# A surface reflectance standard product from LDCM and supporting activities

**Principal Investigator**
**Dr. Eric Vermote**
**Geography Dept.,**
**University of Maryland**

**Co. P.I.**
**Dr. Chris Justice**
**Geography Dept.,**
**University of Maryland**

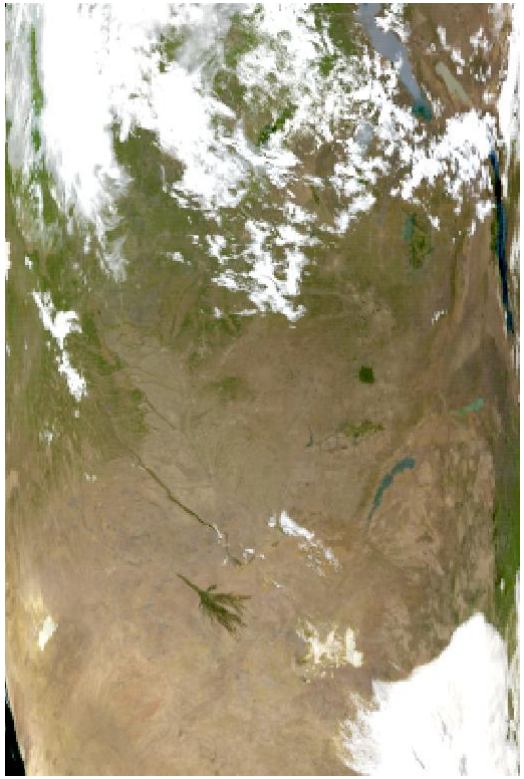
# Rationale for the research activities

- A Surface Reflectance standard product developed for MODIS provides the basis for a number of higher order land products for global change and applications research
- It is possible to develop an operational robust, globally applicable and fully automated code for integration into the LDCM processing chain and the code made openly available for others to use (e.g. LDCM ground stations).
- The approach has already been tested by the LEDAPS project.

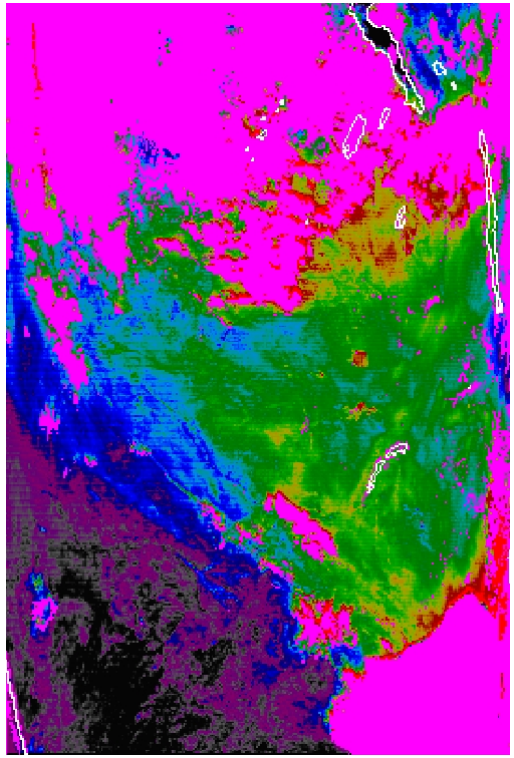
# Atmospheric effect has a strong impact on remotely sensed data

**MODIS Granule over South Africa (Sept,13,2001, 8:45 to 8:50 GMT)**

RGB no correction for aerosol effect



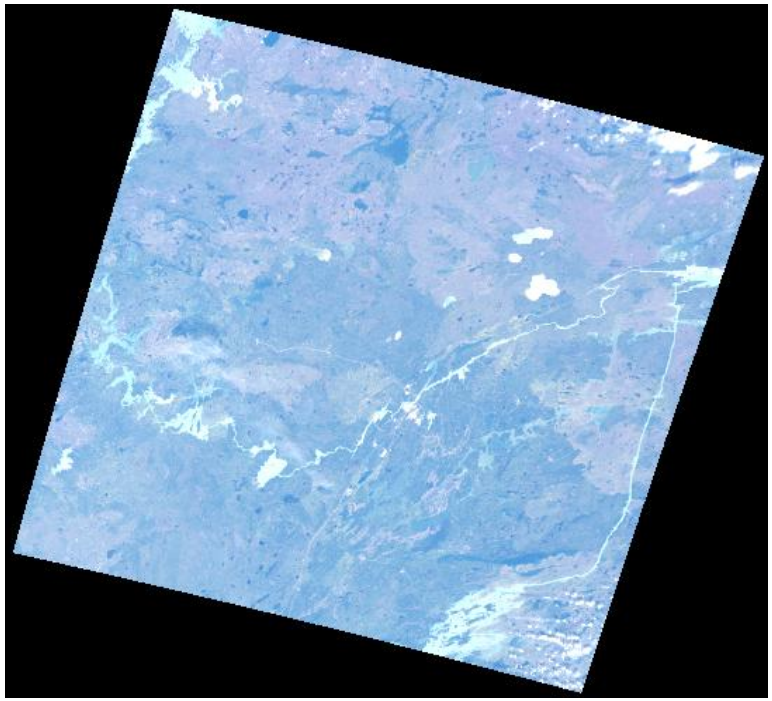
RGB surface reflectance (corrected for aerosol)



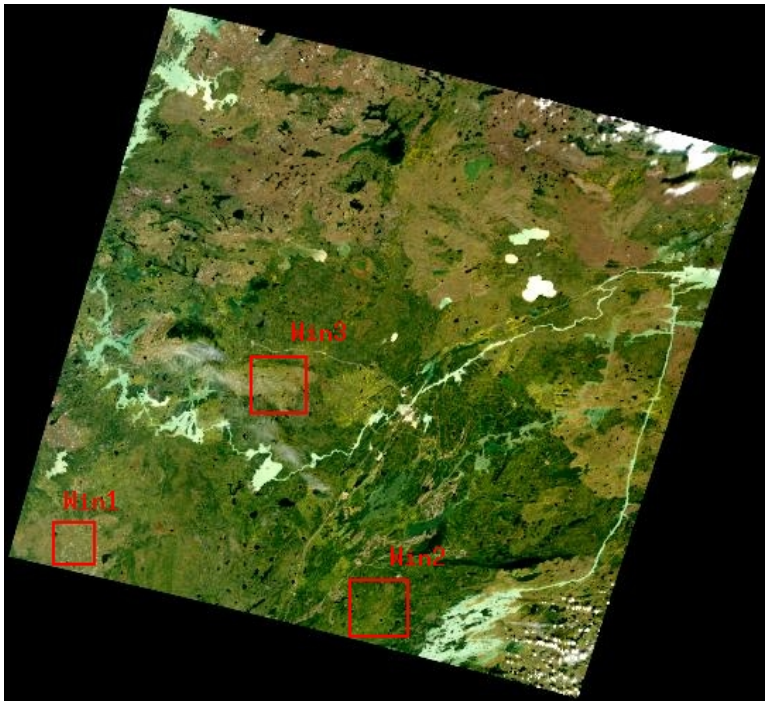
Corresponding aerosol optical thickness at 670nm (0 black, 1.0 and above red) linear rainbow scale. Clouds are in magenta, water bodies are outlined in white.

