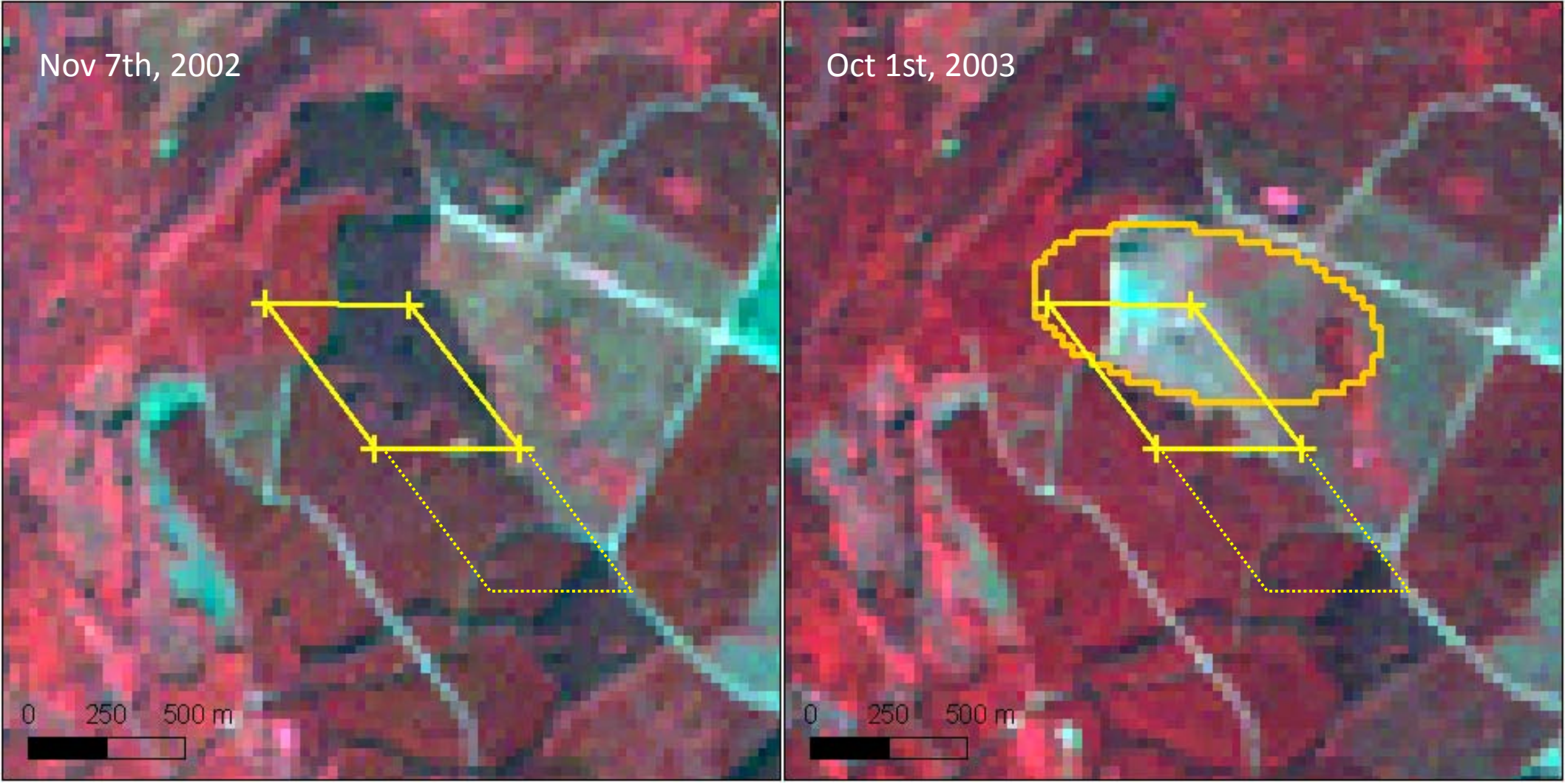
"Strength" of forest clearing flag

1
2
3
4
5
6

4. R1765 C405


MODIS SR, Band 7 (2.105–2.155 µm)
0.3
0.25
0.2
0.15
0.1
0.05
0
200
400
600
800
1000
1200
1400
Days 2001–2005

