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REVEALING INSIGHTS

# Impact of Atmospheric and Topographic Compensation on Change Detection


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17th Annual Civil Commercial Imagery Evaluation Workshop sponsored by JACIE

September 19, 2018

NOAA Center for Weather and Climate Prediction

5830 University Research CT

College Park, Maryland

# Objective

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- To optimize our automated change detection processes
- Existing literature:
  - Says crucial for direct comparison approaches
  - Not conclusive for statistical approaches
  - No work on specifically using our change detection approach
- Question: Can we make our automated change products more accurate by pre-processing our source imagery to a higher level?
  - Surface Reflectance (SR)
  - Terrain Normalization (TN)
- Not addressing geometric accuracy in this study

# Imagery and AOI

3 Tiles of Sentinel-2 Imagery:
1 - Tile37-QED, 2018-09-10 & 2015-08-31, Jeddah, Saudi Arabia

2018-09-10

2015-08-31

# Imagery and AOI

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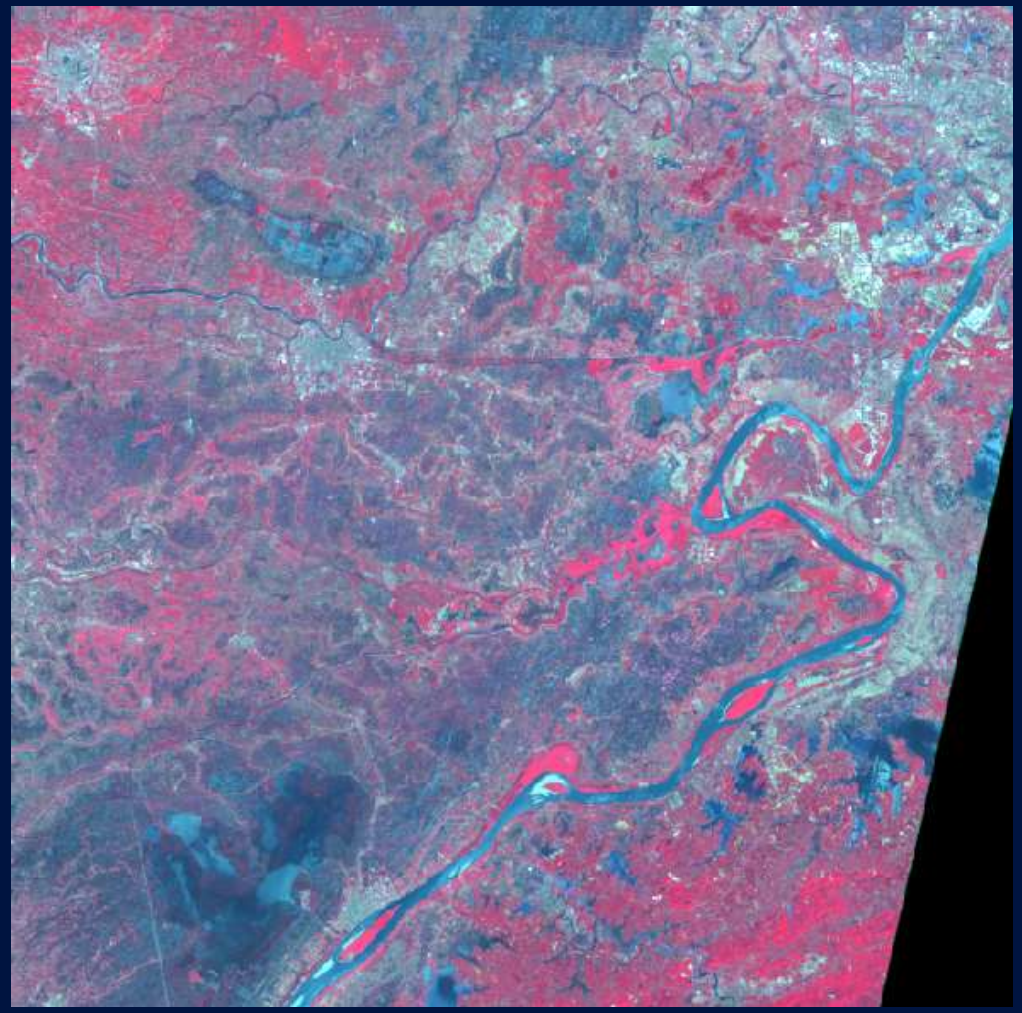
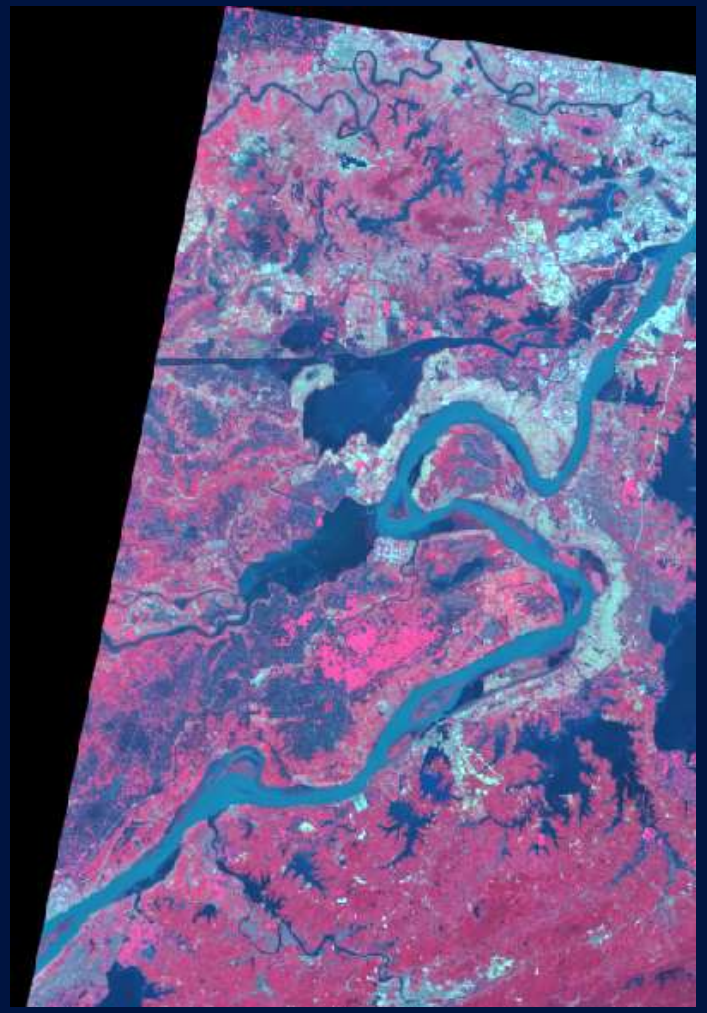
2 – Tile49-RGP, 2018-04-18 & 2016-07-29, Wuhan, China



2018-04-18



2016-07-29

# Imagery and AOI

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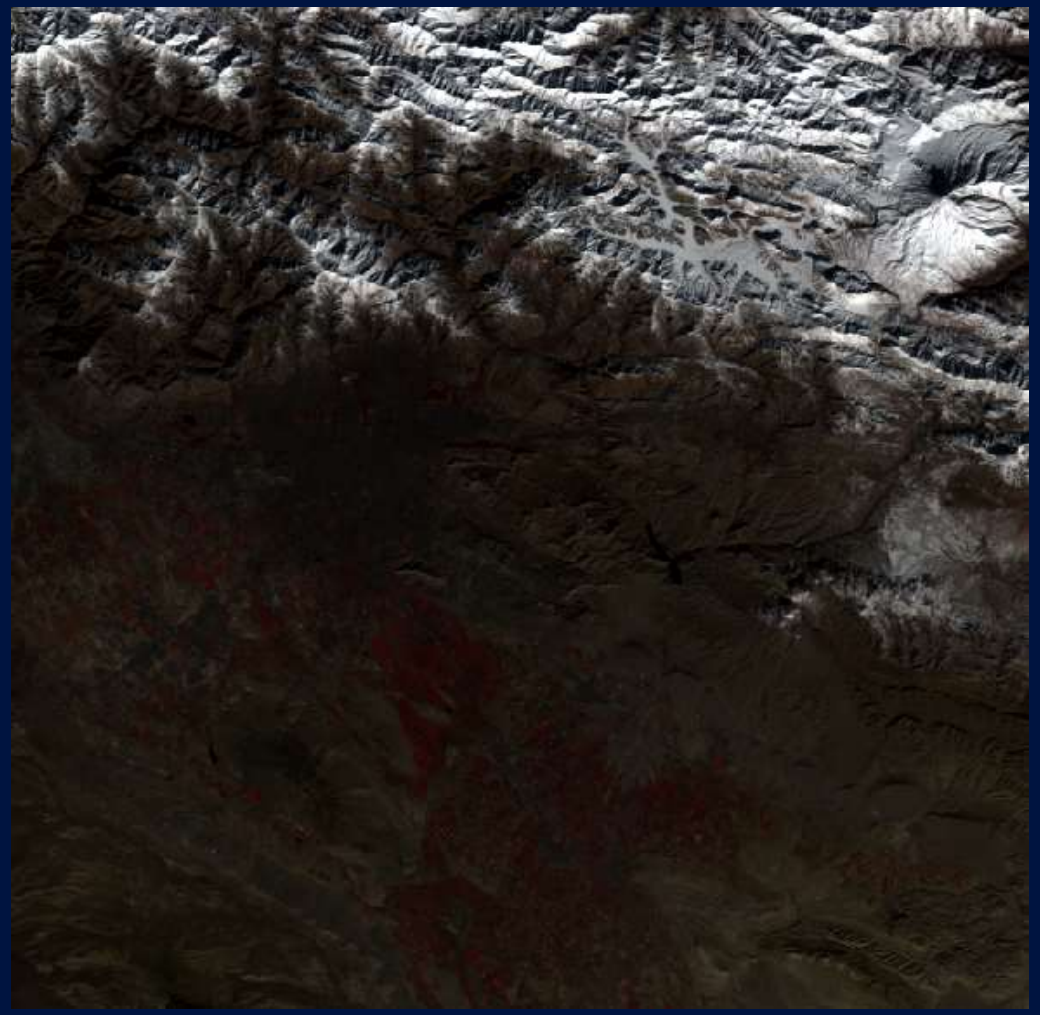
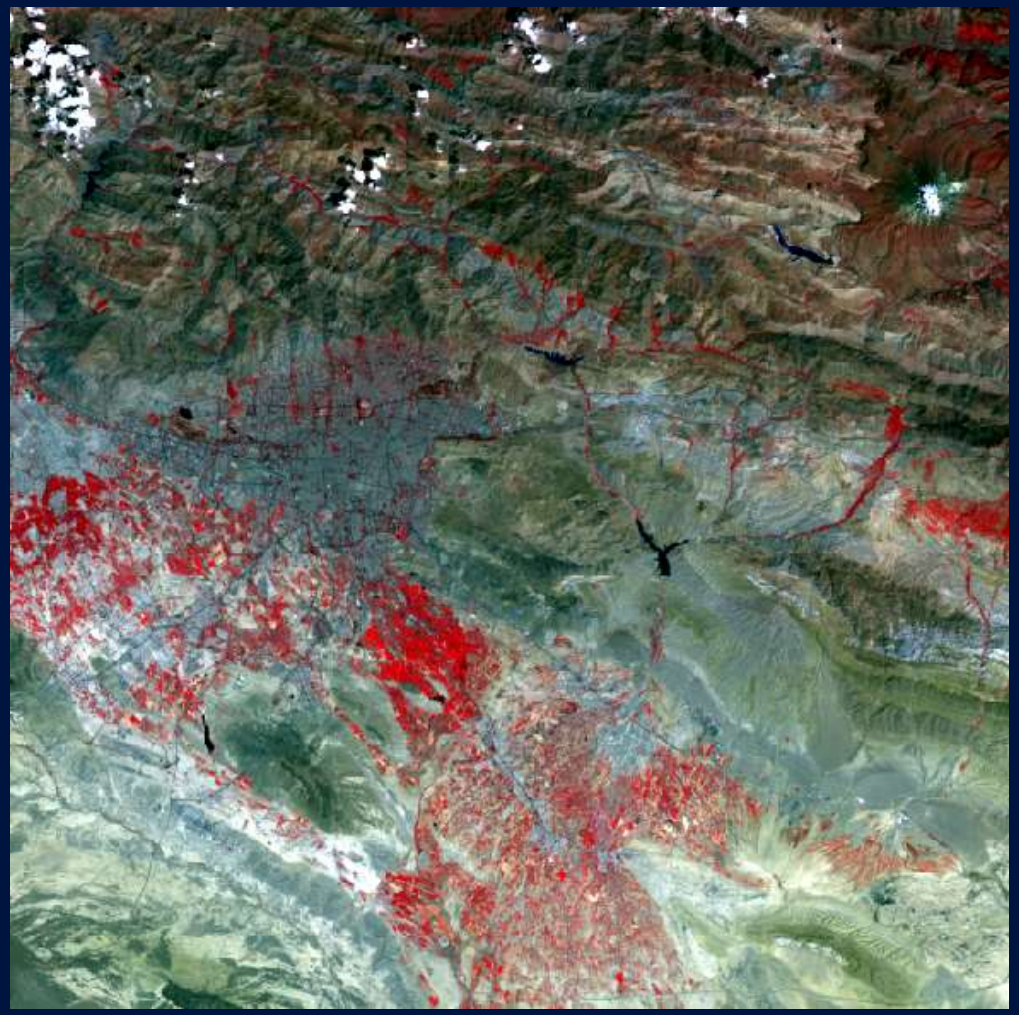
2 – Tile39-SWV, 2018-01-08 & 2015-08-12, Tehran, Iran