# BOREAS ETM+ scene

Scene: p033r021
Date: 09/17/2001



**Top-of-atmosphere TOA**



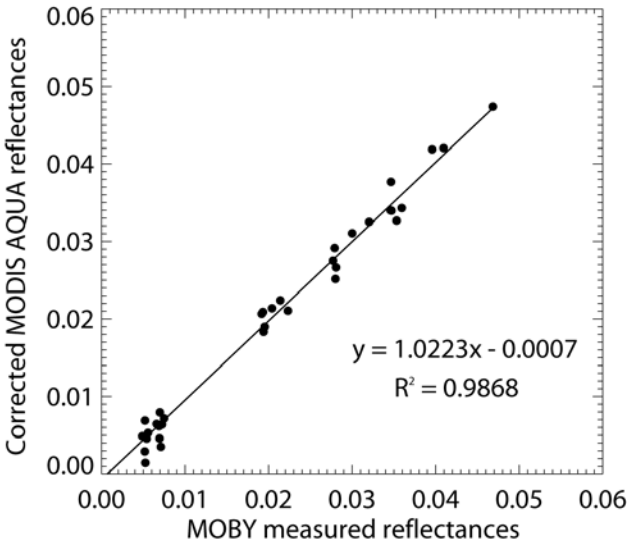

**Surface Reflectance**

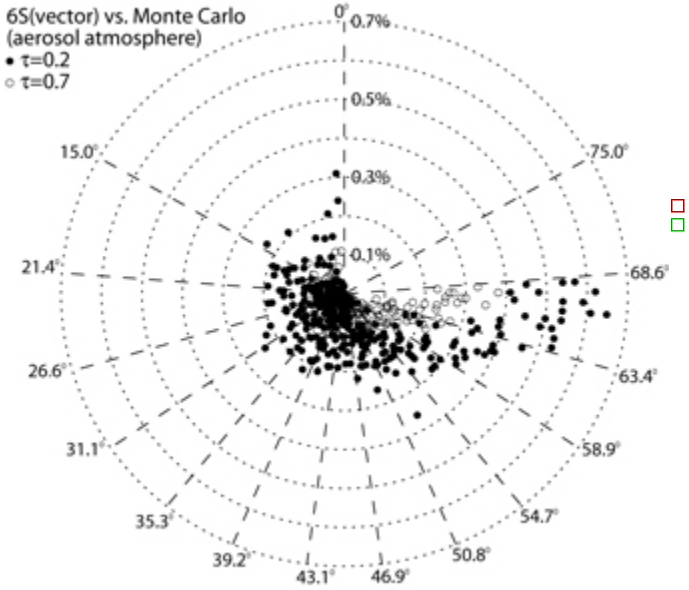
# Approach for the surface reflectance product

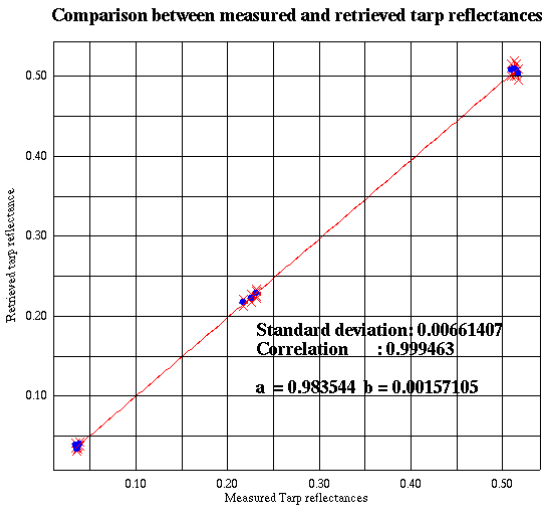
- **Atmospheric correction consistent with the MODIS, AVHRR and NPP-VIIRS approach, ensuring consistent reflectance data across resolutions based on rigorous radiative transfer**

  http://6s.ltdri.org

  http://rtcodes.ltdri.org/



# Approach for the surface reflectance product

- **Validation and uncertainties estimates. Theoretical error budget, comprehensive evaluation.**

FOREST

**Belterra**

| | | Clear | Average | Hazy |
|---|---|---|---|---|
| λ [nm] | ρ x10000 | | Δρx10000 | |
| 470 | 120 | 52 | 51 | 52 |
| 550 | 375 | 49 | 55 | 64 |
| 645 | 240 | 52 | 59 | 65 |
| 870 | 2931 | 40 | 152 | 246 |
| 1240 | 3083 | 38 | 110 | 179 |
| 1650 | 1591 | 29 | 52 | 84 |
| 2130 | 480 | 41 | 28 | 42 |
| NDVIx1000 | | | ΔNDVI x1000 | |
| 849 | | 30 | 34 | 40 |

SAVANNA

**Skukuza**

| | | Clear | Average | Hazy |
|---|---|---|---|---|
| λ [nm] | ρ x10000 | | Δρx10000 | |
| 470 | 400 | 52 | 52 | 53 |
| 550 | 636 | 52 | 58 | 64 |
| 645 | 800 | 53 | 62 | 67 |
| 870 | 2226 | 35 | 103 | 164 |
| 1240 | 2880 | 38 | 97 | 158 |
| 1650 | 2483 | 35 | 66 | 104 |
| 2130 | 1600 | 40 | 36 | 53 |
| NDVIx1000 | | | ΔNDVI x1000 | |
| 471 | | 22 | 28 | 33 |

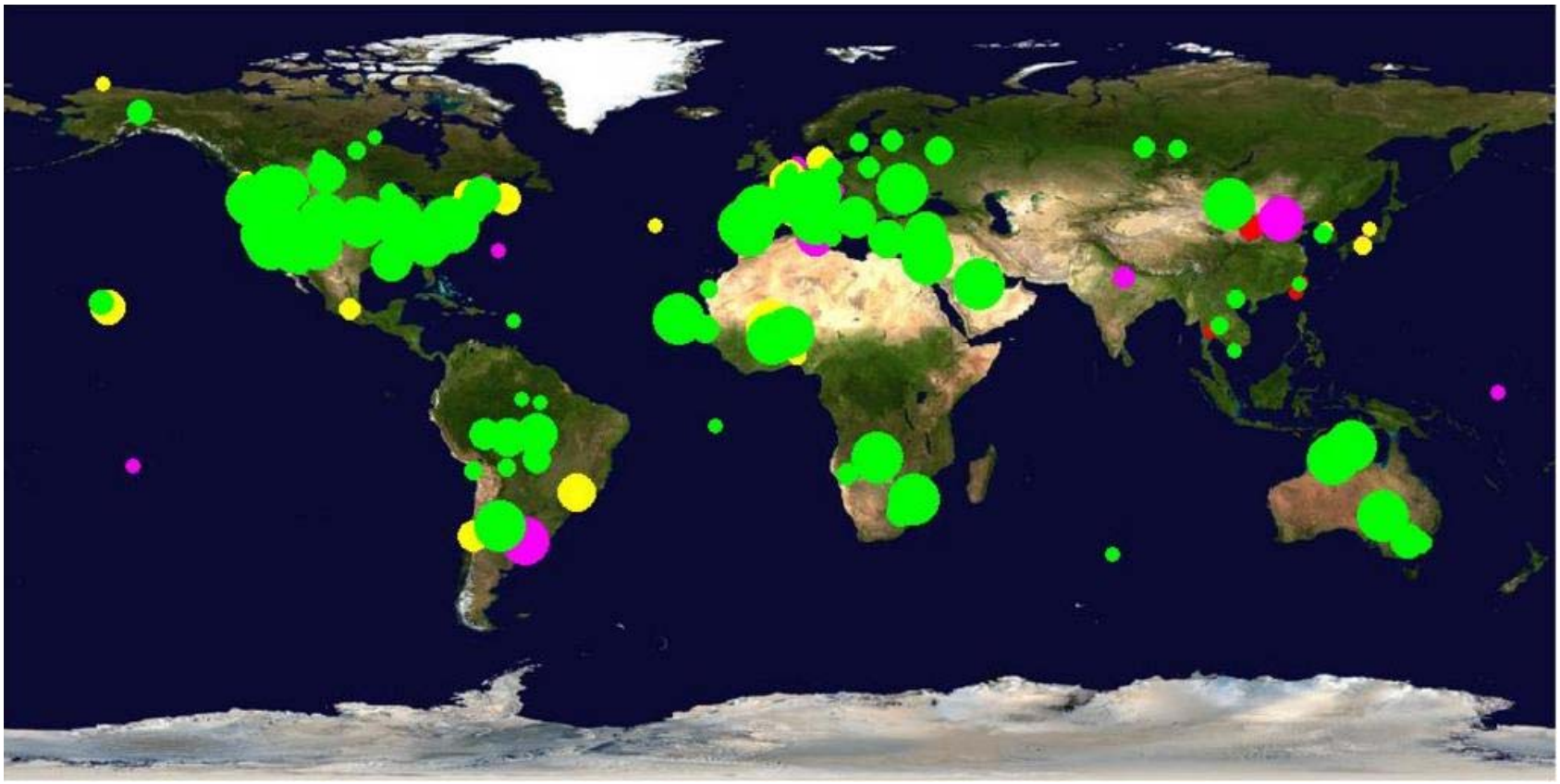
SEMI-ARID

**Sevilleta**

| | | Clear | Average | Hazy |
|---|---|---|---|---|
| λ [nm] | ρ x10000 | | Δρx10000 | |
| 470 | 700 | 51 | 53 | 55 |
| 550 | 1246 | 51 | 70 | 85 |
| 645 | 1400 | 57 | 74 | 85 |
| 870 | 2324 | 41 | 95 | 146 |
| 1240 | 2929 | 45 | 93 | 148 |
| 1650 | 3085 | 55 | 81 | 125 |
| 2130 | 2800 | 56 | 60 | 87 |
| NDVIx1000 | | | ΔNDVI x1000 | |
| 248 | | 11 | 15 | 19 |