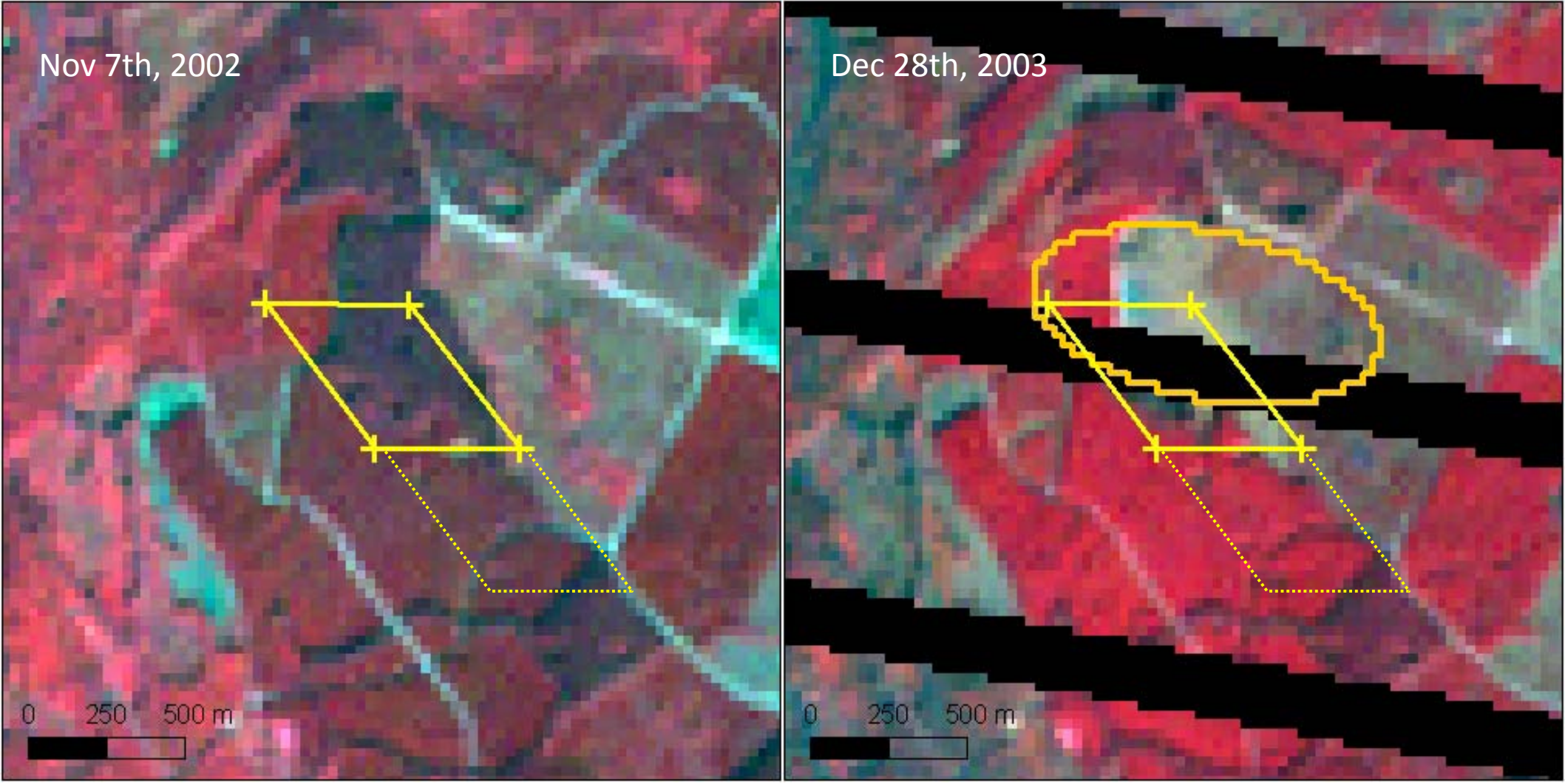

NDVI
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
1400
1600
1800
Days 2001–2005



Location of the MODIS 500 m "change" pixel (dashed polygon shows the reference pixel)