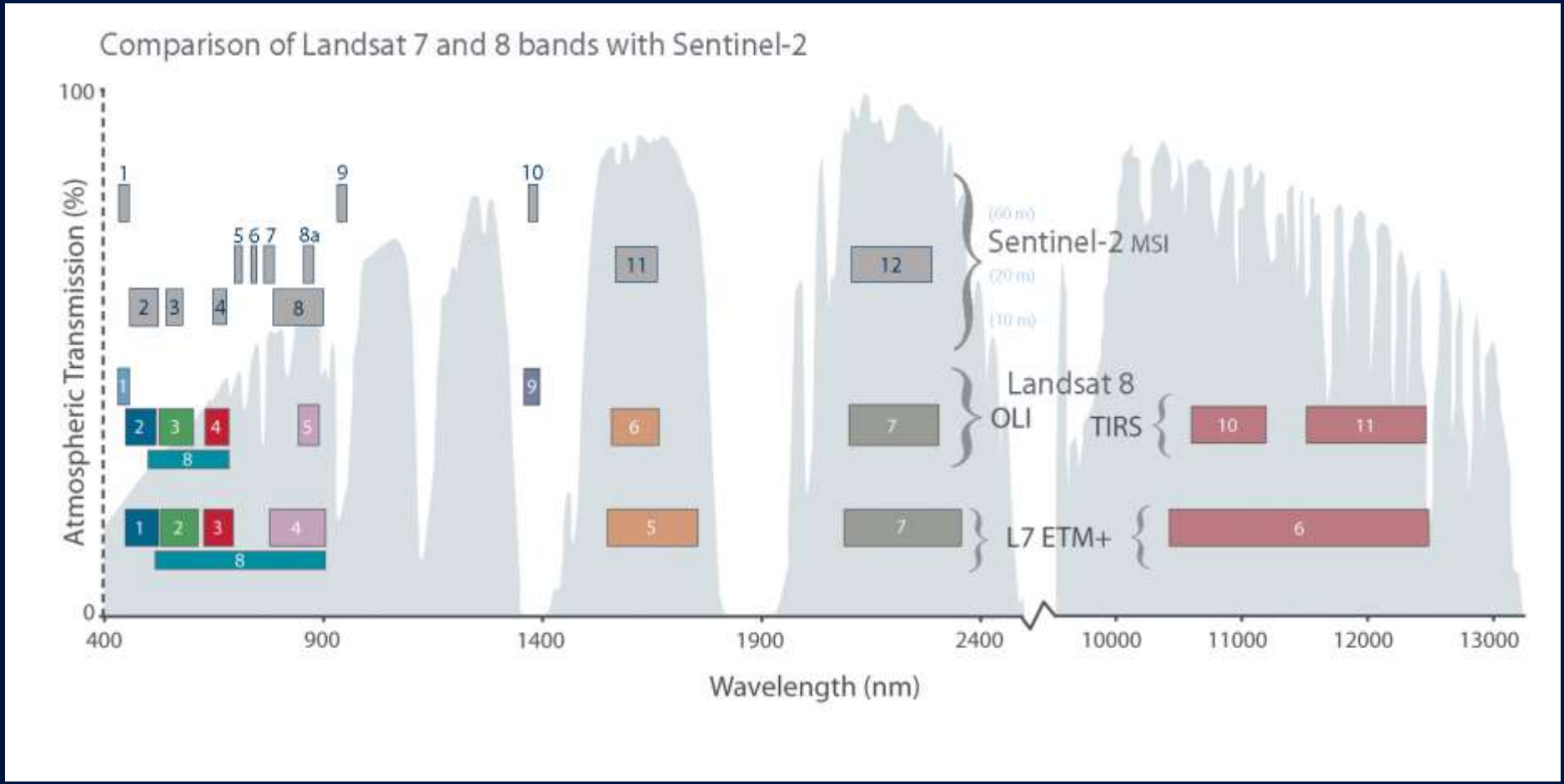
2018-01-08



2015-08-12

# Imagery

- Orthorectified
- 4-band
  - VNIR (2,3,4,8)
  - 10m res
- 6-band
  - VNIR + SWIR1 and SWIR2 (2,3,4,8,11,12)
  - 10m res
- 10-band
  - All bands except for 3 60m atmospheric bands (1,9,10)
  - 20m res



# Pre-processing methods

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- Parameters tested:
  - Number of bands – 4, 6, 10
  - Atmospheric correction level – TOA, BOA (SR)
  - Terrain correction level – Corrected for terrain slope albedo, not corrected
- 12 (3x2x2) permutations of 3 footprints tested = 36 runs
- Run at 10m resolution
  - Except 10 band layers are 20m res
- Atmospheric correction performed using ATCOR to produce the SR
- Terrain normalization (TN) performed using C-Correction (Teillet, P.M, et al, 1982)
- DEM used: AW3D30 resampled to 10m and 20m from 30m (bilinear)

| Permutations per Scene Footprint |
|---|
| 4 band, 10m res, TOA, no TN |
| 4 band, 10m res, AC, no TN |
| 4 band, 10m res, TOA, TN |
| 4 band, 10m res, AC, TN |
| 6 band, 10m res, TOA, no TN |
| 6 band, 10m res, AC, no TN |
| 6 band, 10m res, TOA, TN |
| 6 band, 10m res, AC, TN |
| 10 band, 20m res, TOA, no TN |
| 10 band, 20m res, AC, no TN |
| 10 band, 20m res, TOA, TN |
| 10 band, 20m res, AC, TN |

# Change reference layer

- Define what is change?
  - NOAA C-CAP standards
  - Focus on new, destroyed, or moved features
  - No seasonal change: agriculture, vegetation phenology, snow/ice
  - Land use change vs. land cover change
- Reference change layer created for each of the 3 scene pairs
  - Created using automated change methods, post-classification, and lots of hand edits
  - < 3 pixels filtered out

# Change detection method

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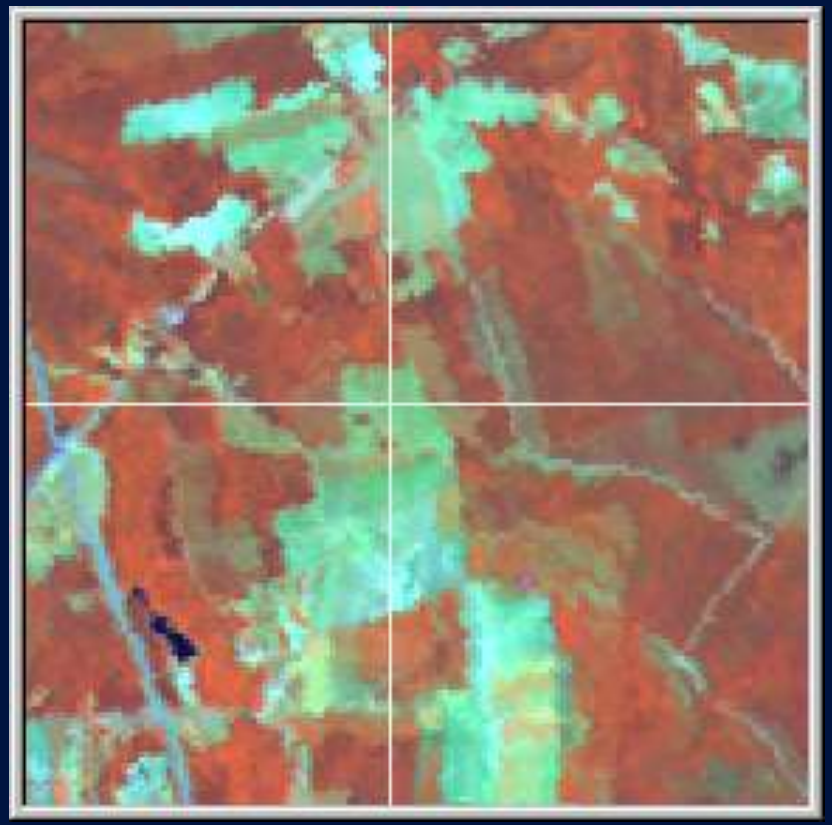
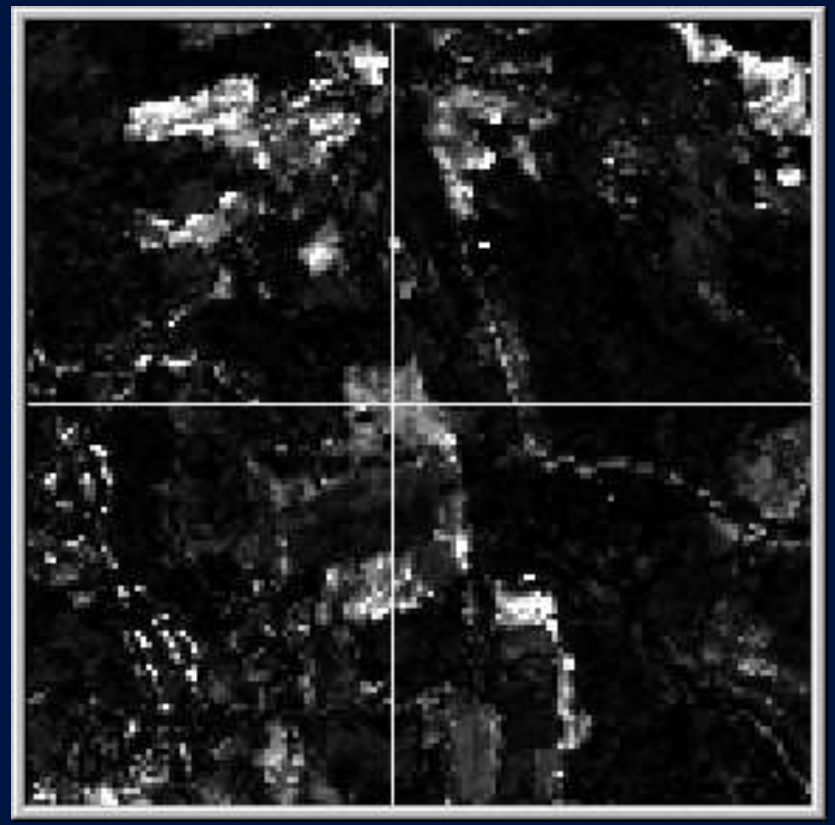
- Cross Correlation Analysis (CCA)
- Statistical approach measuring variation of late-date DN values from strata means where strata are derived from the early-date imagery
- No direct comparison of imagery
- Output is a 16-bit Z-score layer correlated to probability of change
- Usually threshold layer to create binary change using an empirically derived universal coefficient
- For this test we won’t assume a single threshold

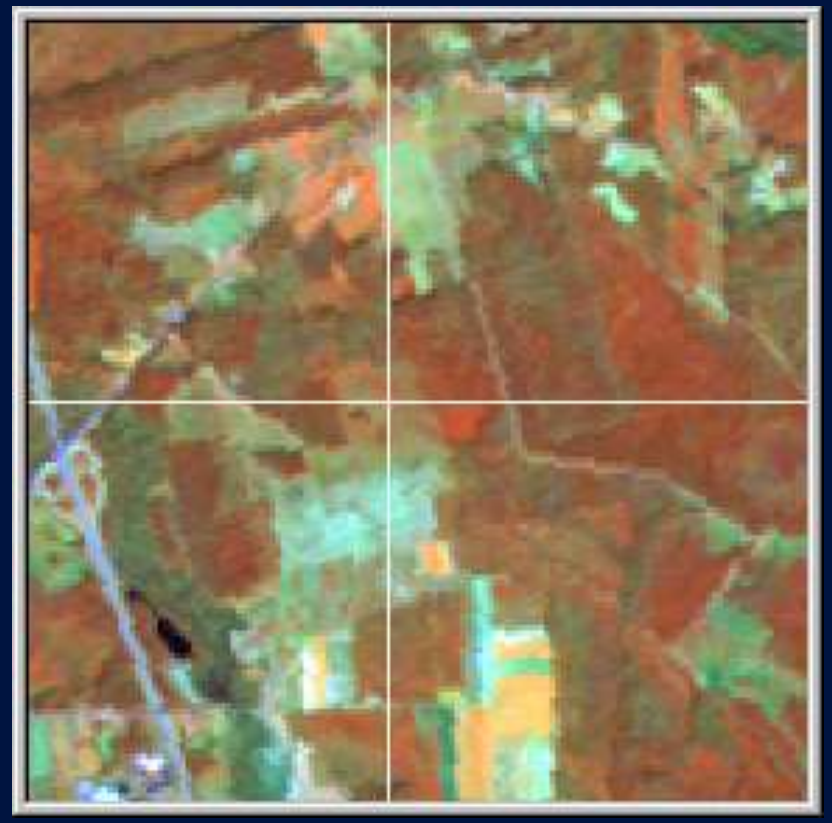
# CCA Output



Early date scene, May 8 1990.