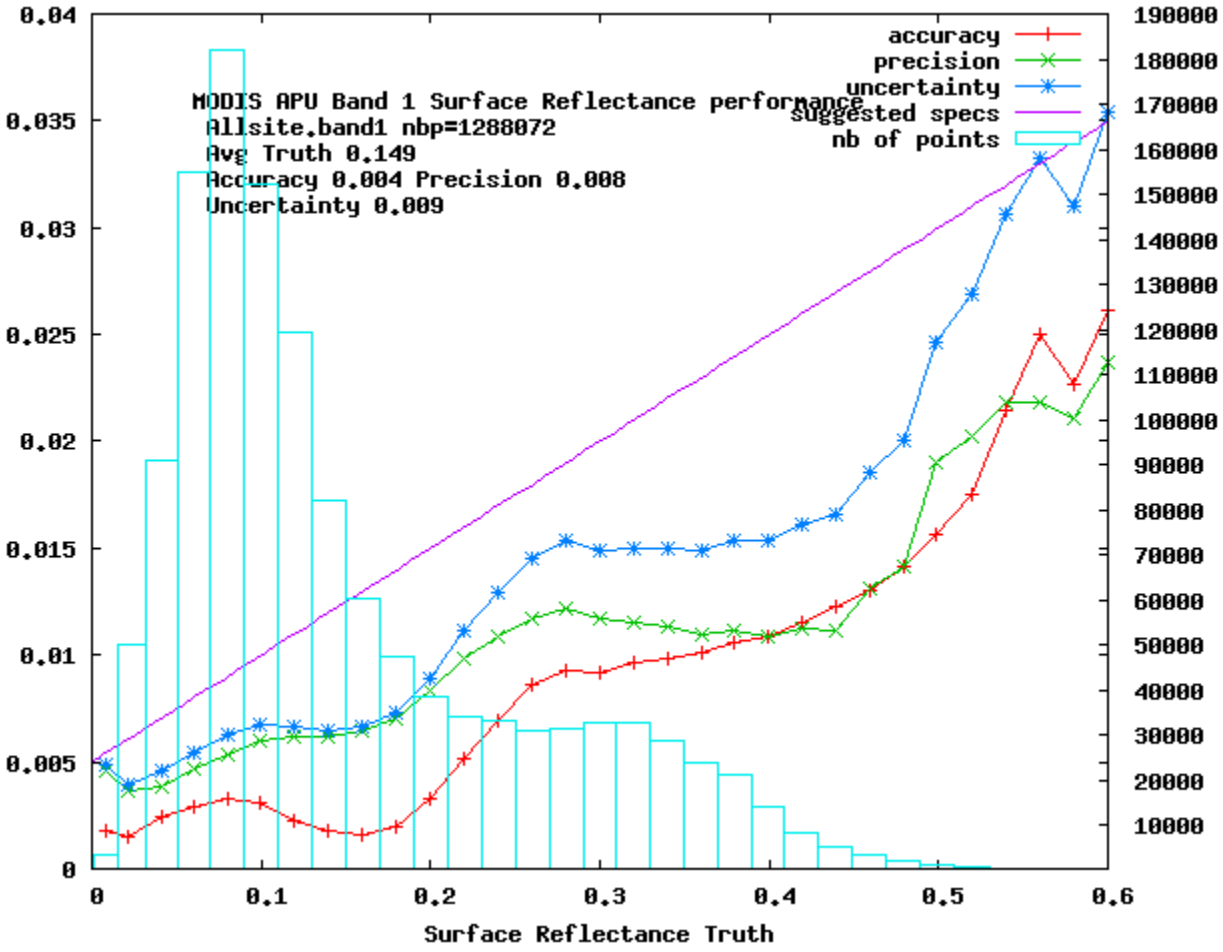
Error in ~0.5% in reflectance unit

# 2000-2007 Results (25542 cases)
# Fraction of good 88.85% (band1)



Version 2 AERONET (i.e. with Background correction and spheroid)

# Toward a quantitative assessment of performances (APU)



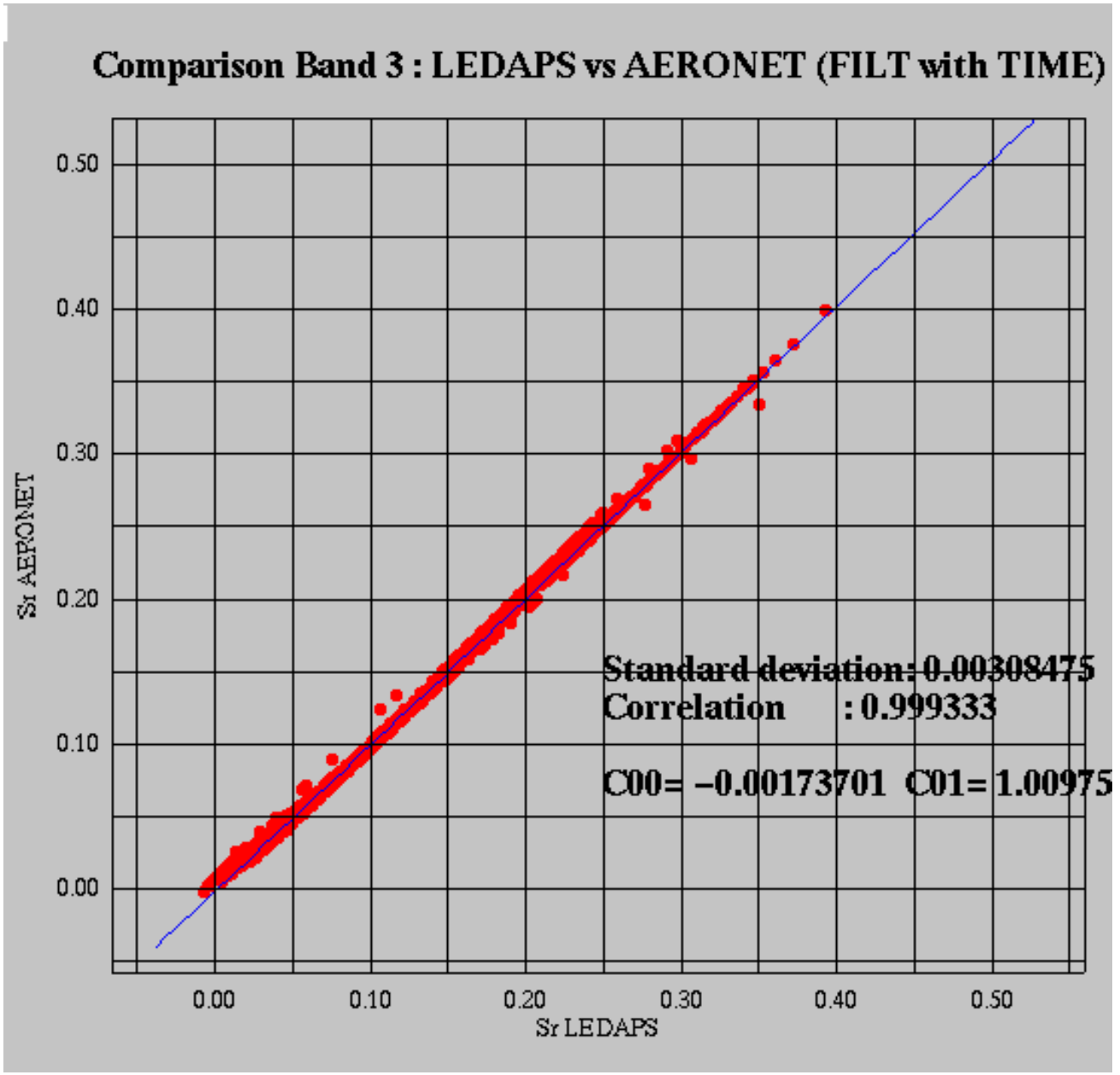

1,3 Millions 1 km pixels were analyzed for each band.