"Strength" of forest clearing flag

1
2
3
4
5
6

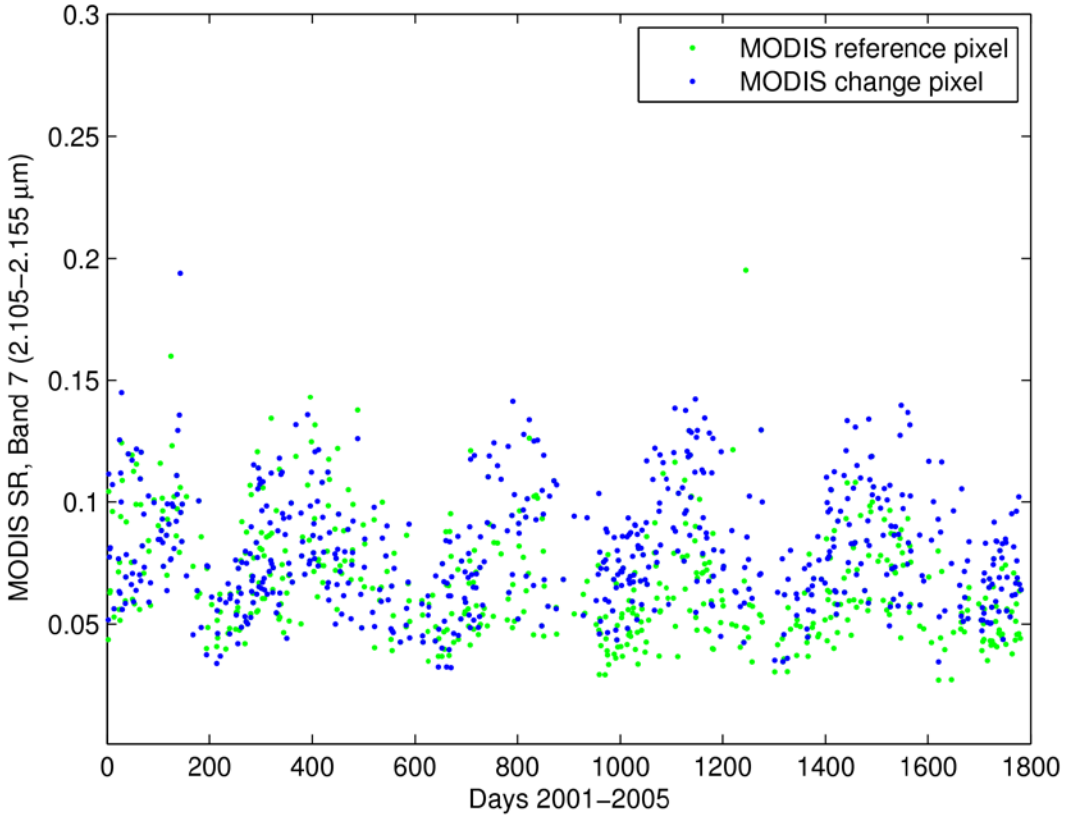


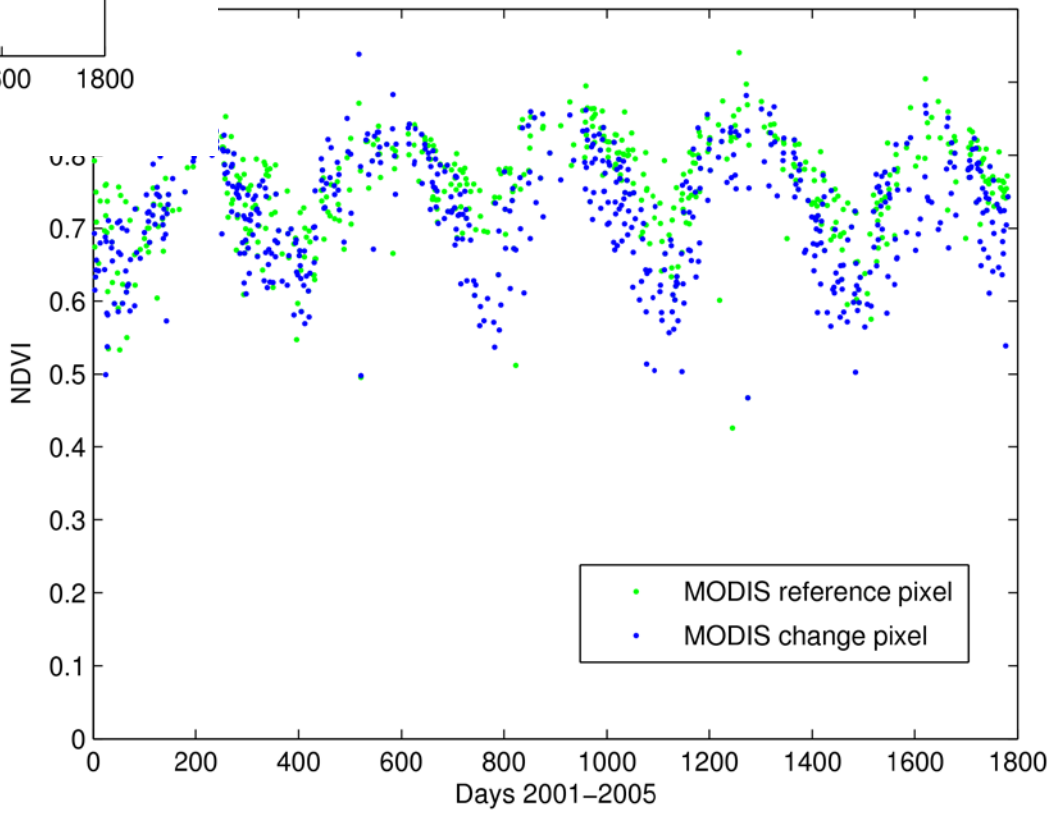
Location of the MODIS 500 m "change" pixel (dashed polygon shows the reference pixel)