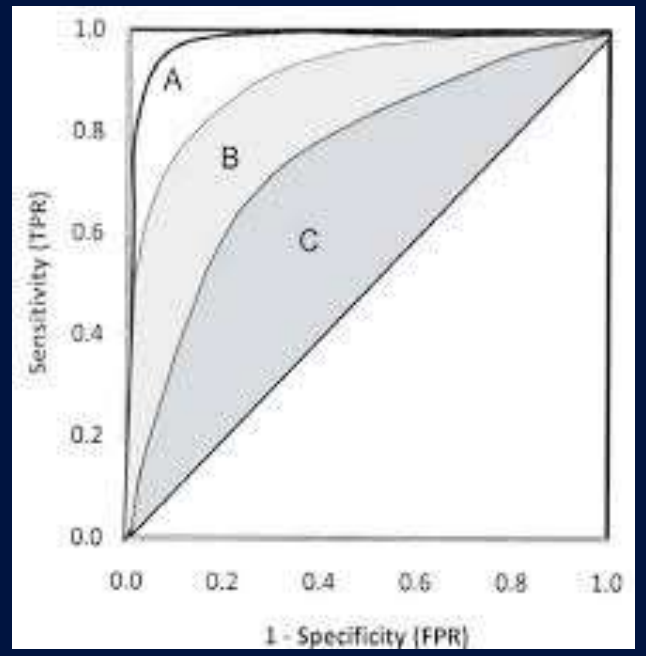
Z-score range of values

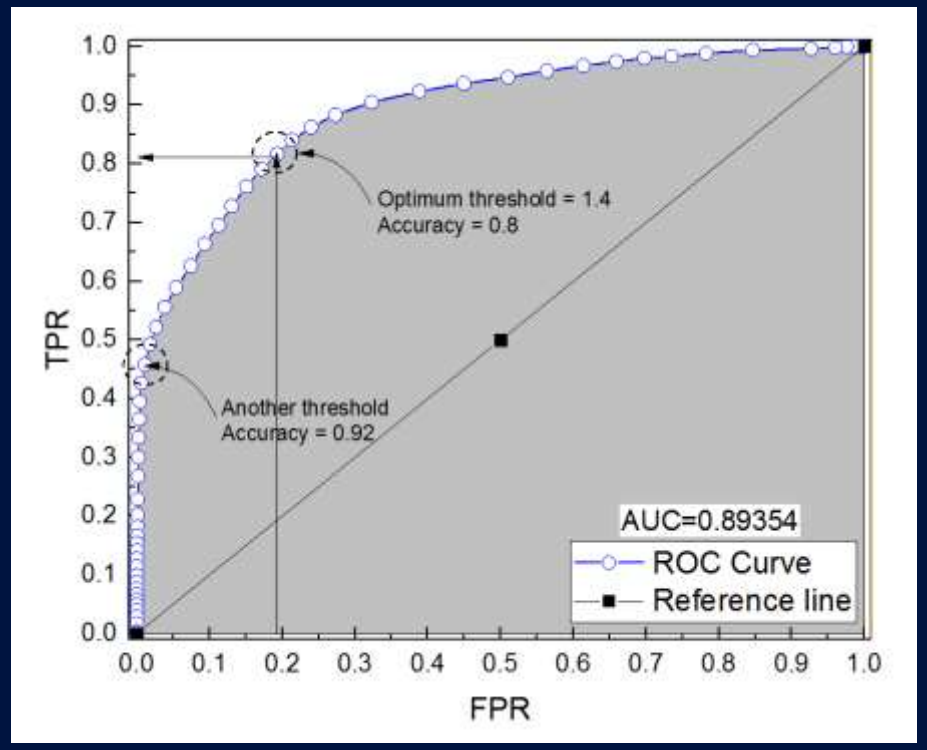


Late date scene, Oct 31 1996

# Assessment approach

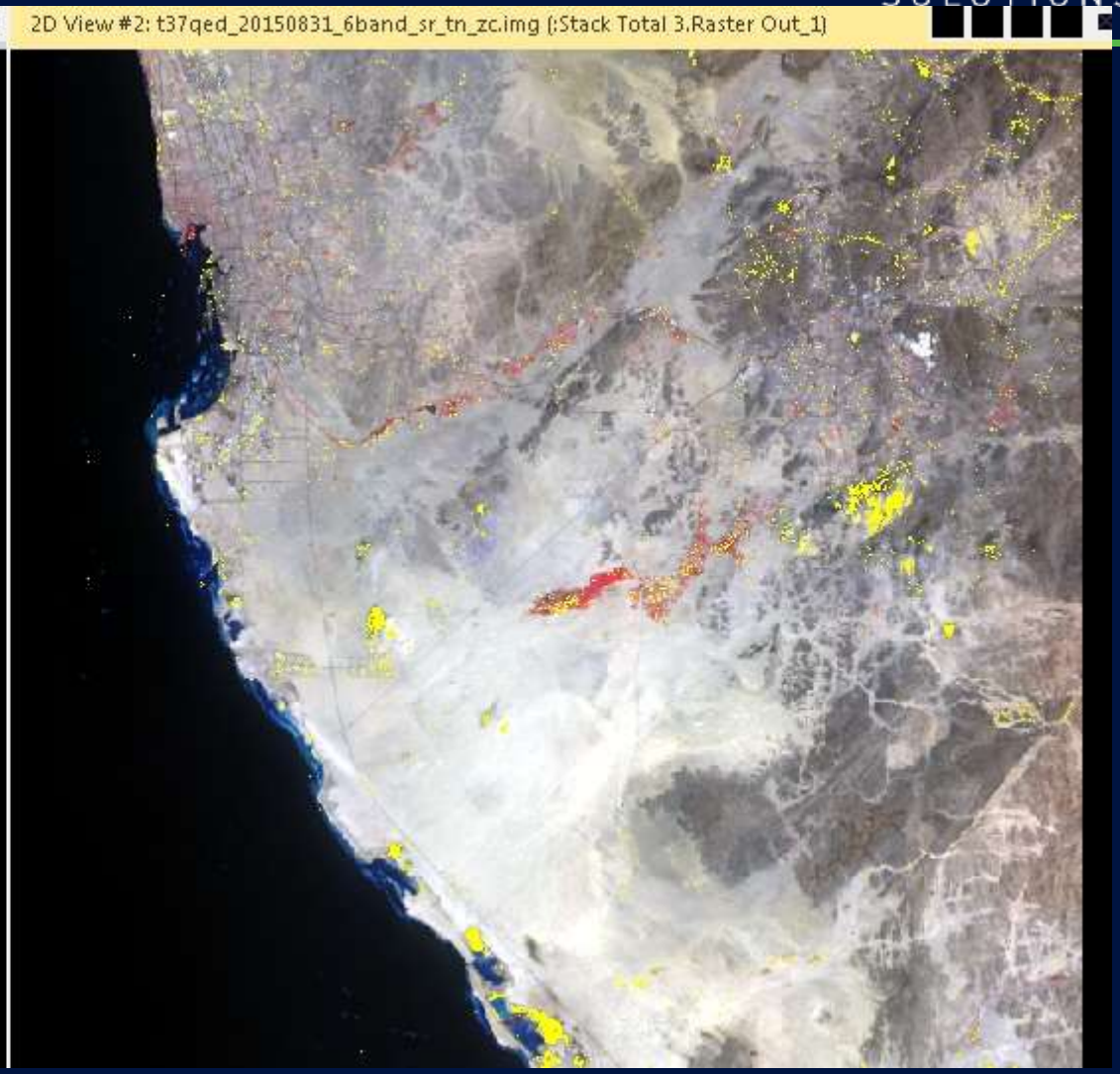
- Change reference layer (mask) compared to Z-scores (16-bit continuous)
- ROC Curve
  - Receiver Operating Characteristic
  - Graph Probability of Correct Change Detections vs Probability of False Positives
- AUC – Area Under Curve



# Reference Change Mask T37QED

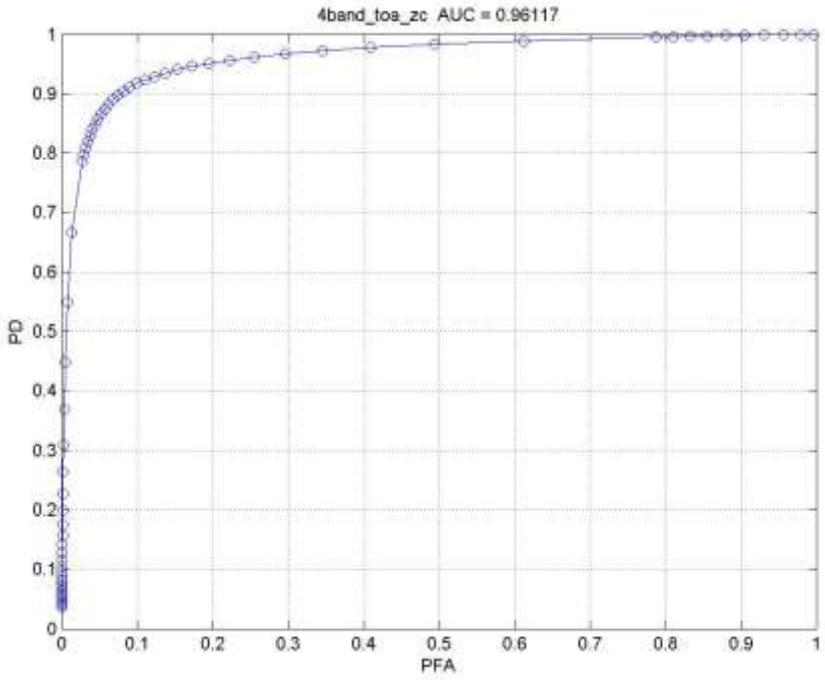

2018-09-10 S-2 image with reference change mask in yellow

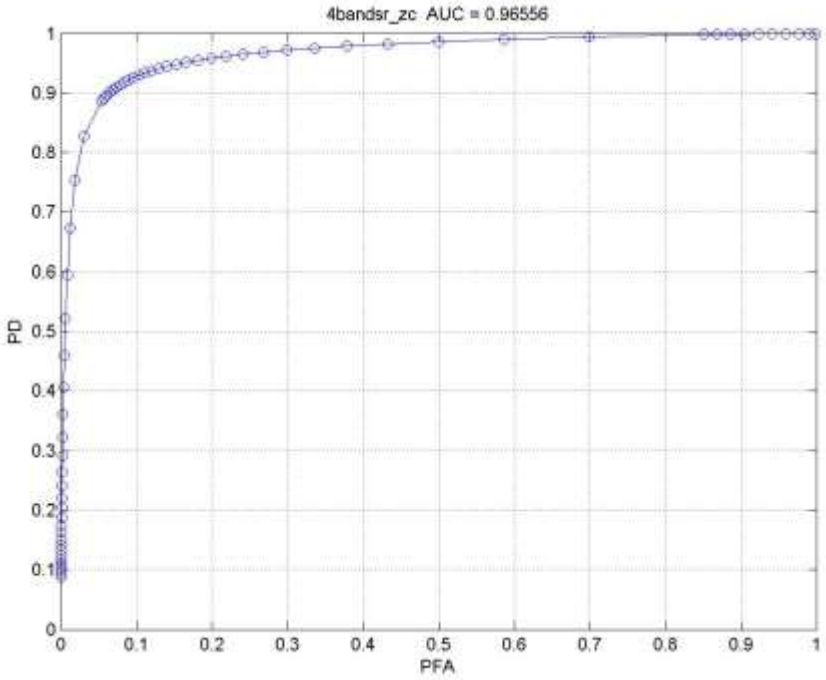


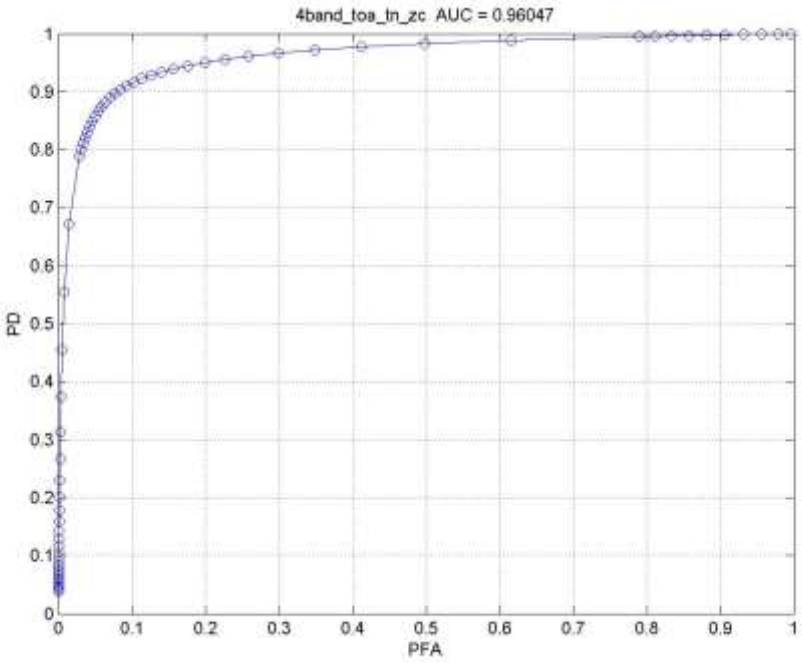

2015-08-31 S-2 image with thresholded Z-score in yellow

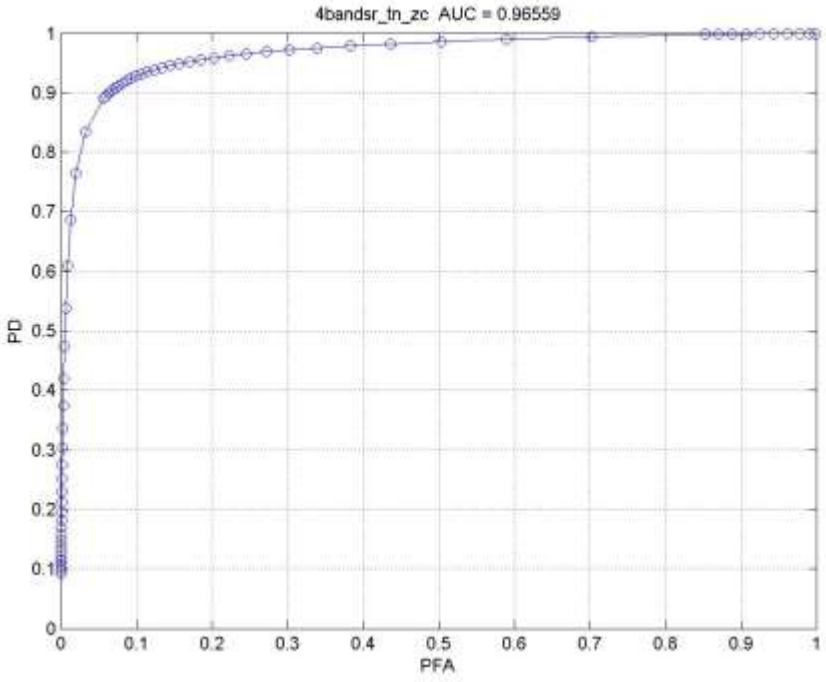
# Results 4-band T37QED

- SR increases accuracy slightly
- TN does not have much impact
- Desert scenes tend to be difficult to correct
- This scene pair has very little terrain variability
- TN, if not performed well or with poor DEM, often adds error in flat areas
- This reference change mask was probably the most precise, most time spent
- Also this scene pair is near anniversary