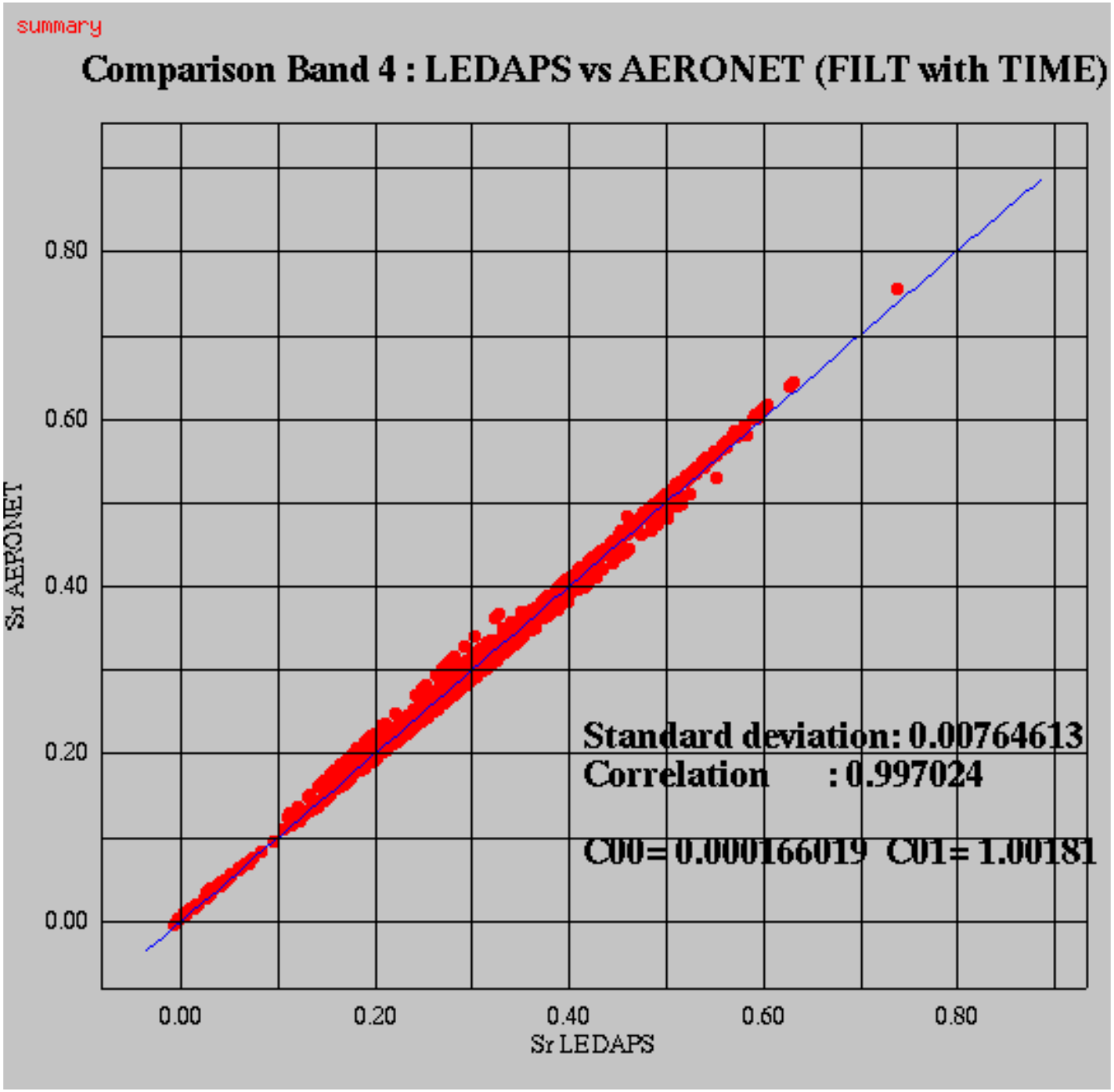
Red = Accuracy (mean bias)
Green = Precision (repeatability)
Blue = Uncertainty (quadatric sum of A and P)

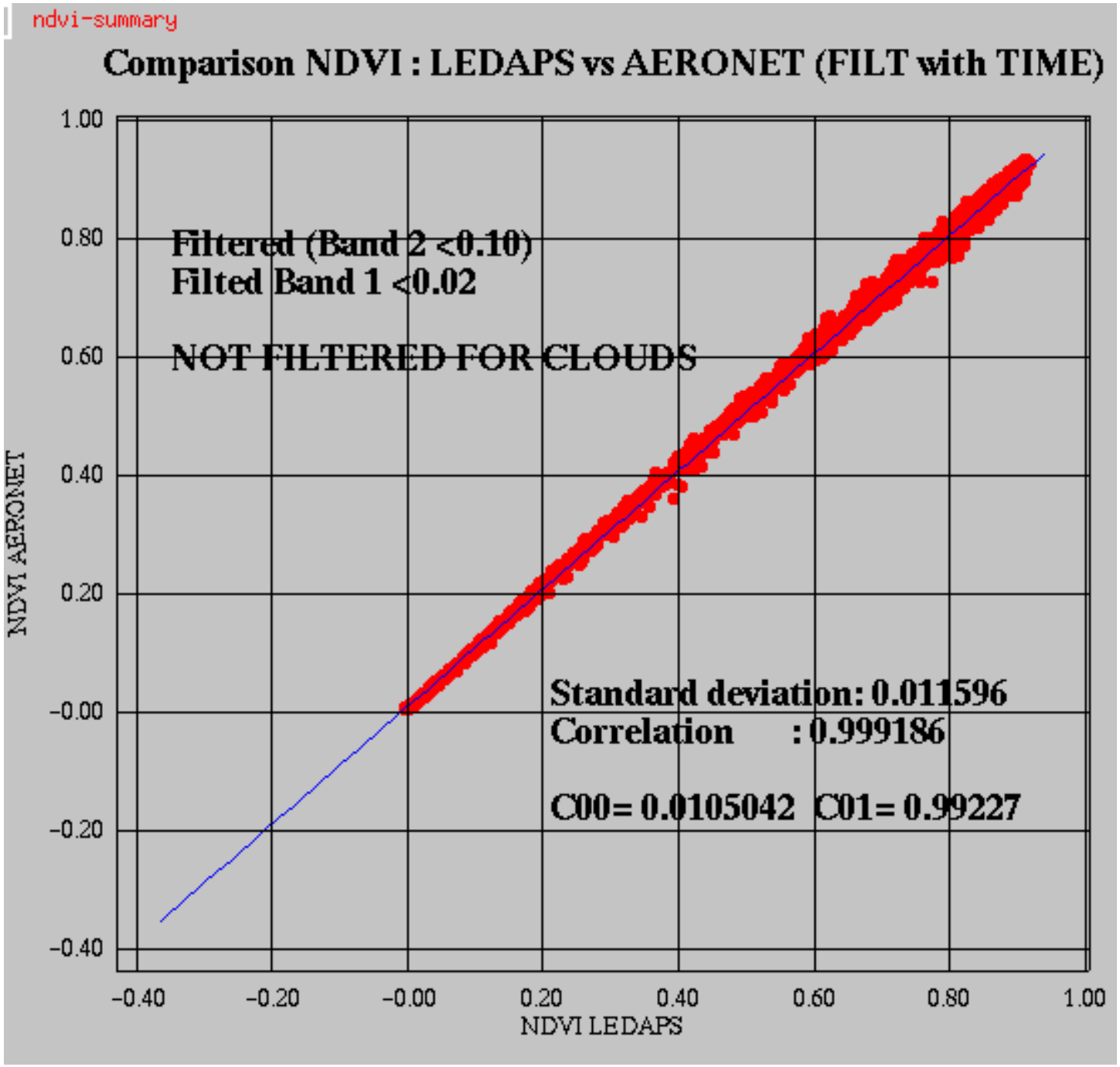
On average well below magenta theoretical error bar

# Preliminary evaluation of the LEDAPS ETM+ surface reflectance product

| DATE.PATH/ROW | AOT | TIMEDIFF | AERONET SITE |
|---|---|---|---|
| a2000122.w2p041r036 | 0.0932345 | 15 | Rogers_Dry_Lake-001221821.mie |
| a2000122.w2p041r037 | 0.162749 | 15 | UCLA-001221823.mie |
| a2000170.w2p009r029 | 0.0449007 | 60 | Kejimkujik-001701451.mie |
| a2000191.w2p028r035 | 0.0858729 | 30 | Cart_Site-001911659.mie |
| a2000247.w2p036r038 | 0.0365191 | 205 | Tucson-002471753.mie |
| a2000261.w2p022r039 | 0.0722956 | 14 | Stennis-002611628.mie |
| a2000267.w2p048r026 | 0.0727889 | 14 | Saturn_Island-002671842.mie |
| a2001155.w2p034r036 | 0.105914 | 29 | Sevilleta-011551737.mie |
| a2001216.w2p029r030 | 0.133025 | 14 | Sioux_Falls-012161656.mie |
| a2001217.w2p036r025 | 0.0797376 | 188 | Bratts_Lake-012171728.mie |
| a2001218.w2p043r028 | 0.0735507 | 254 | Rimrock-012181817.mie |
| a2001267.w2p034r032 | 0.0717833 | 14 | BSRN_BAO_Boulder-012671730.mie |
| a2001278.w2p015r033 | 0.147011 | 15 | GSFC-012781537.mie |