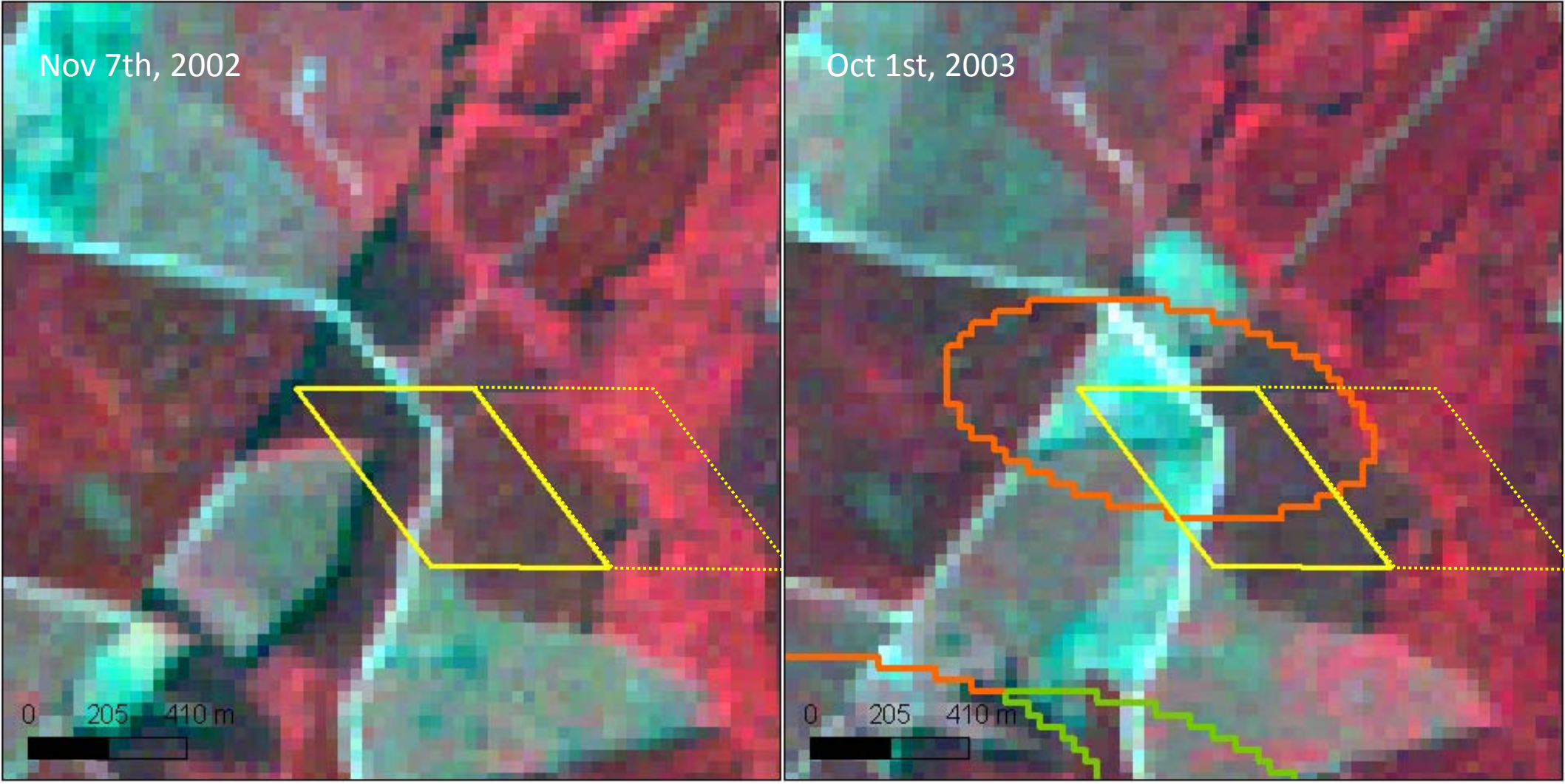
"Strength" of forest clearing flag

1
2
3
4
5
6

1. R1765 C354


MODIS reference pixel
MODIS change pixel
MODIS SR, Band 7 (2.105–2.155 µm)
Days 2001–2005
0.3
0.25
0.2
0.15
0.1
0.05
0
200
400
600
800
1000
1200
1400
1600
1800

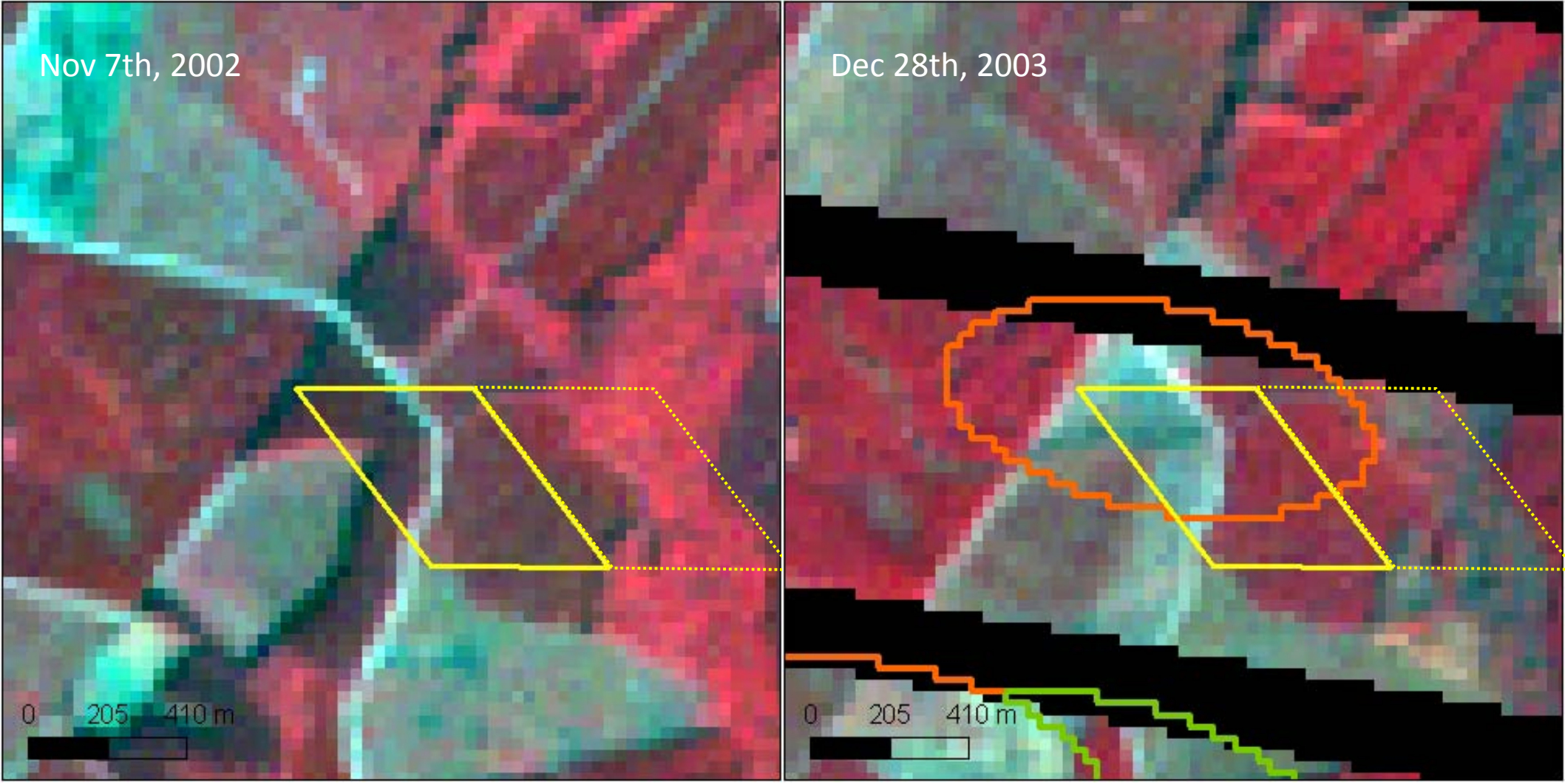

MODIS reference pixel
MODIS change pixel
NDVI
Days 2001–2005
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
200
400
600
800
1000
1200
1400
1600
1800