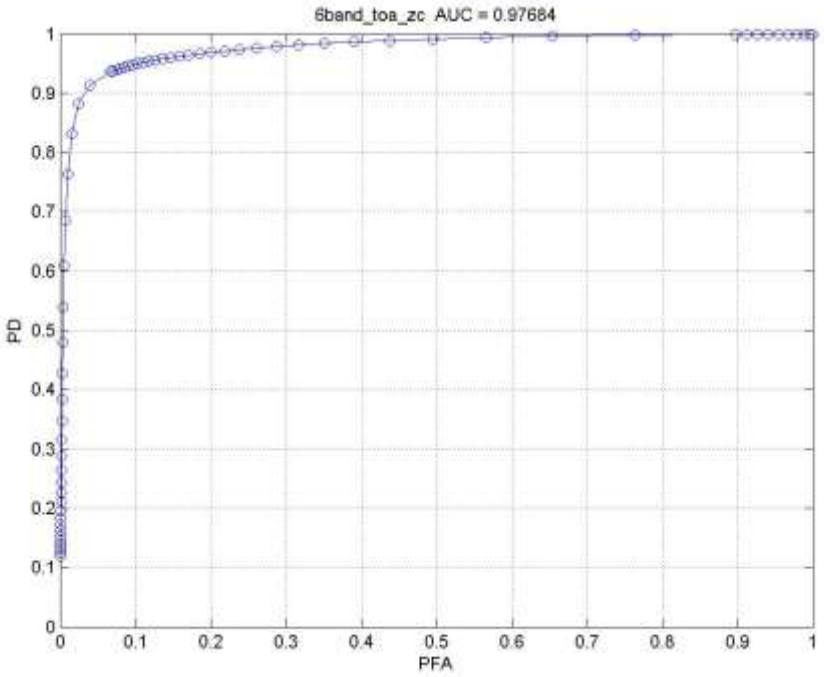



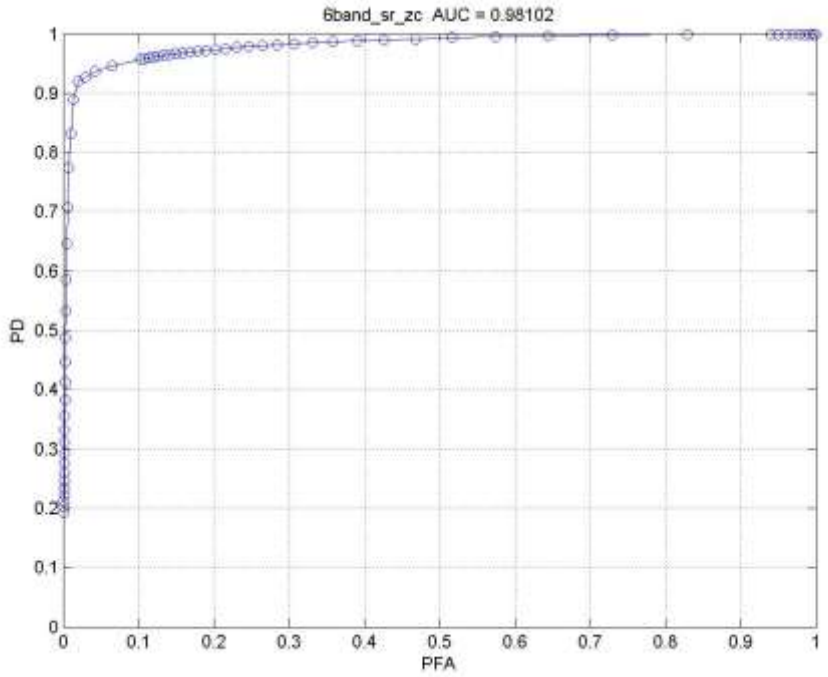



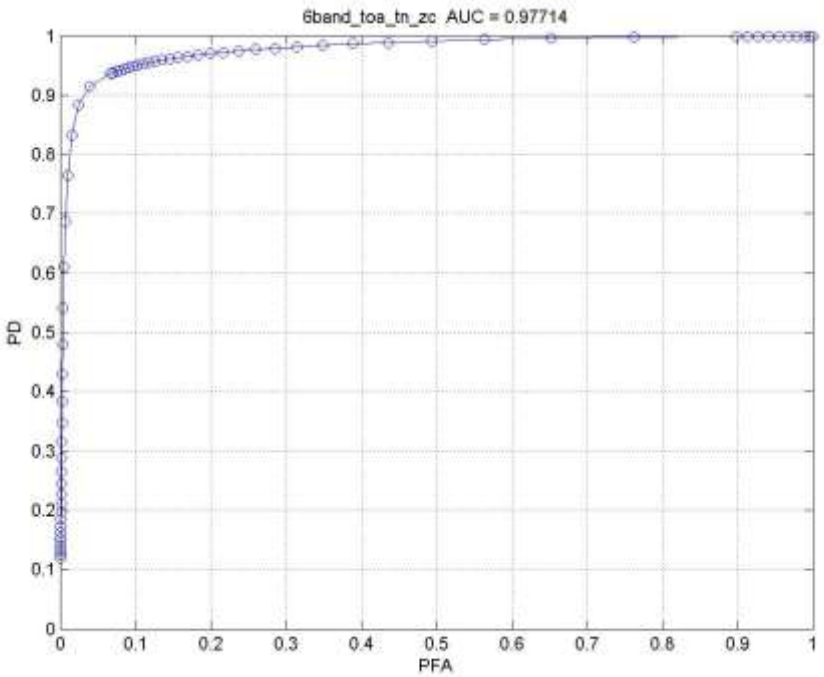



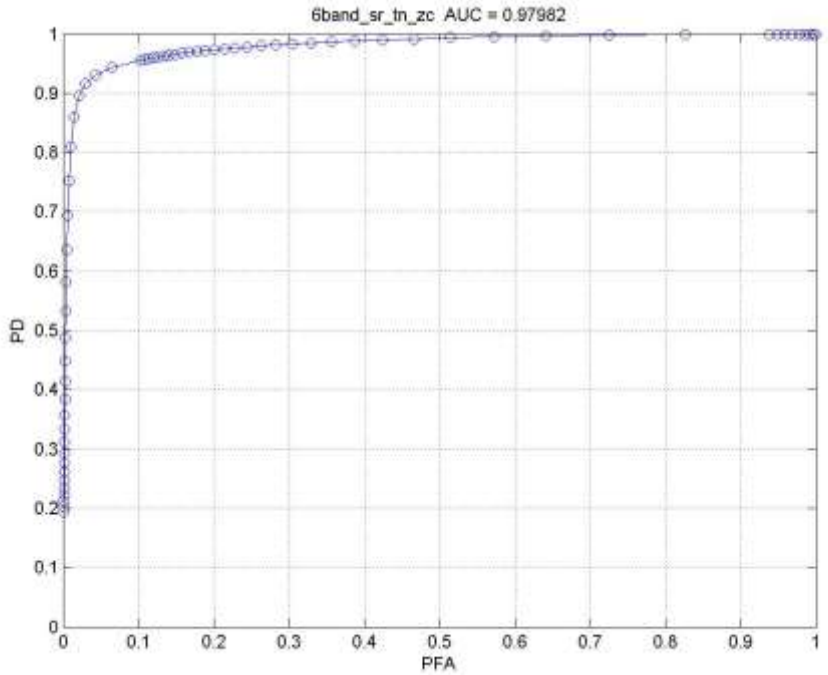
# Results 6-band T37QED

- SR increases probability accuracy
- TN has almost no effect
- 6-band appears to be more accurate than 4-band change