Comparison Band 3 : LEDAPS vs AERONET (FILT with TIME)
Sr AERONET
Sr LEDAPS
0.00
0.10
0.20
0.30
0.40
0.50
Standard deviation: 0.00308475
Correlation : 0.999333
C00= −0.00173701 C01= 1.00975

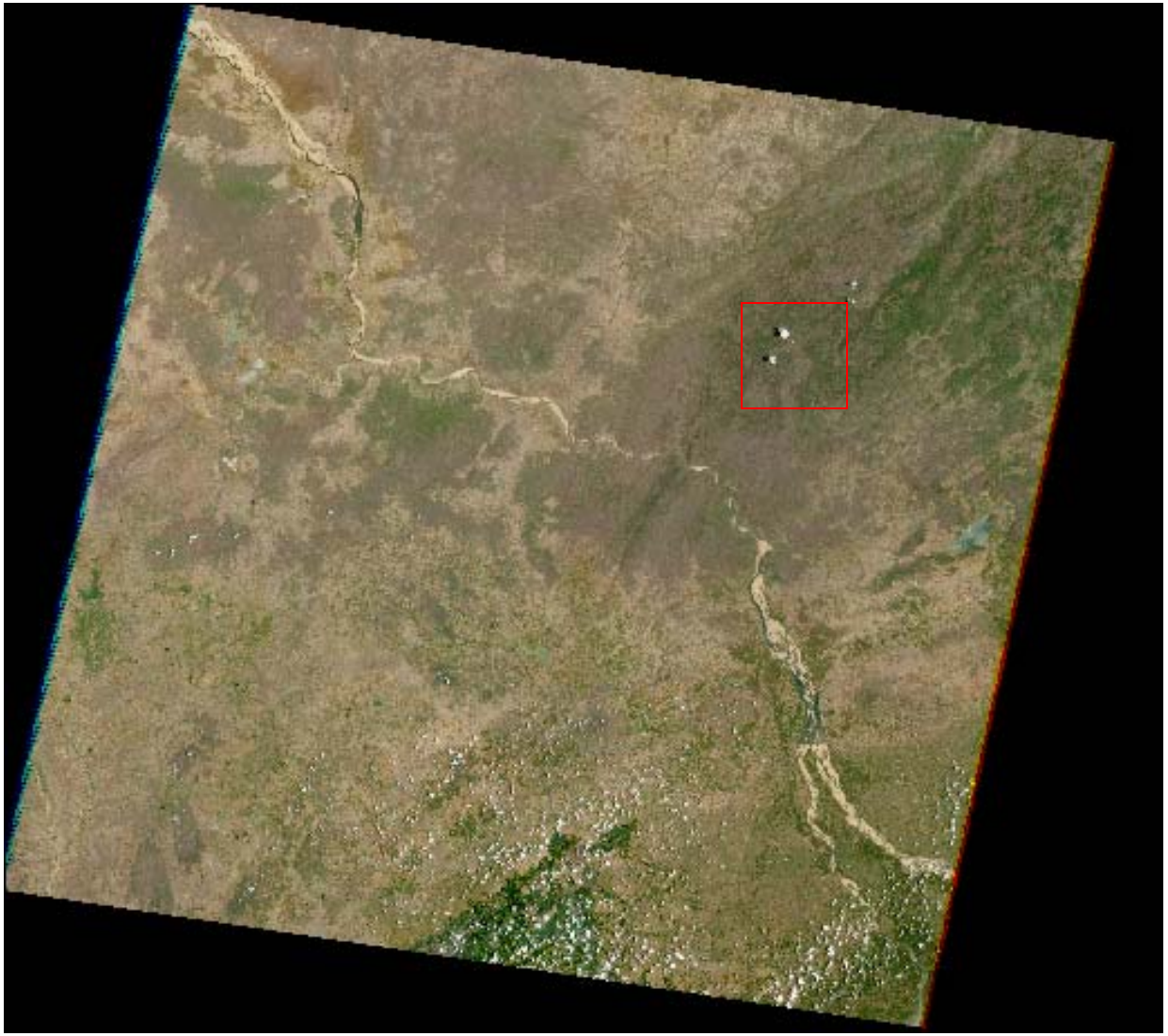

summary
Comparison Band 4 : LEDAPS vs AERONET (FILT with TIME)
Sr AERONET
Sr LEDAPS
0.00
0.20
0.40
0.60
0.80
Standard deviation: 0.00764613
Correlation : 0.997024
C00= 0.000166019 C01= 1.00181


ndvi-summary
Comparison NDVI : LEDAPS vs AERONET (FILT with TIME)
Filtered (Band 2 <0.10)
Filted Band 1 <0.02
NOT FILTERED FOR CLOUDS
Standard deviation: 0.011596
Correlation : 0.999186
C00= 0.0105042 C01= 0.99227
NDVI AERONET
NDVI LEDAPS
1.00
0.80
0.60
0.40
0.20
-0.00
-0.20
-0.40
-0.40
-0.20
-0.00
0.20
0.40
0.60
0.80
1.00

# The cloud/cloud shadow mask

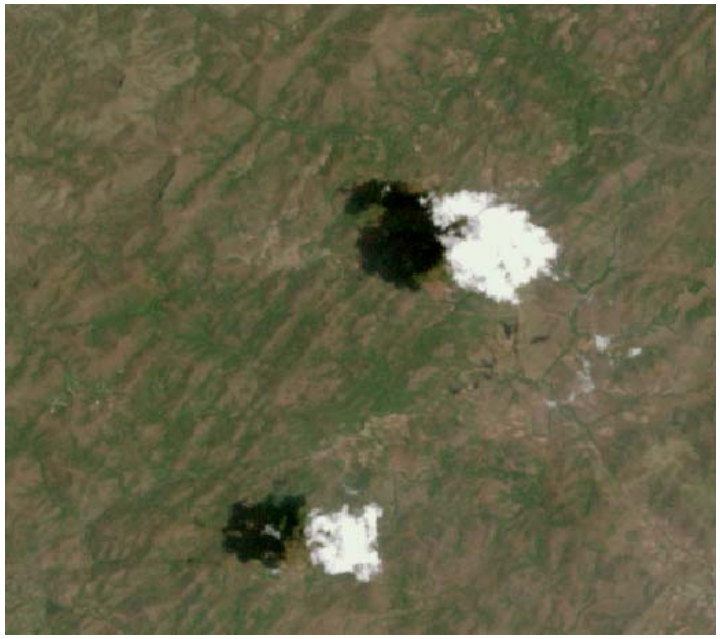
- Use the surface reflectance /thermal band
  1) First step cloud and snow mask (visible and thermal) done prior to aerosol inversion
  2) Second step - Aerosol is derived and Surface reflectance product is generated
  3) On the corrected data for non snow pixels, clouds are derived from Red-Blue anomaly (Red-Blue/2 >0.03) (Whiteness) for land pixels (1.6mic >0.05), additional test (Blue >0.30 and Temperature < NCEP based Threshold) is performed to account for saturation in the blue
  4) Clear pixel temperature is used for the shadow detection algorithm based on a hybrid of geometric and spectral approach.