Location of the MODIS 500 m "change" pixel (dashed polygon shows the reference pixel)

"Strength" of forest clearing flag

1
2
3
4
5
6

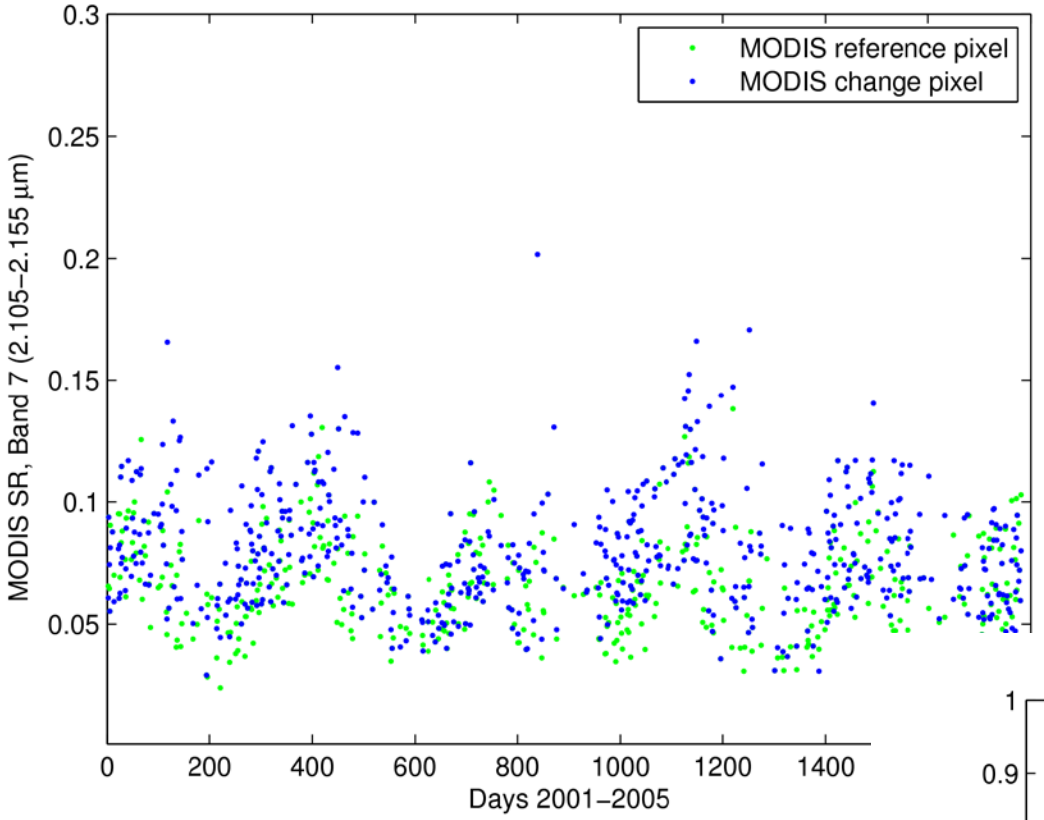


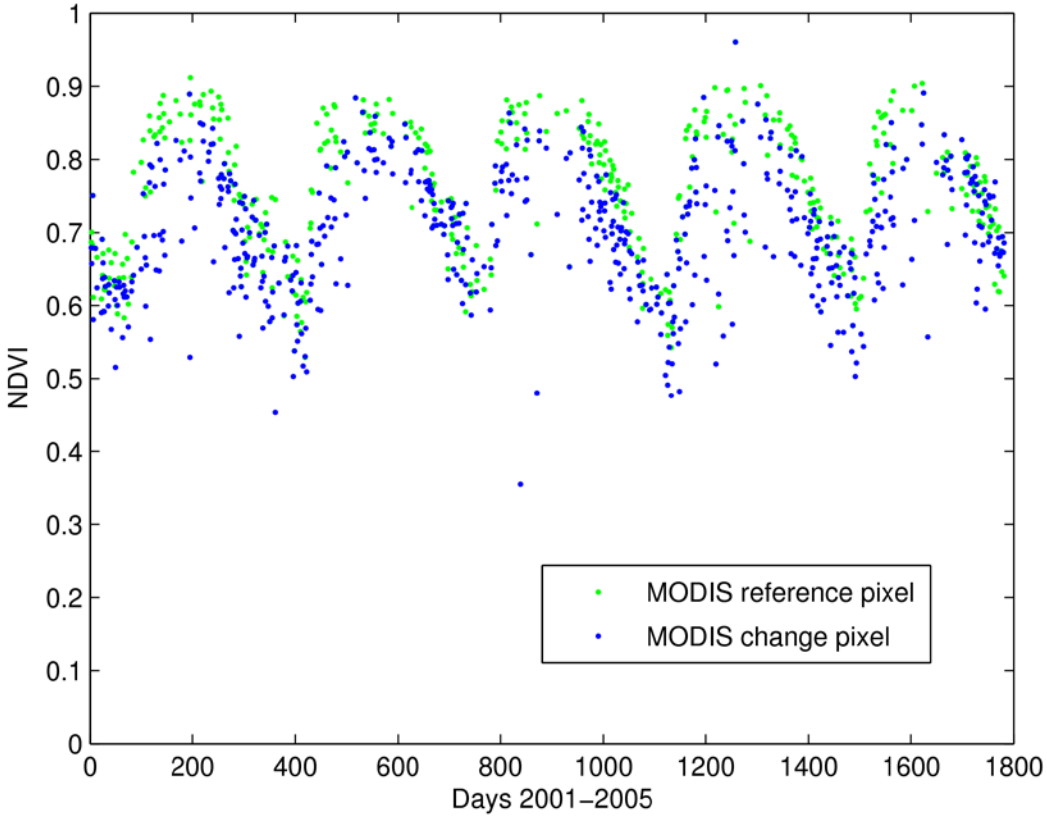
Location of the MODIS 500 m "change" pixel (dashed polygon shows the reference pixel)