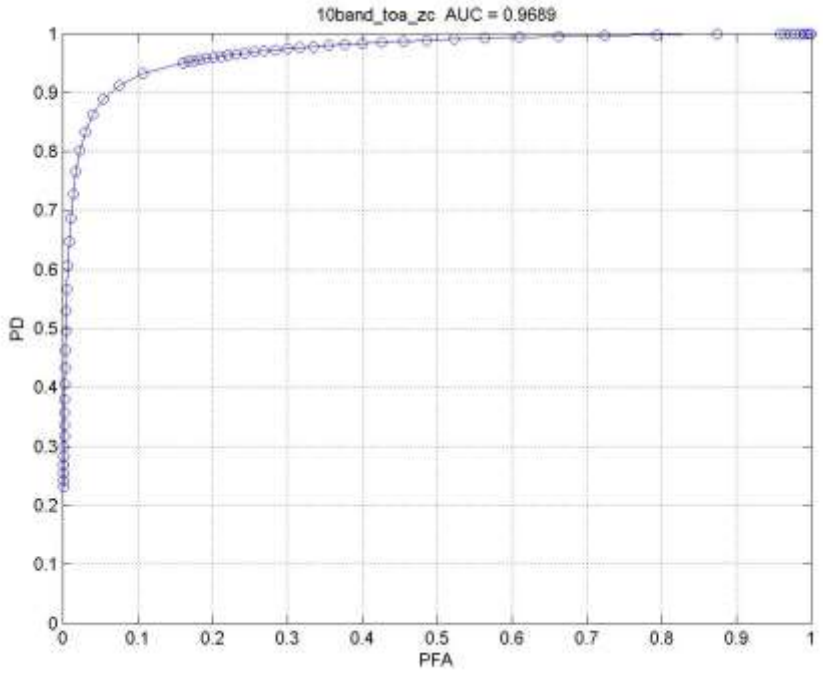



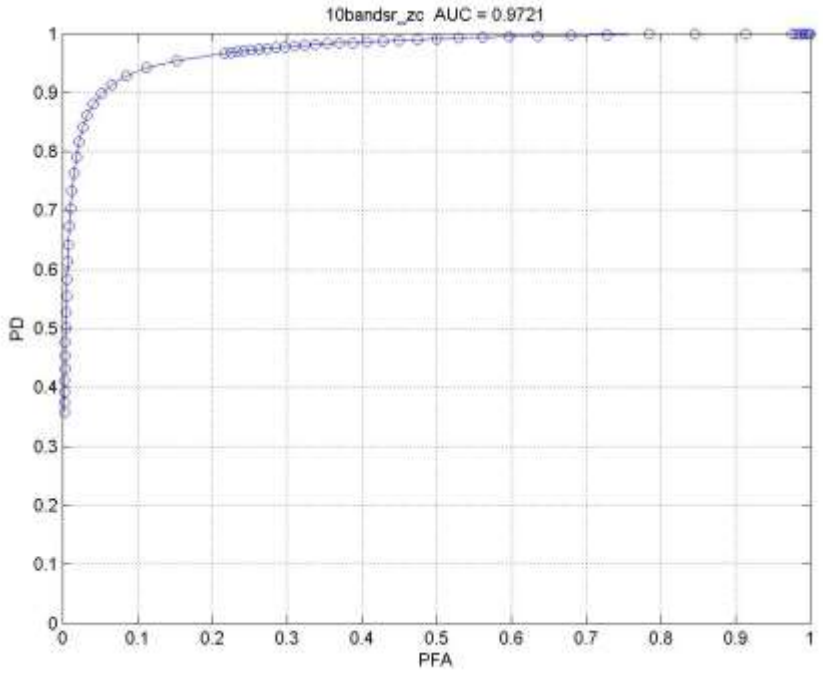



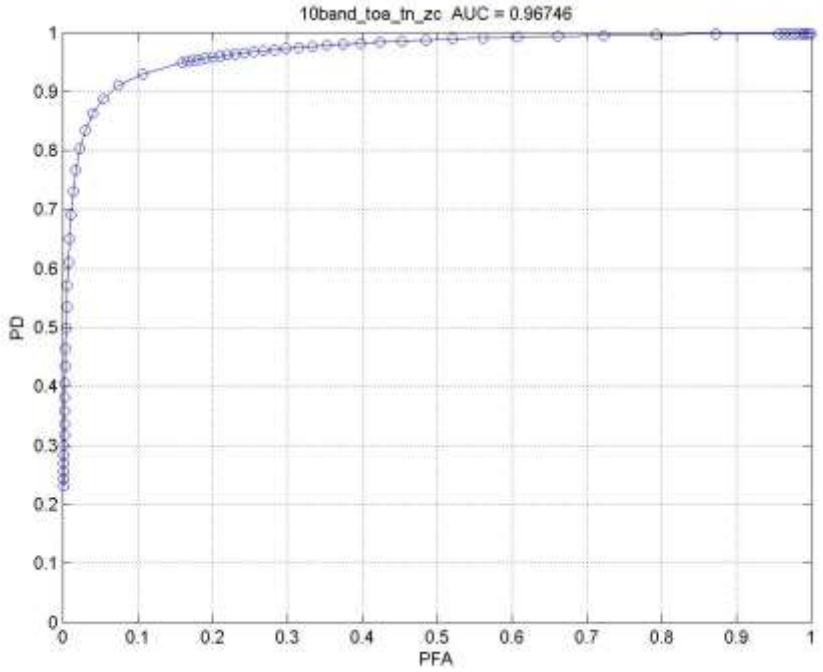



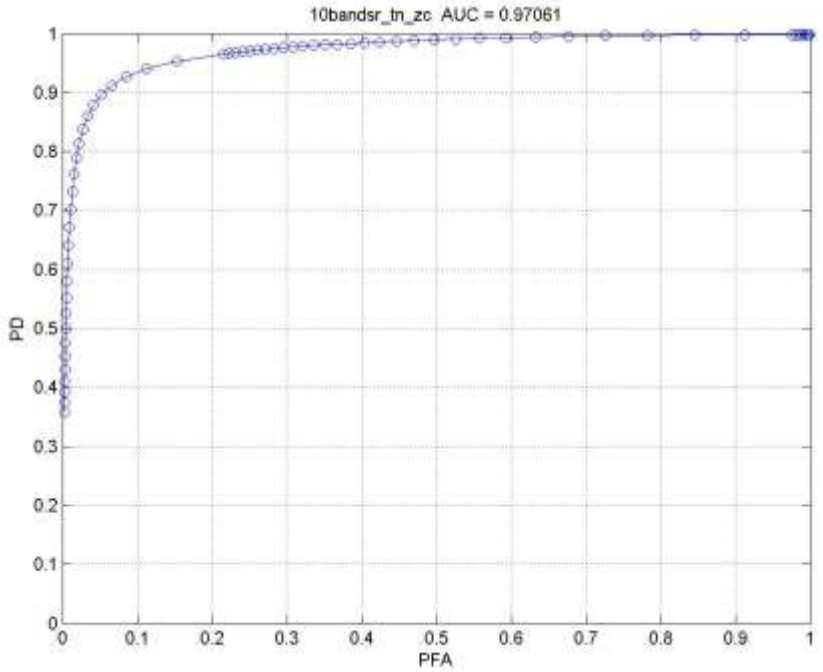
# Results 10-band T37QED

- SR processing increases accuracy
- TN decreases accuracy slightly



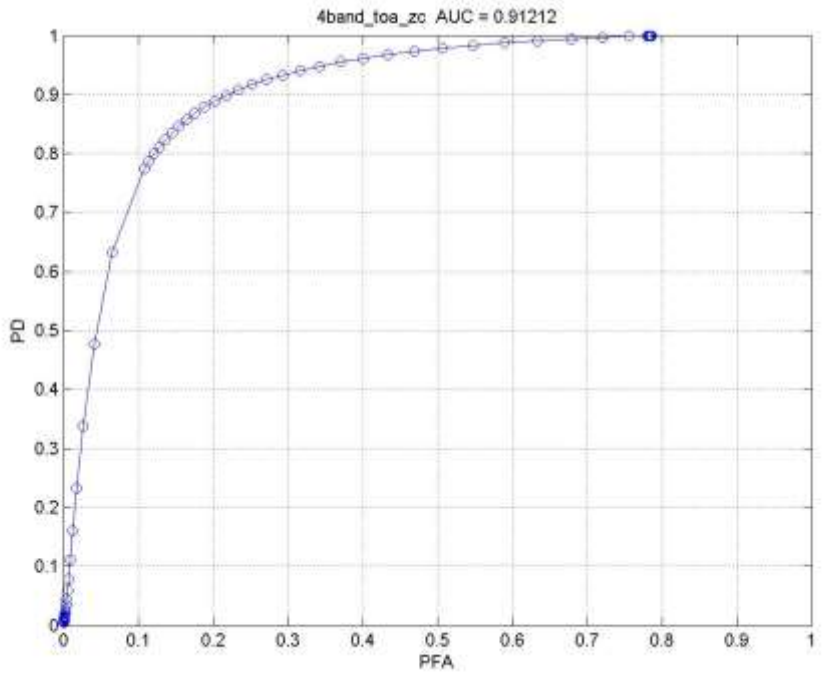
# Reference Change Mask T49RGP

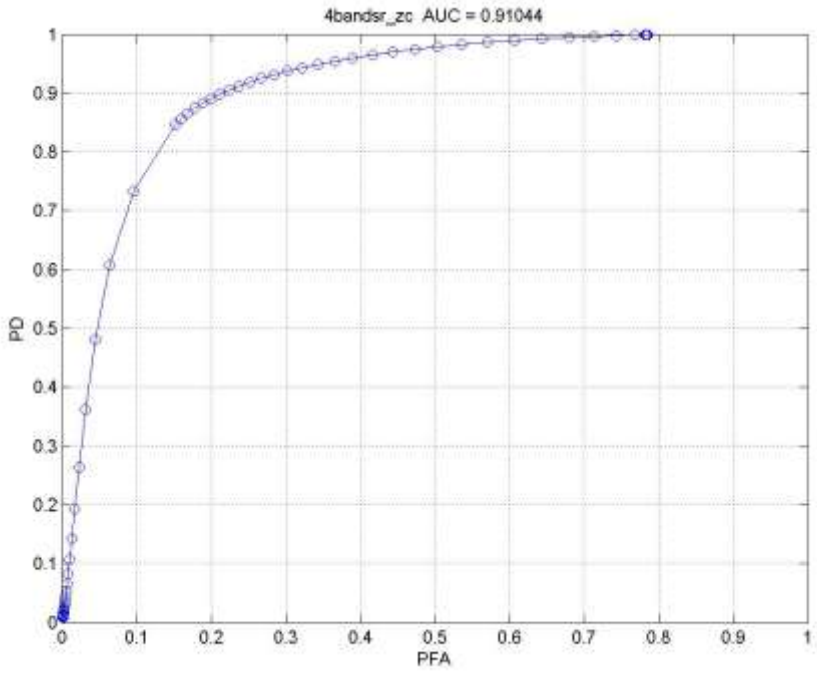

2018-04-18 S-2 image with reference change mask in yellow

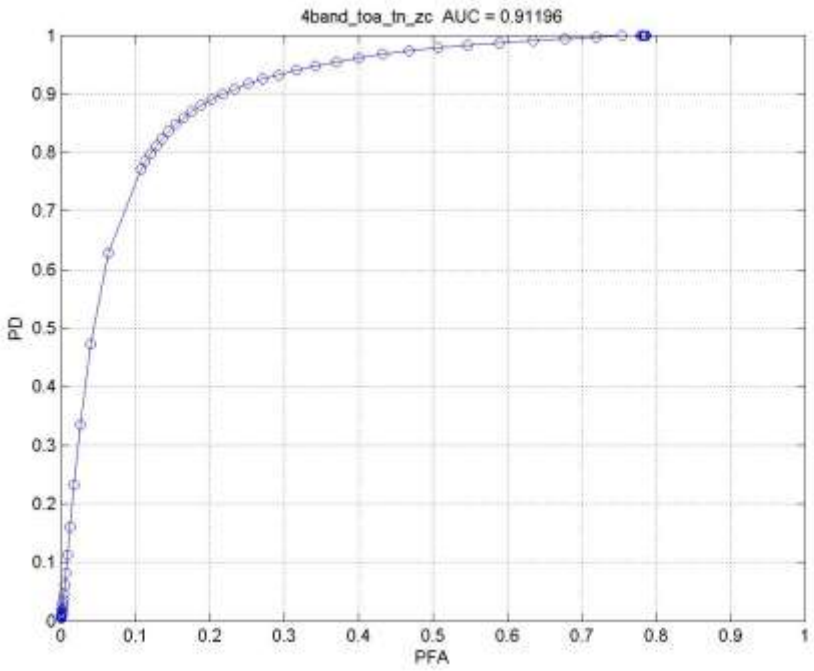

2016-07-29 S-2 image with thresholded Z-score in yellow

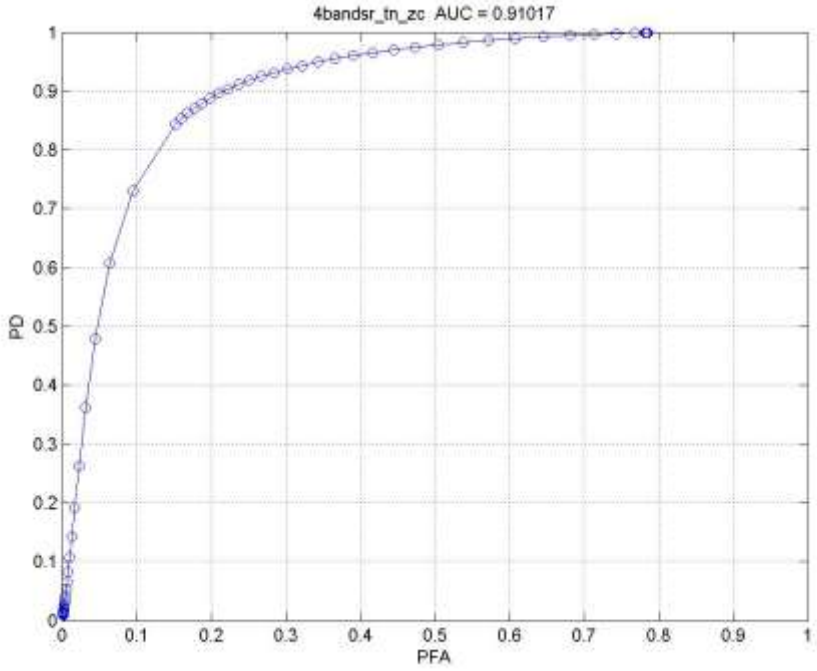
# Results 4-band T49RGP

- SR slightly reduced accuracy
- TN slightly reduced accuracy
- This scene has little terrain variability
- It is nearly totally vegetated and contains lots of water