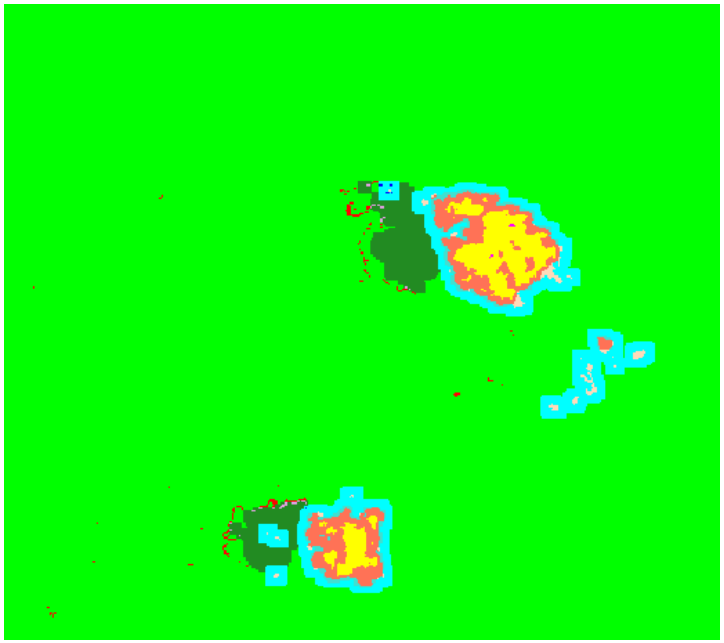
# Example of cloud/cloud shadow mask



# Cloud Mask
# Cloud are in yellow

# Details

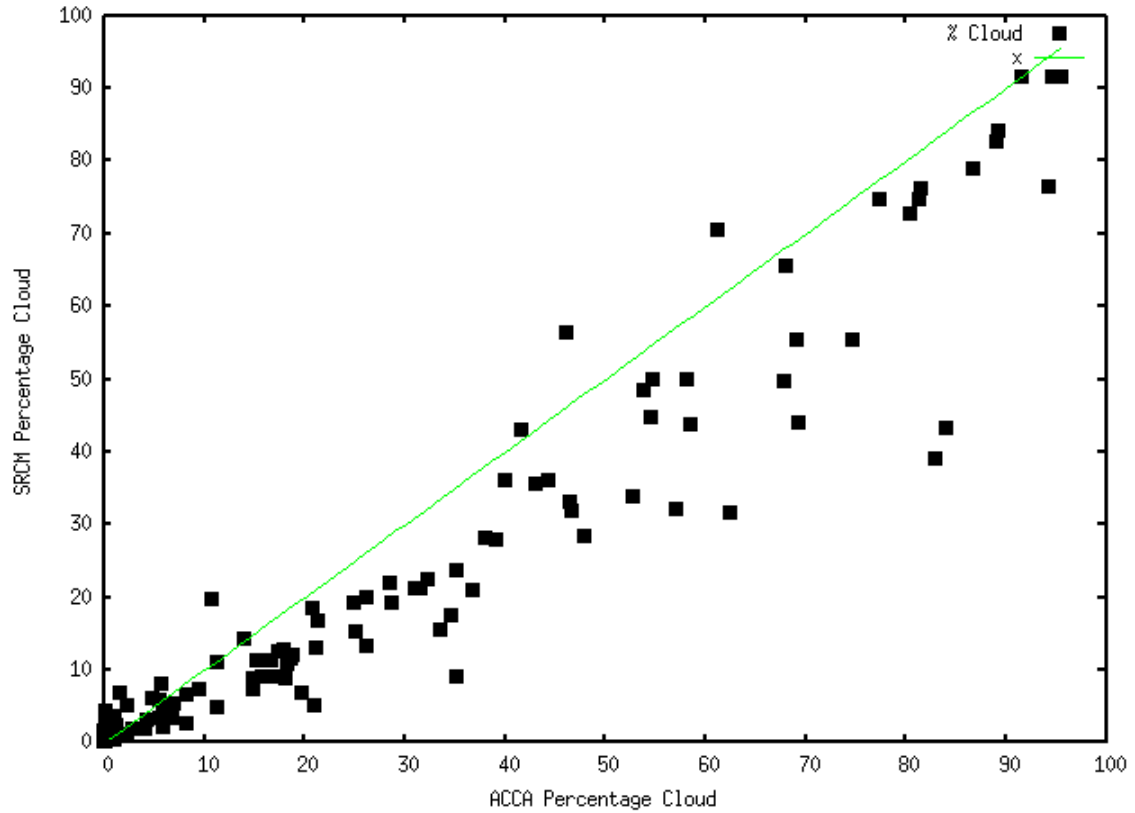


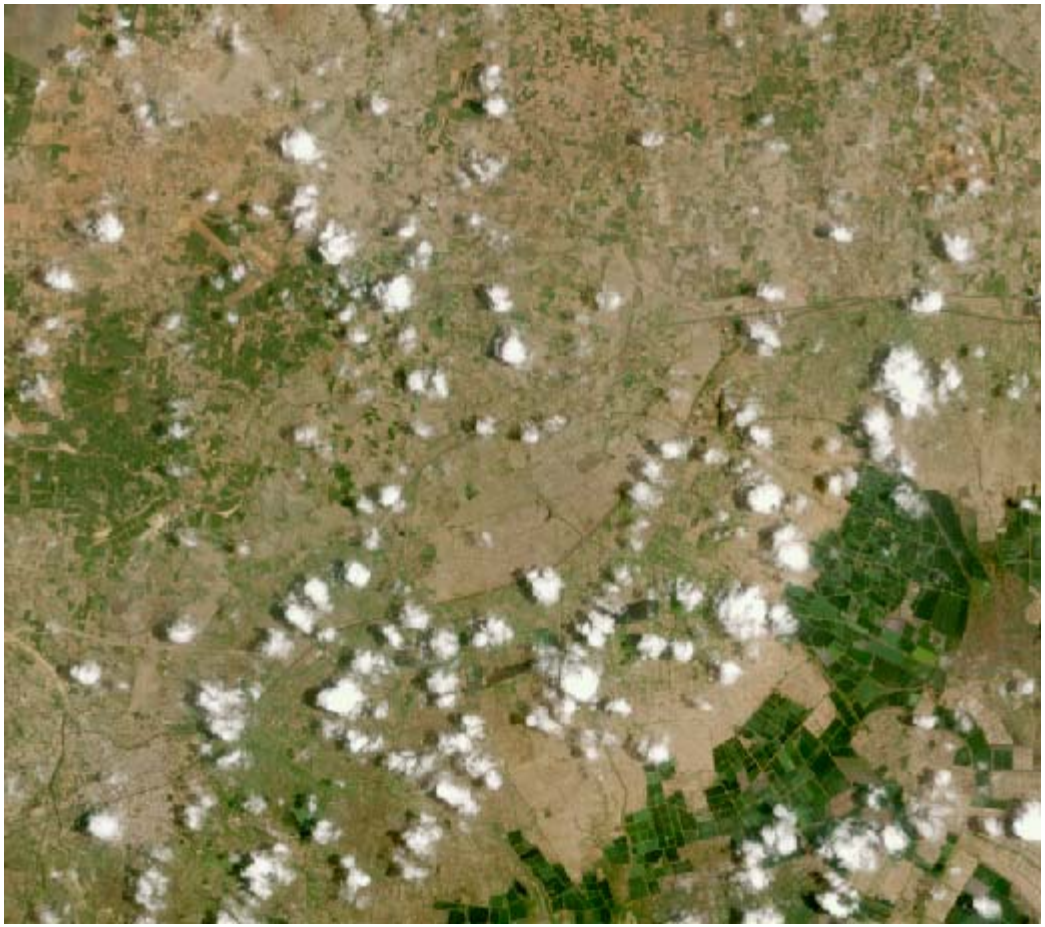


**Yellow,Orange**: clouds
**Blue**: Adjacent to cloud
**Dark Green**: Shadow
**Light green**: Clear

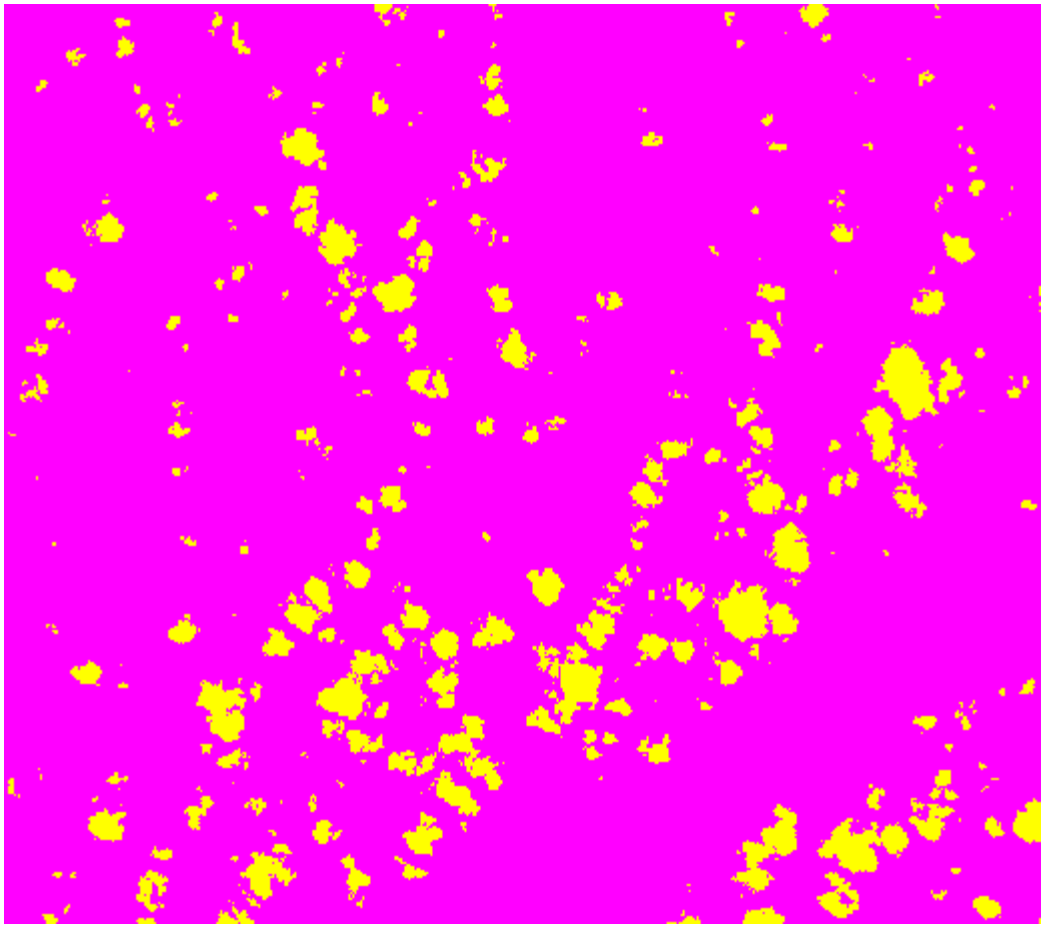
# Comparison to ACCA

- First version of simple cloud algorithm run on 2500 scenes (122 scenes, ACCA validation data set)
- Initial result shows good consistency w. ACCA showing slightly more cloud
  - Identifying those scenes with large differences for further evaluation
- Will also compare scene stats with MODIS cloud stats
- General Issue – how do you evaluate cloud mask accuracy ?