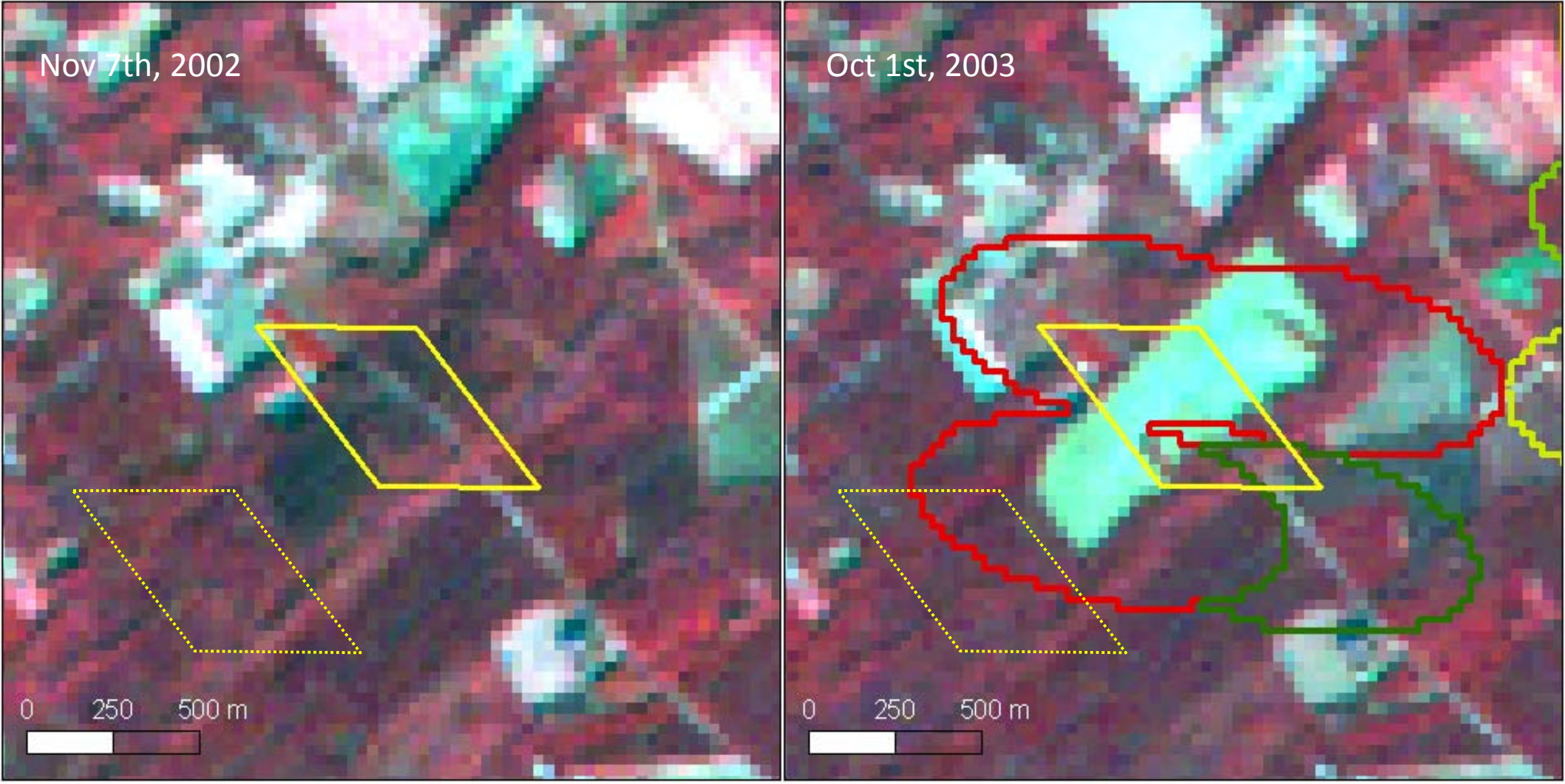
"Strength" of forest clearing flag

1
2
3
4
5
6

2. R1768 C358


MODIS reference pixel
MODIS change pixel
MODIS SR, Band 7 (2.105–2.155 µm)
Days 2001–2005
0.3
0.25
0.2
0.15
0.1
0.05
0
200
400
600
800
1000
1200
1400