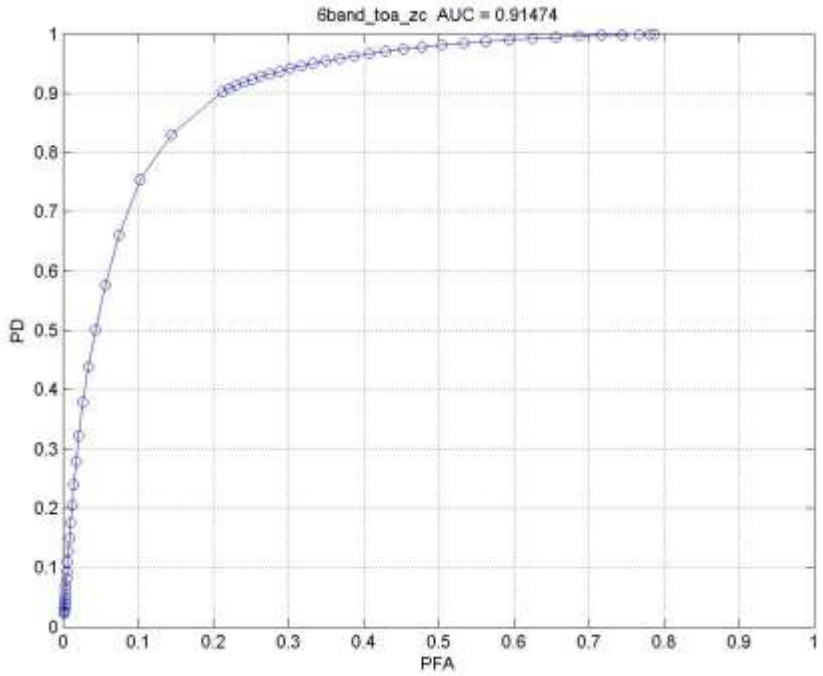



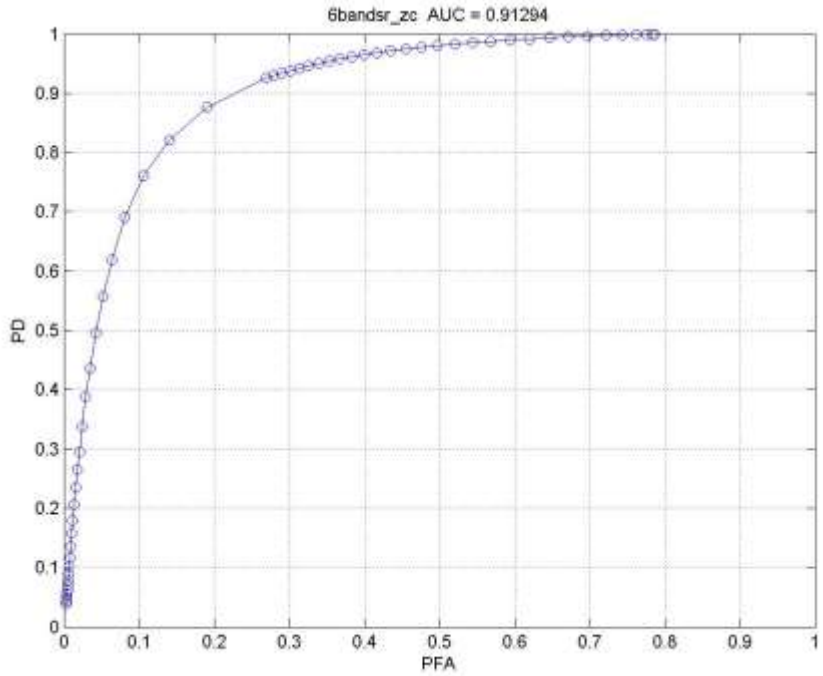



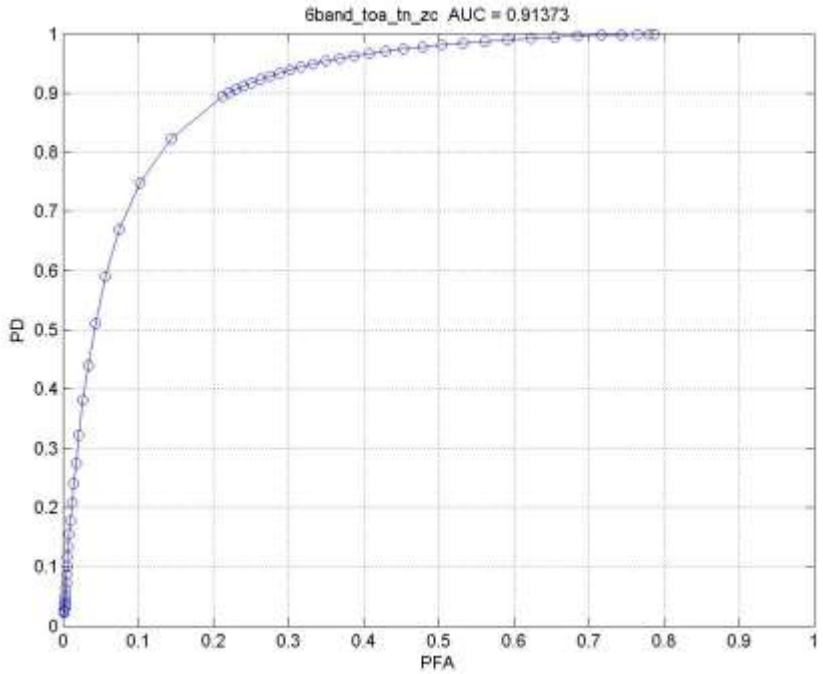



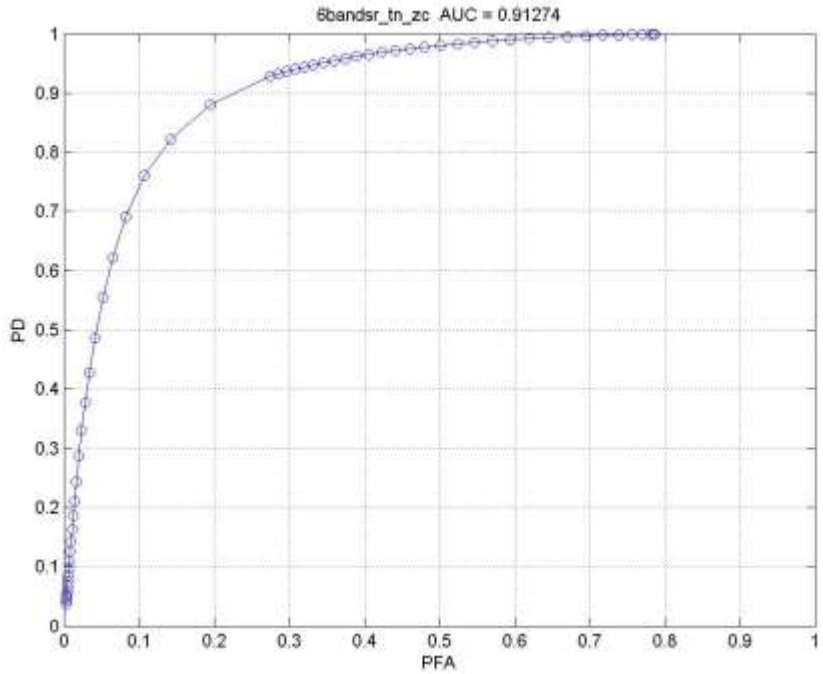
# Results 6-band T49RGP

- SR slightly reduced accuracy
- TN slightly reduced accuracy



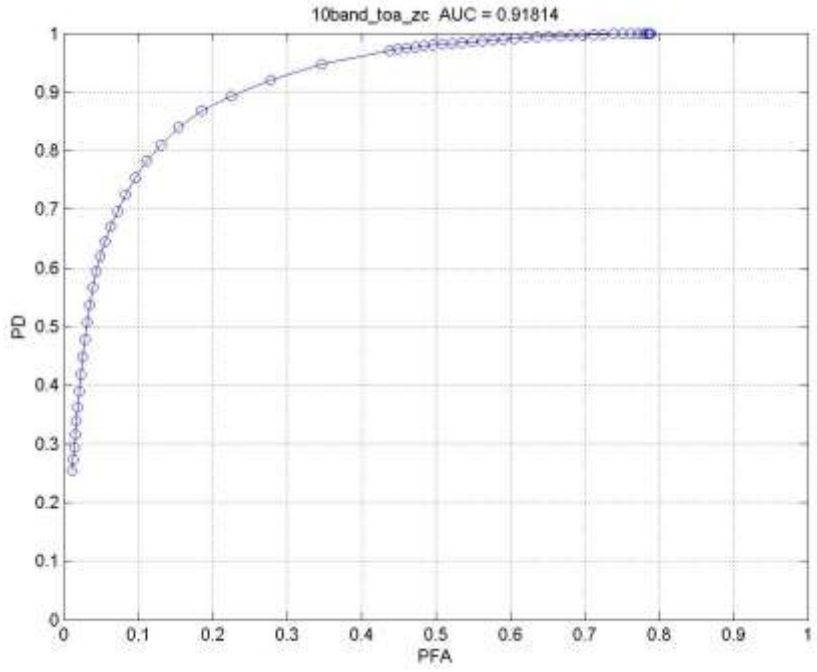



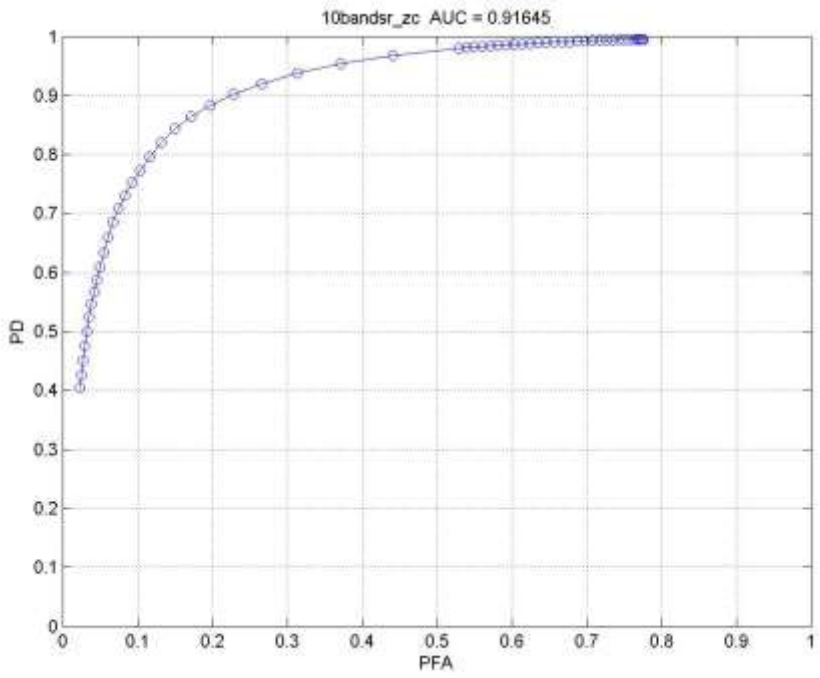



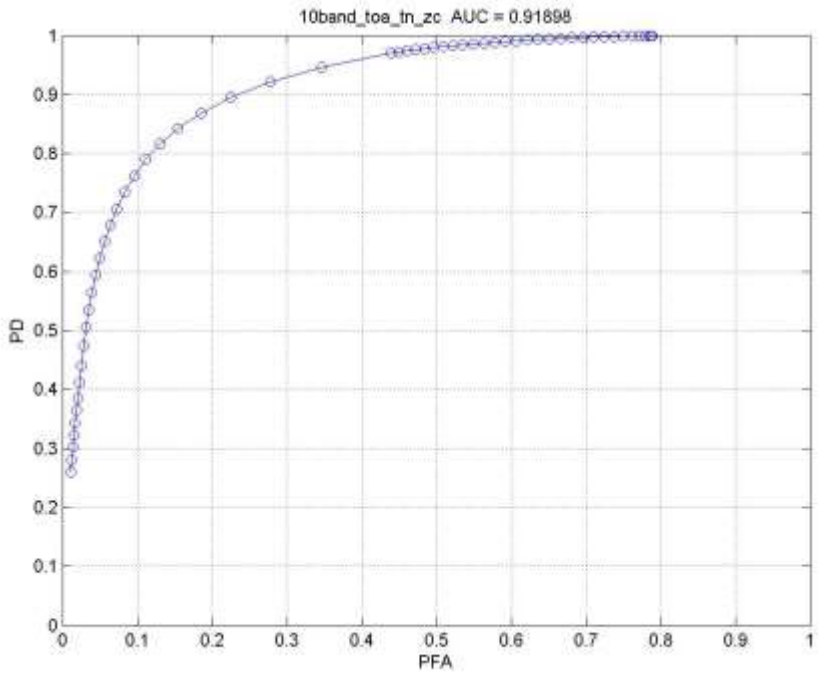



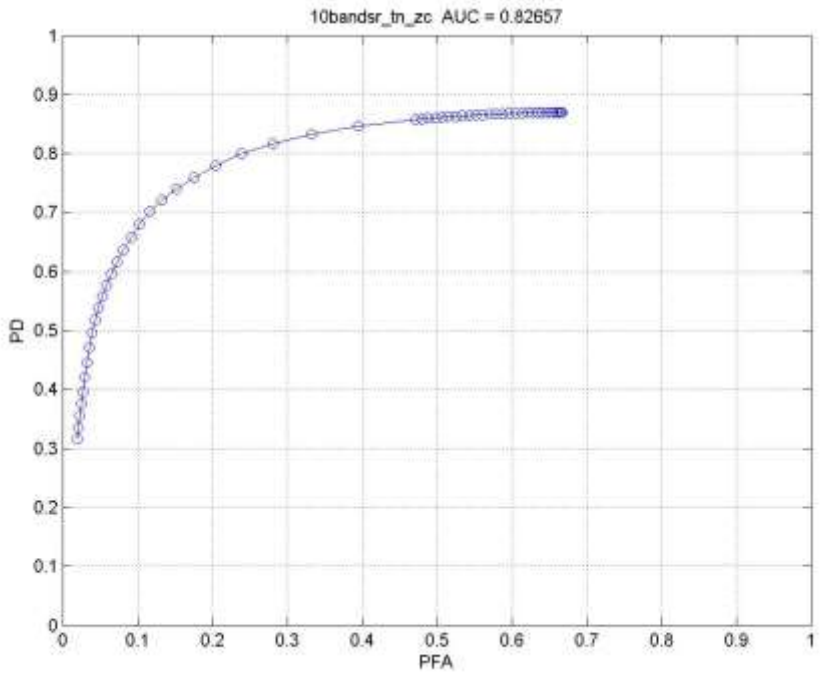
# Results 10-band T49RGP

- SR decreased accuracy
- TN did not consistenly impact accuracy
- SR/TN run anomalous