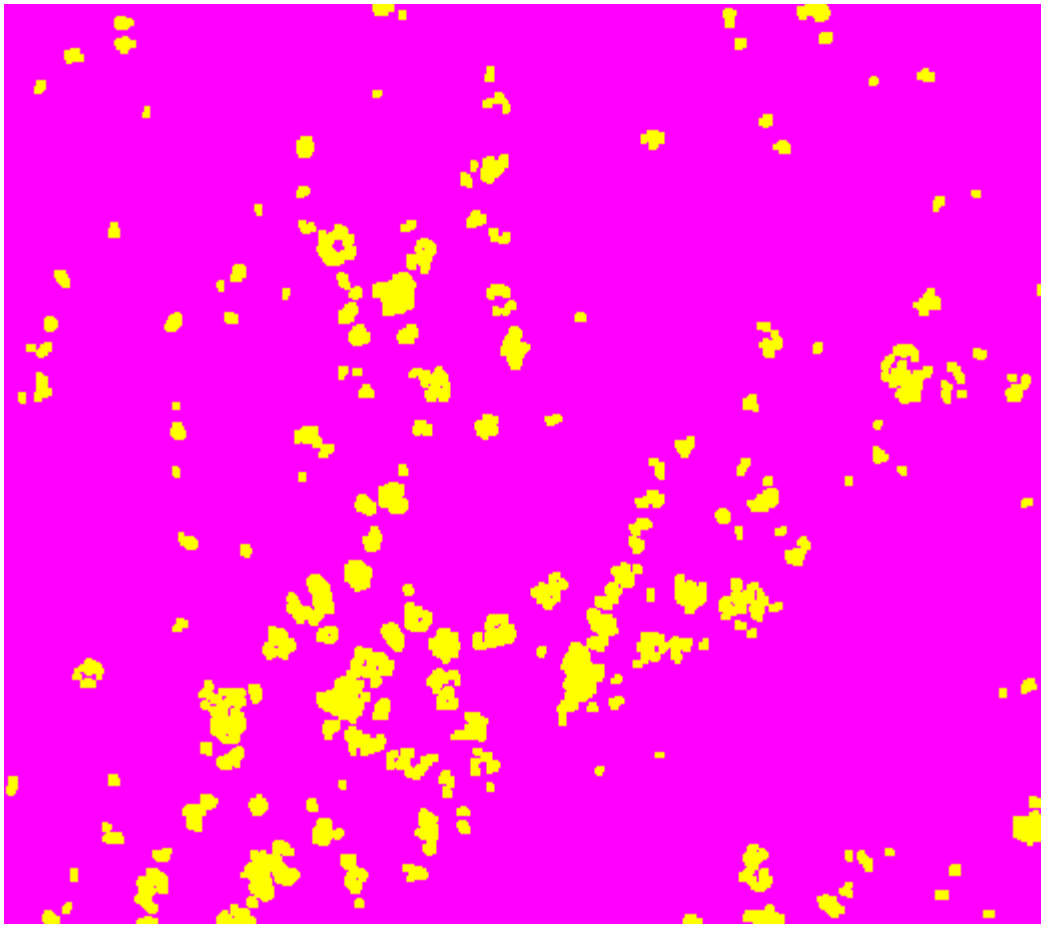


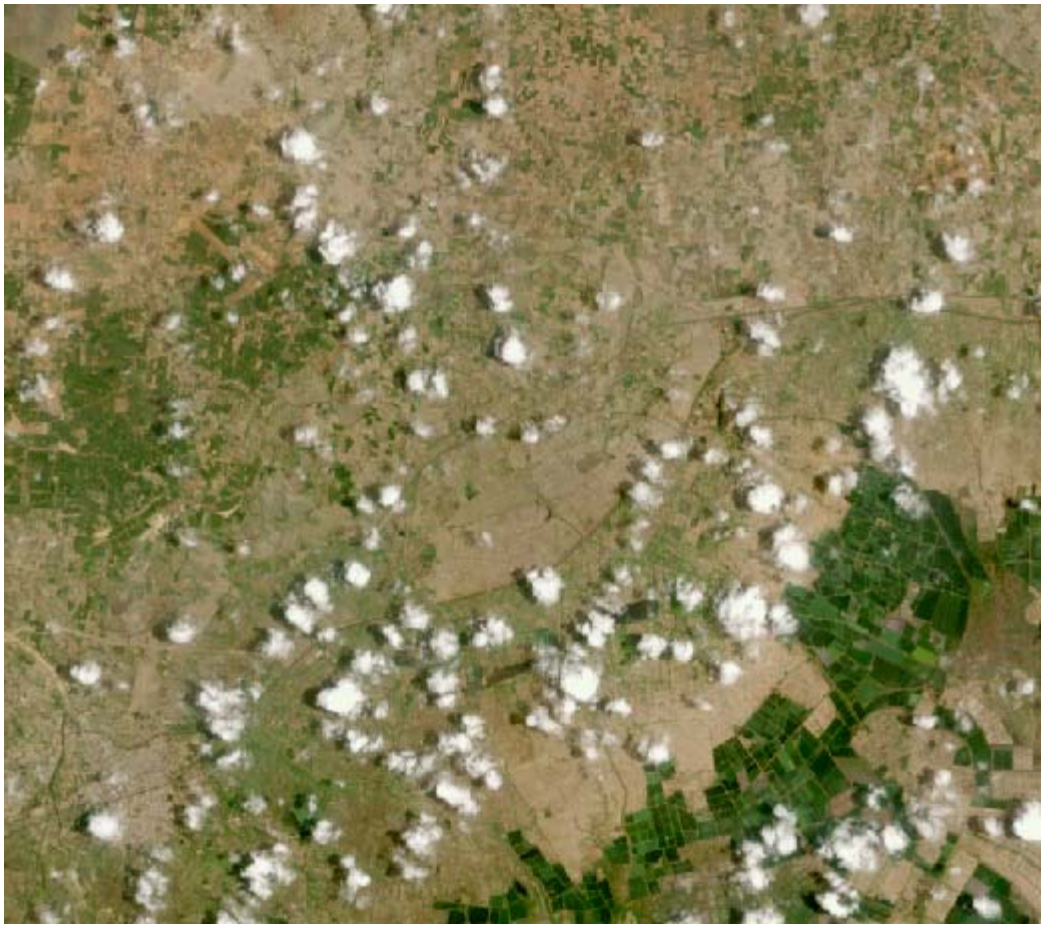


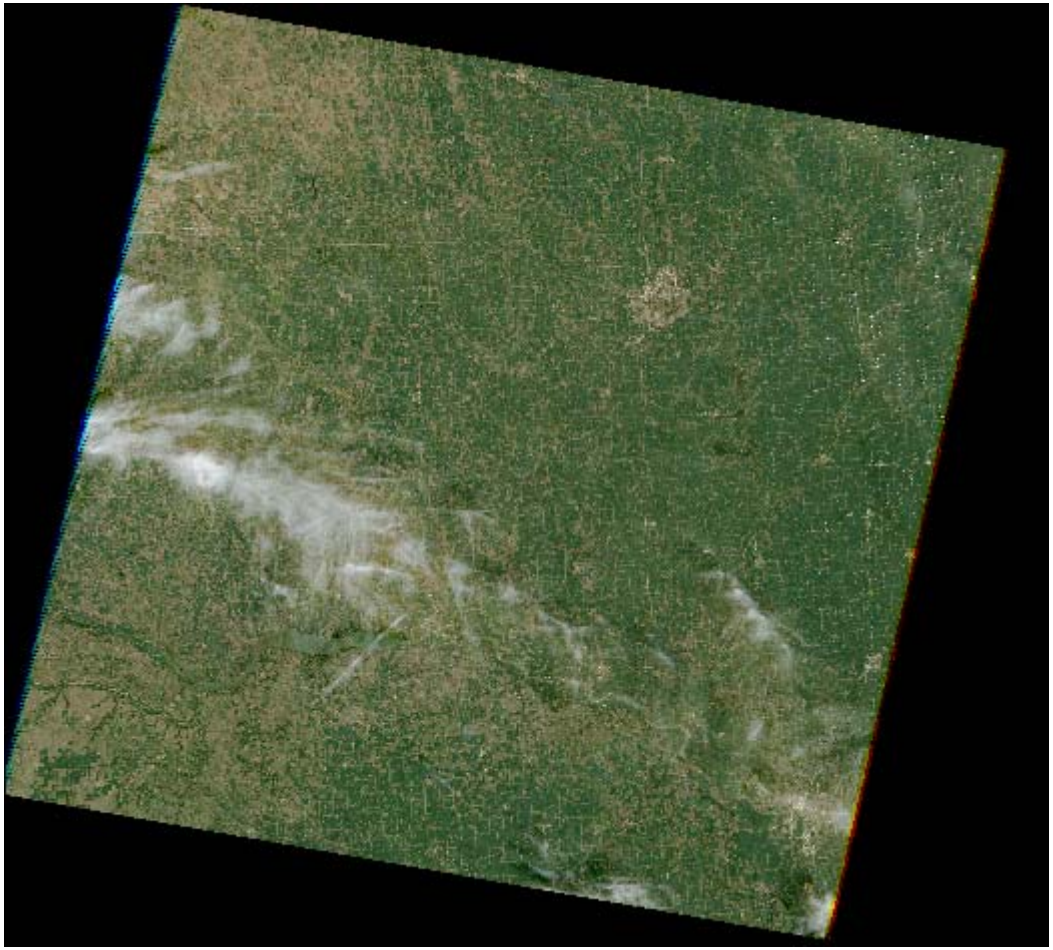