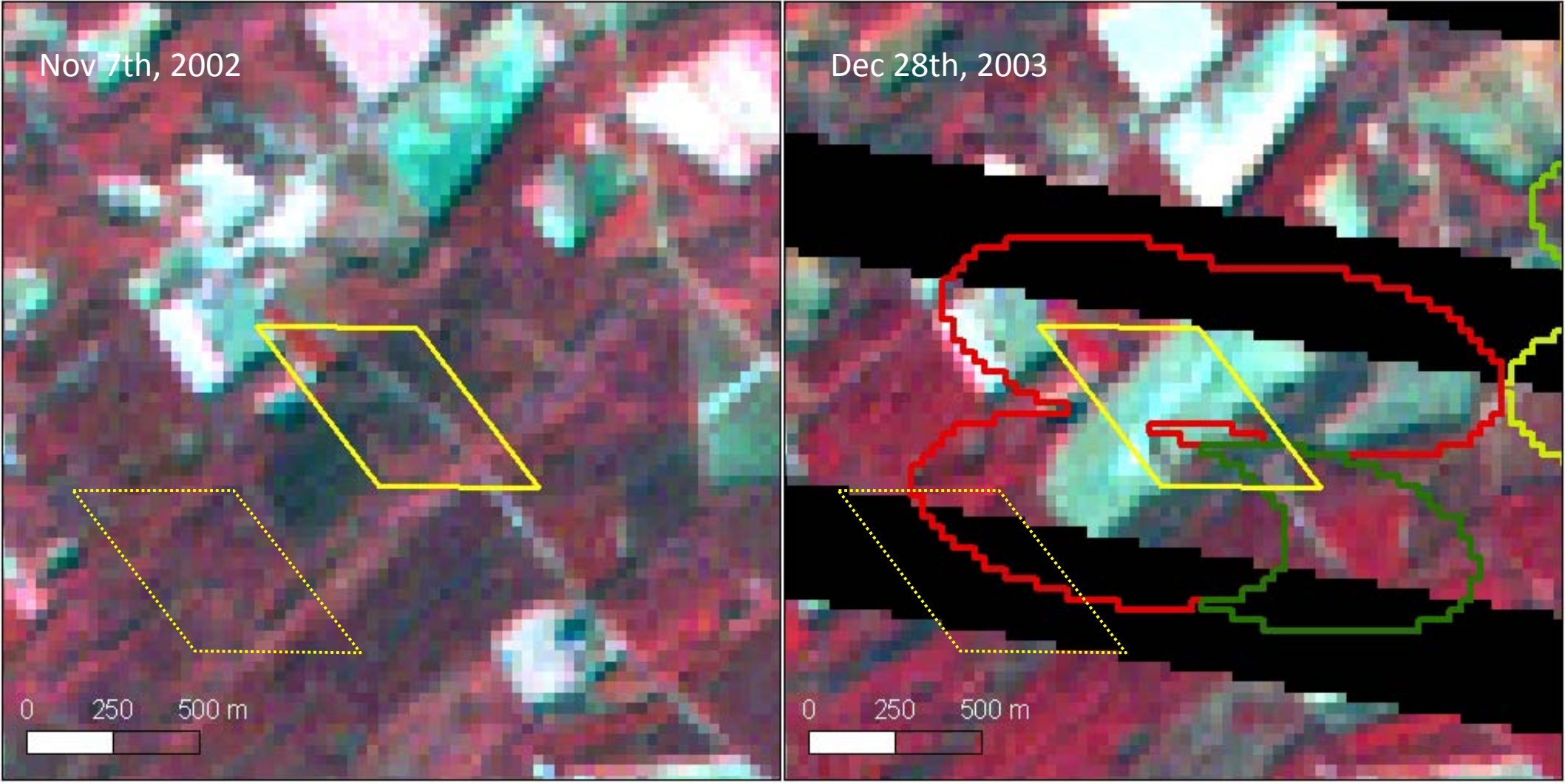

MODIS reference pixel
MODIS change pixel
NDVI
Days 2001–2005
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
1400
1600
1800



Location of the MODIS 500 m "change" pixel (dashed polygon shows the reference pixel)