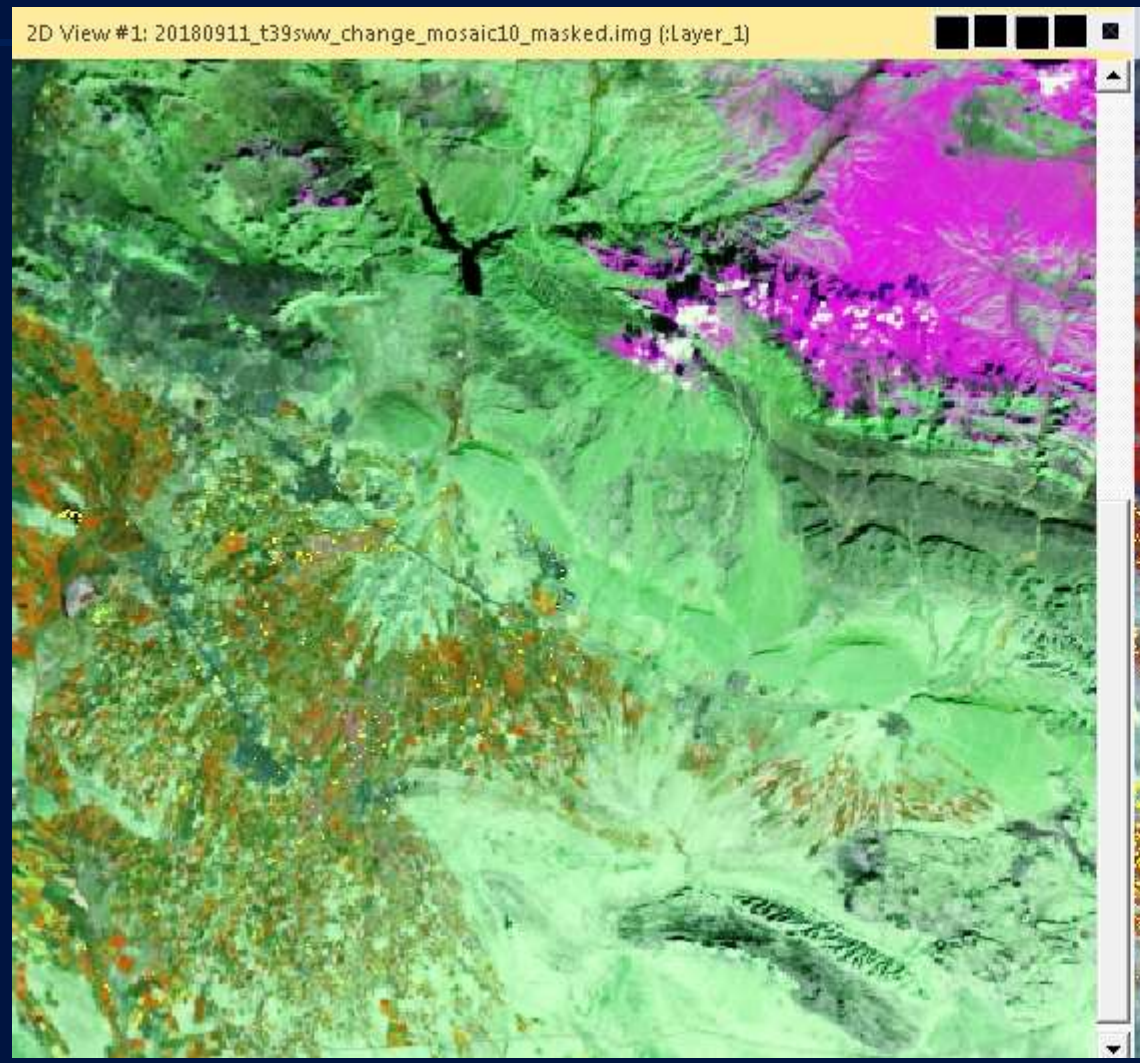


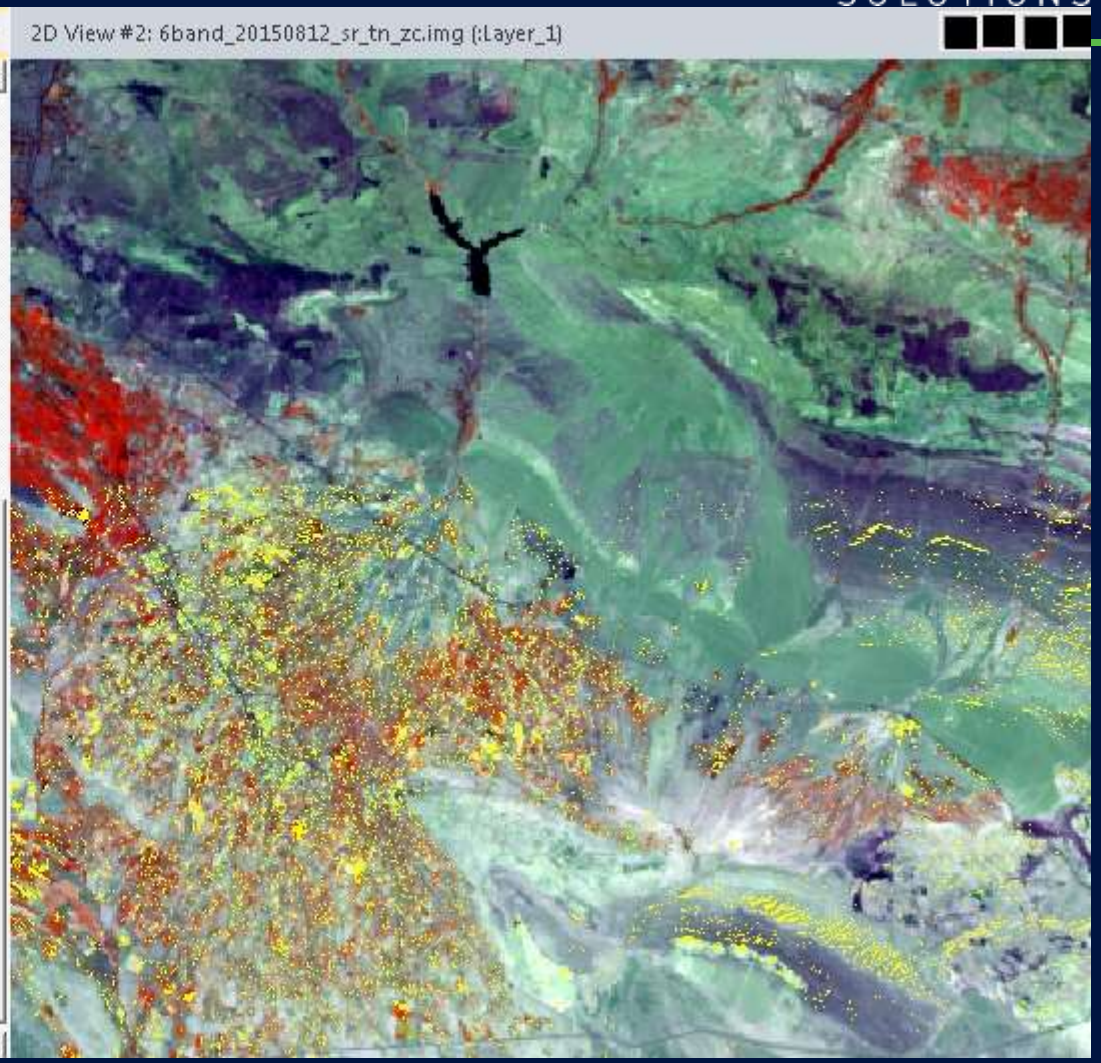



# Reference Change Mask T39SWV



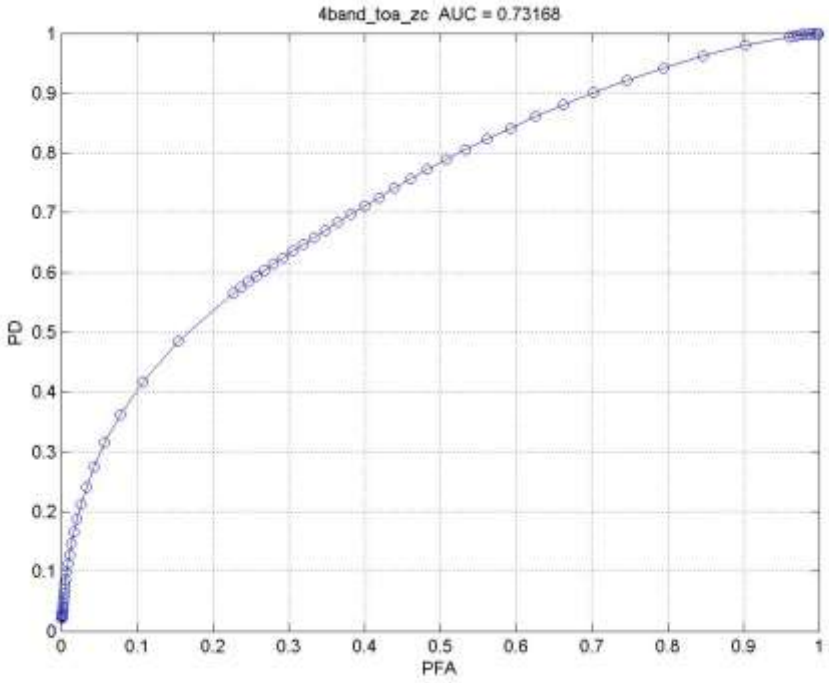

2018-09-11 S-2 image with reference change mask in yellow

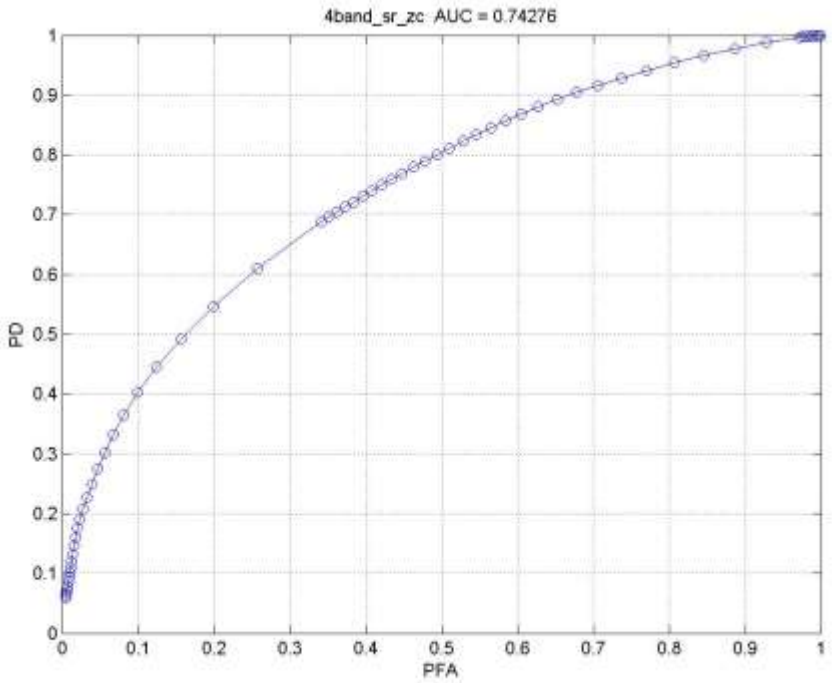


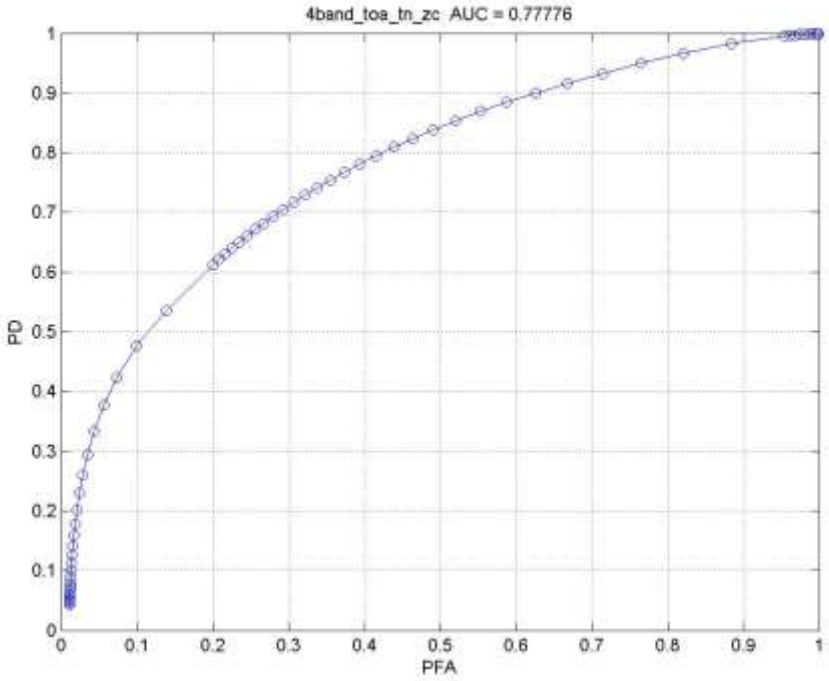

2015-08-12 S-2 image with thresholded Z-score in yellow

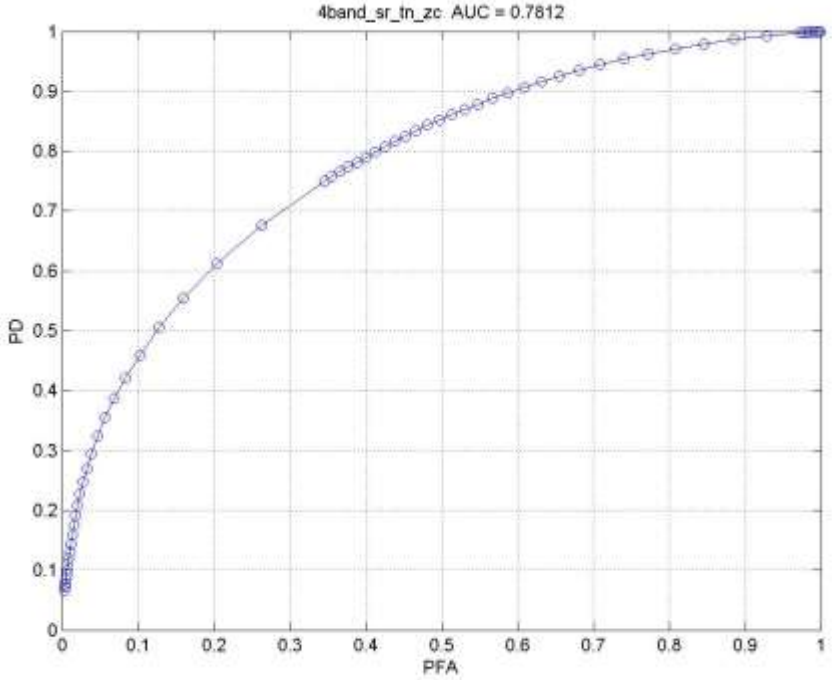
# Results 4-band T39SWV

- SR improved results
- TN improved results
- This scene has varied terrain
- It has a good mix of land cover types



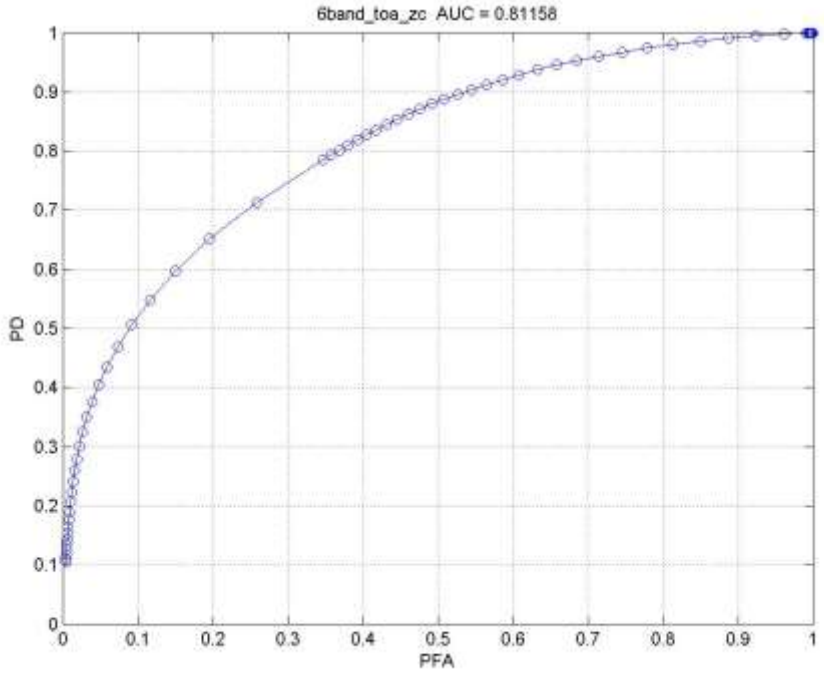



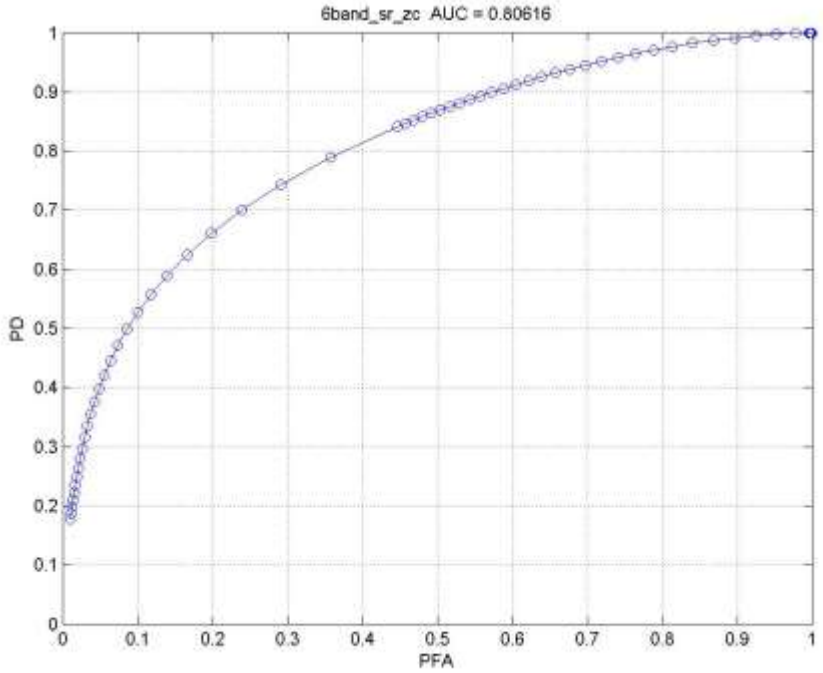



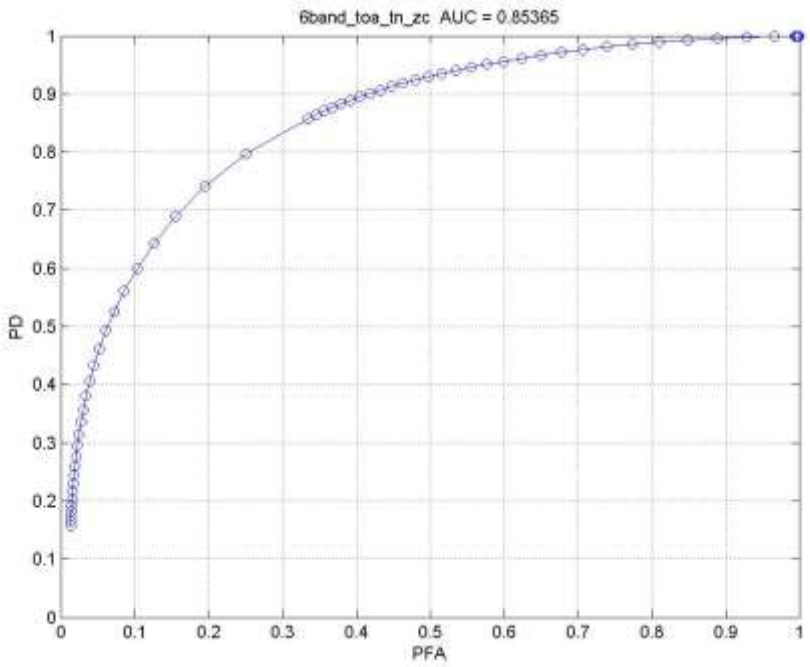



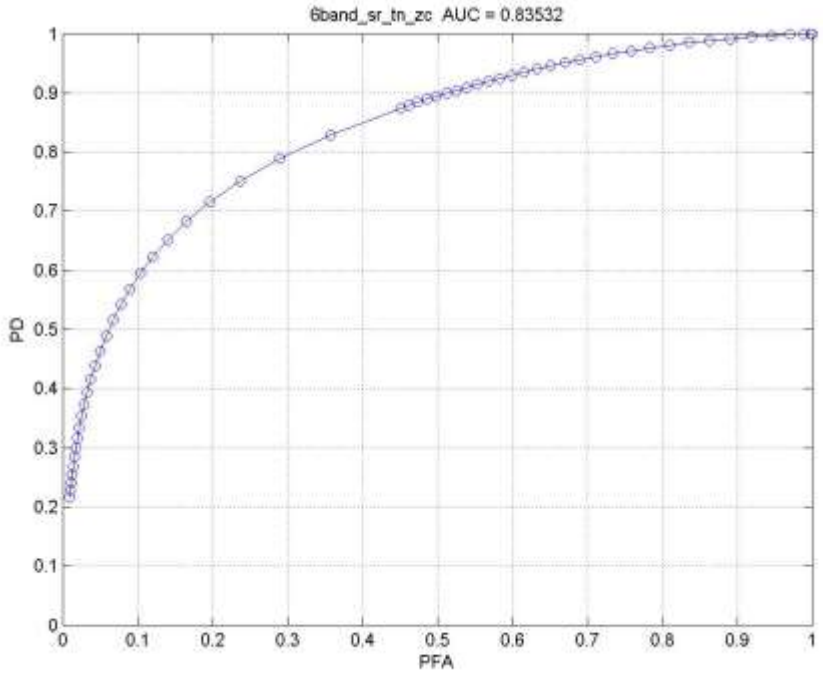
# Results 6-band T39SWV

- SR slightly decreased accuracy
- TN increased accuracy



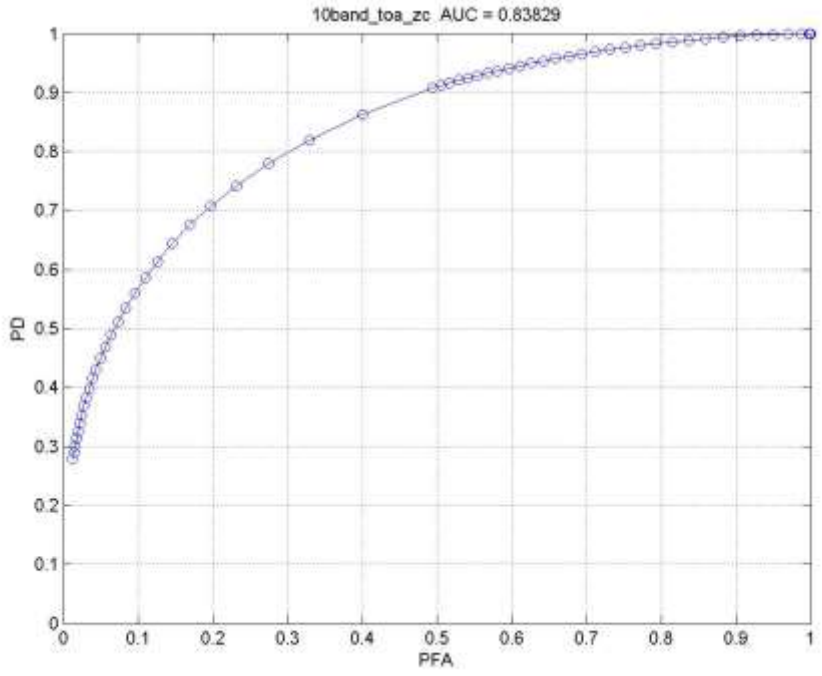



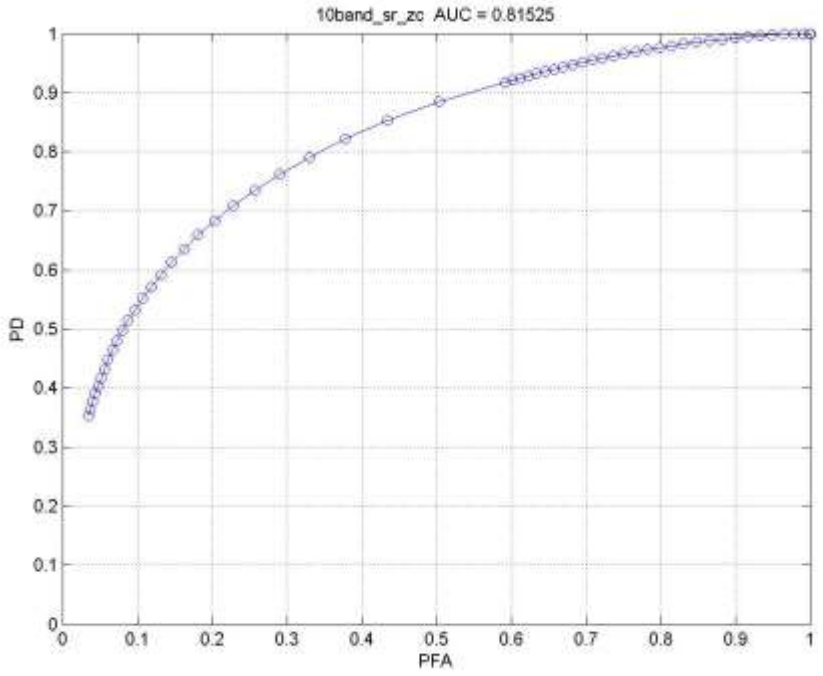



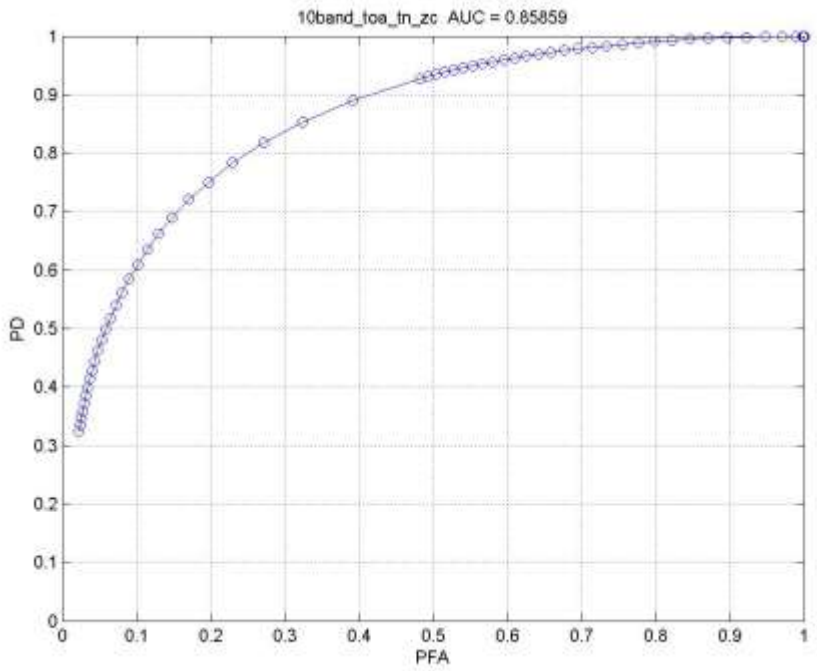



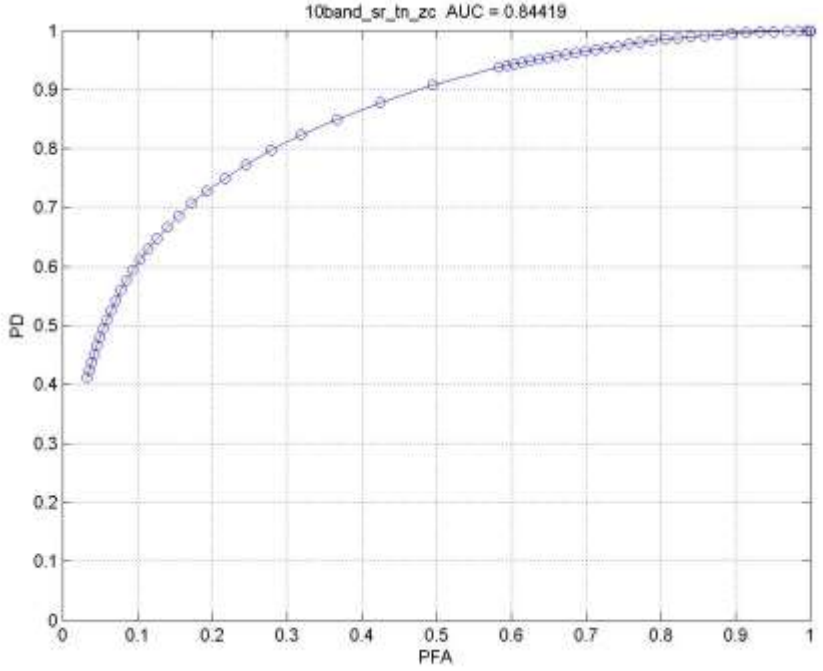
# Results 10-band T39SWV

- SR slightly reduced accuracy
- TN increased accuracy



# Summary of AUC scores

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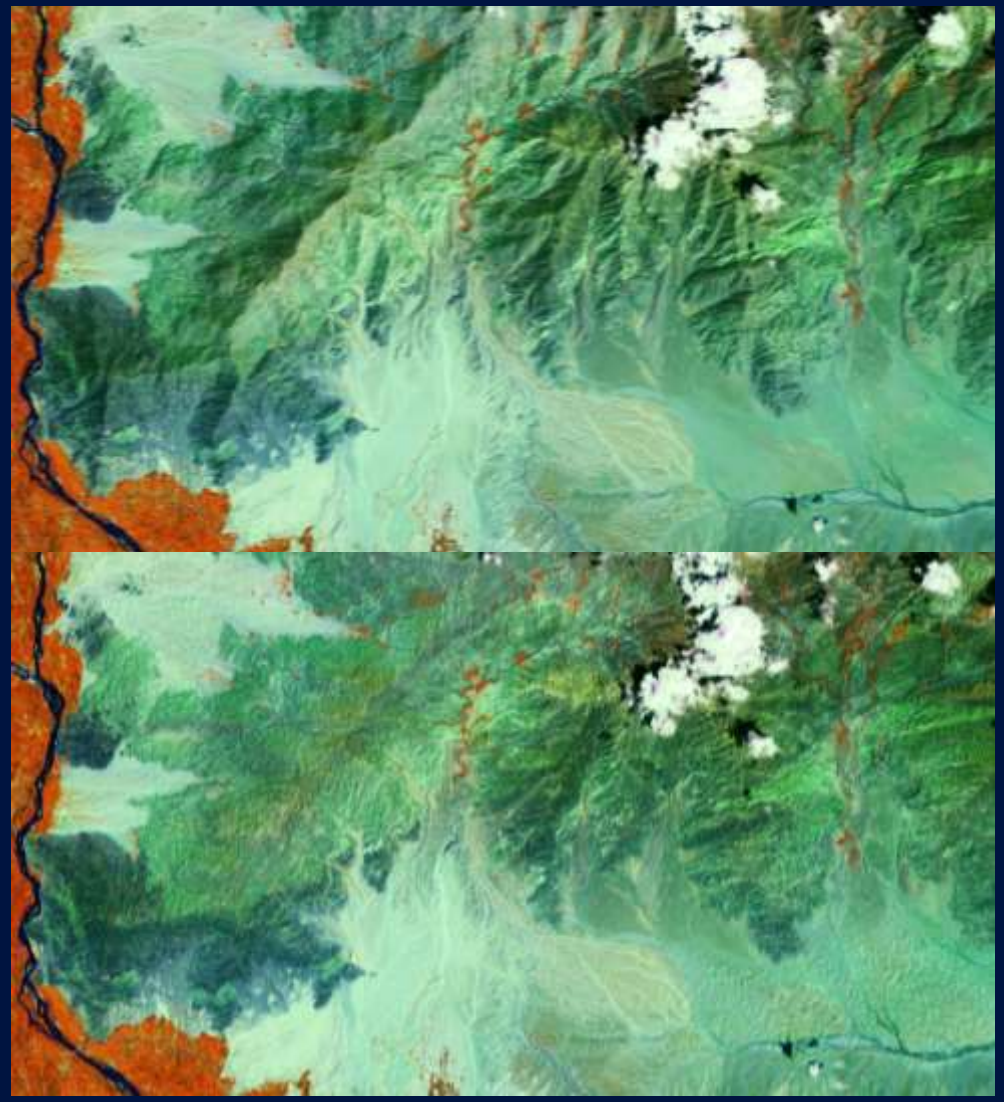
| File\Tile | T37QED | T49RGP | T39SWV | MEANS | Statistics | |
|---|---|---|---|---|---|---|
| 4-band TOA TN | 0.9605 | 0.912 | 0.7778 | 0.8834 | 0.8776 | MEAN |
| 4-band TOA | 0.9612 | 0.9121 | 0.7317 | 0.8683 | 0.8857 | MAX |
| 4-band SR TN | 0.9656 | 0.9102 | 0.7812 | 0.8857 | 0.8683 | MIN |
| 4-band SR | 0.9656 | 0.9104 | 0.7428 | 0.8729 | 0.0083 | SD |
| 6-band TOA TN | 0.9771 | 0.9137 | 0.8536 | 0.9148 | 0.9063 | MEAN |
| 6-band TOA | 0.9768 | 0.9147 | 0.8116 | 0.9010 | 0.9148 | MAX |
| 6-band SR TN | 0.9798 | 0.9127 | 0.8353 | 0.9093 | 0.9000 | MIN |
| 6-band SR | 0.981 | 0.9129 | 0.8062 | 0.9000 | 0.0070 | SD |
| 10-band TOA TN | 0.9675 | 0.919 | 0.8586 | 0.9150 | 0.9013 | MEAN |
| 10-band TOA | 0.9689 | 0.9181 | 0.8383 | 0.9084 | 0.9150 | MAX |
| 10-band SR TN | 0.9706 | 0.8266 | 0.8442 | 0.8805 | 0.8805 | MIN |
| 10-band SR | 0.9721 | 0.9164 | 0.8152 | 0.9012 | 0.0150 | SD |
| MEANS | 0.9706 | 0.9066 | 0.8080 | | | |

# Conclusions

- SR does not consistently increase accuracy in statistical change product
  - Maybe it makes more impact when imagery is spectrally or temporally more variable
- TN increases accuracy in scenes with variable terrain
- TN does not consistently decrease accuracy in flat scenes
  - Provided you use a good quality DEM
- More important what bands used than pre-processing used
- 4-band VNIR imagery consistently returns the lowest accuracies, SWIR bands are important
- General recommendation: 6-band TOA TN



# Future study

radiant SOLUTIONS

- Assess on more Sentinel-2 tiles
- Increase sample to include:
  - Areas of more variable terrain
  - Varied biomes such as tropical and arctic
- Assess on varied sensors
- Cross-sensor change detection
- Assess using varied change detection techniques

# Thank You