"Strength" of forest clearing flag

1
2
3
4
5
6

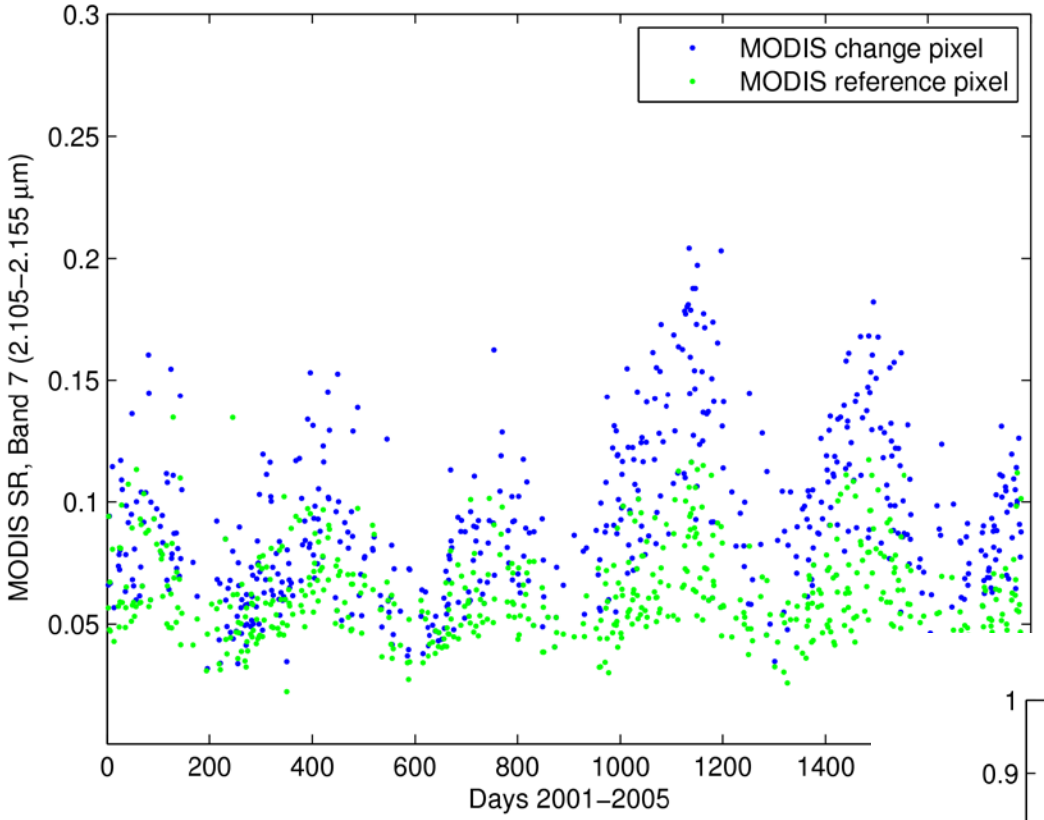


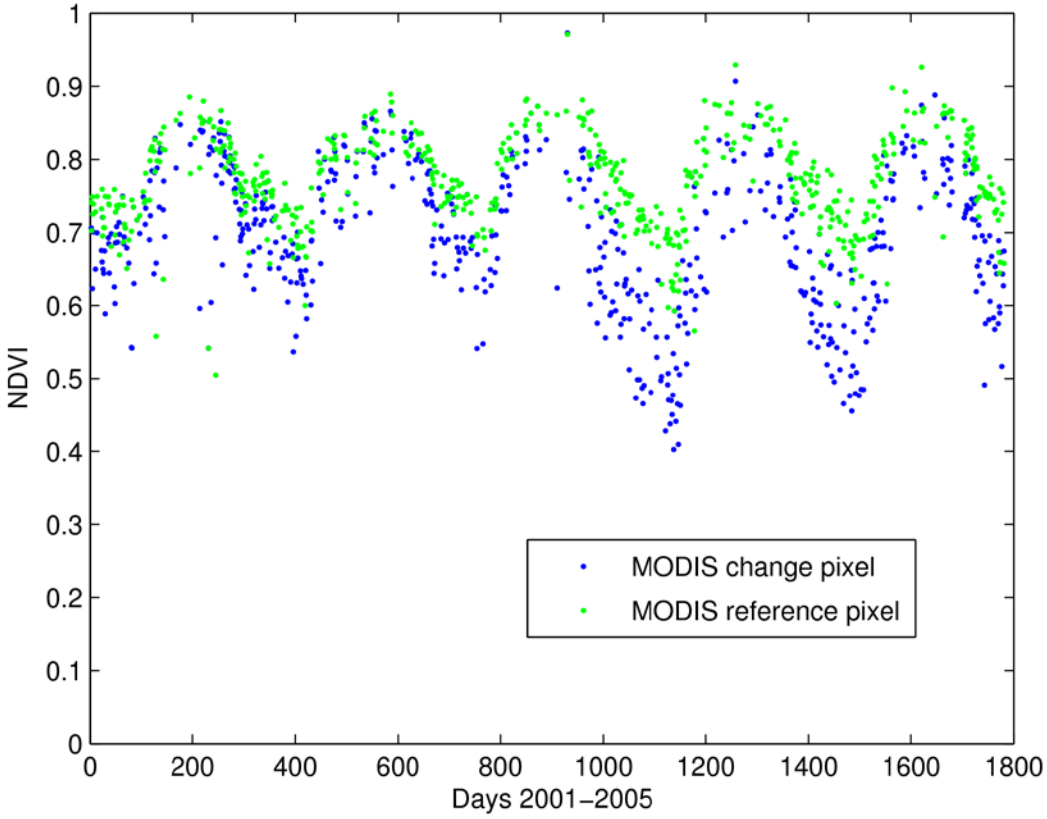
Location of the MODIS 500 m "change" pixel (dashed polygon shows the reference pixel)

"Strength" of forest clearing flag

1
2
3
4
5
6

7. R1770 C422


MODIS change pixel
MODIS reference pixel
MODIS SR, Band 7 (2.105–2.155 µm)
Days 2001–2005
0.3
0.25
0.2
0.15
0.1
0.05
0
200
400
600
800
1000
1200
1400


MODIS change pixel
MODIS reference pixel
NDVI
Days 2001–2005
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
1400
1600
1800

Conclusions

We need every observation we can get – even images with 50-60% cloud cover are useful

The key to change detection using MODIS is having something to compare the MODIS observations with

Near real-time monitoring of change (a few days) appears to be possible at sub-MODIS pixel scales – particularly for pronounced changes like forest clearing and harvest

For the future:

- Let's be more systematic about providing a comprehensive history of the surface of Earth!

- Let's continue to move monitoring of Earth toward real-time so that what we learn can better inform land management