# New cloud mask

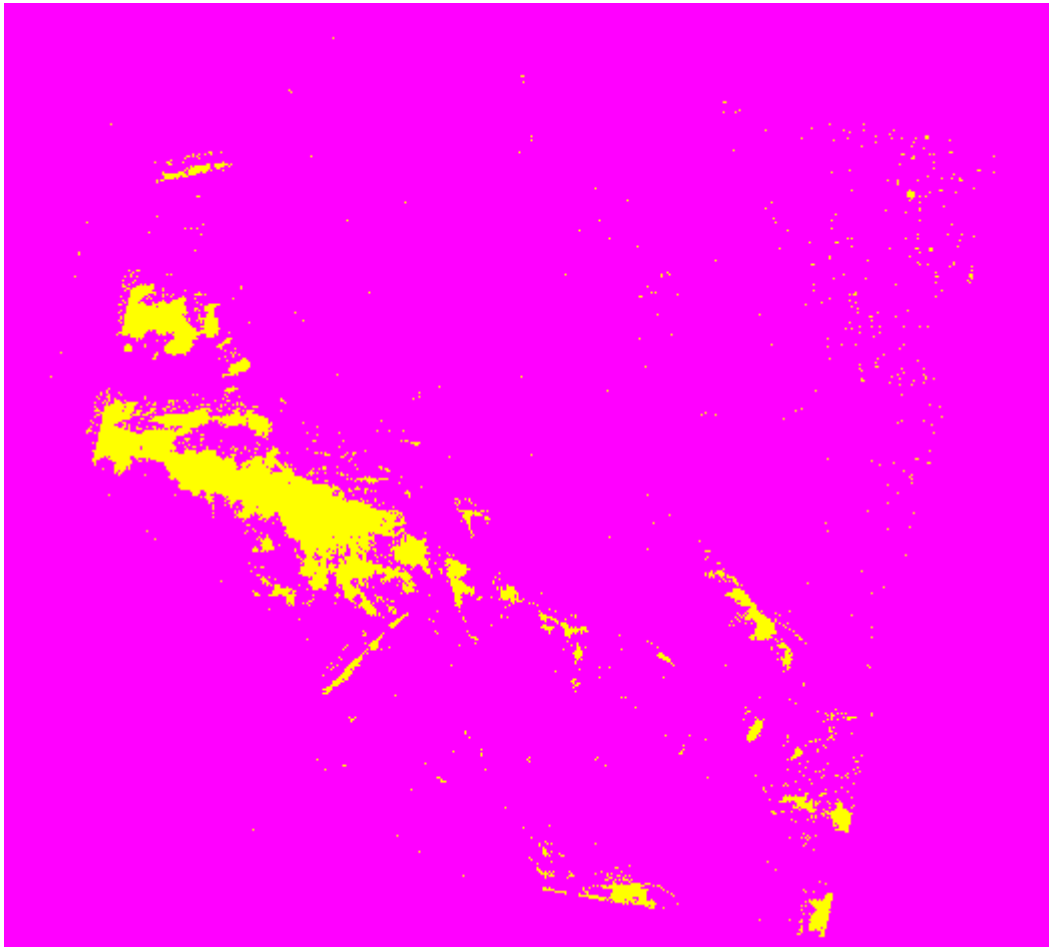


# ACCA

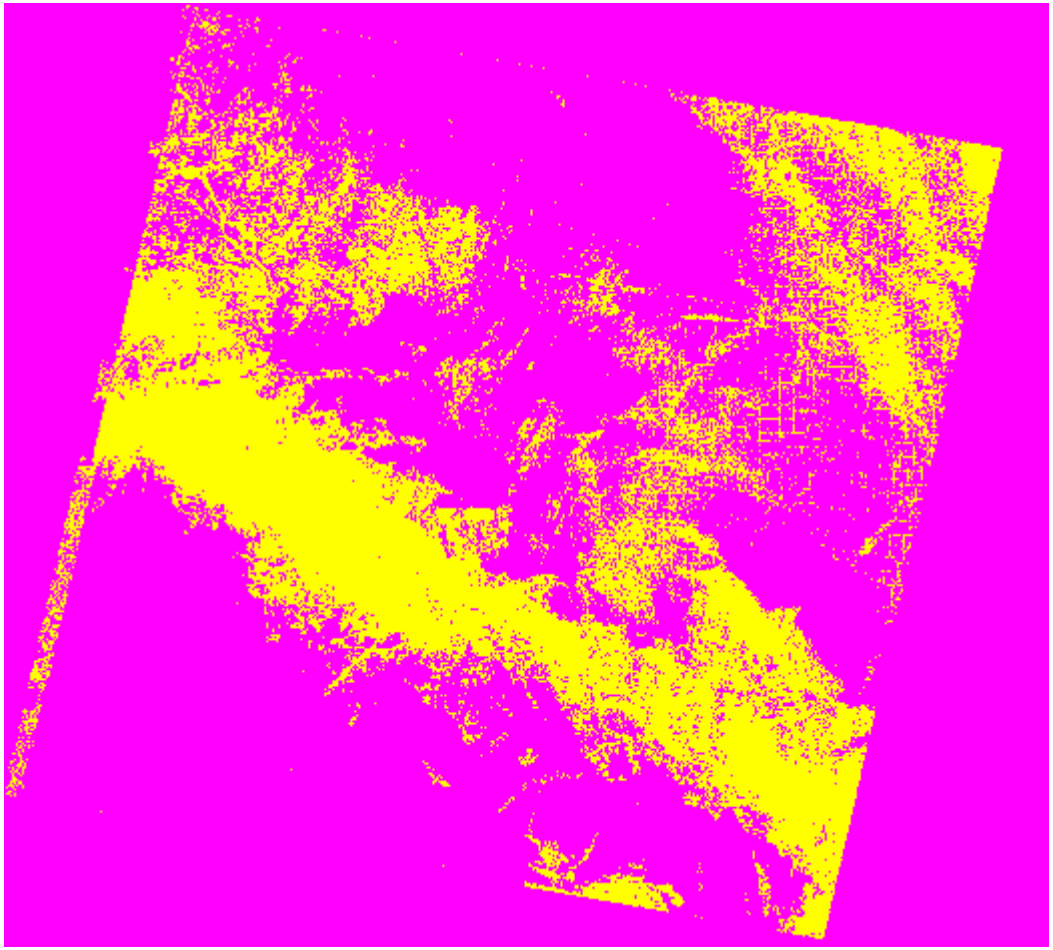


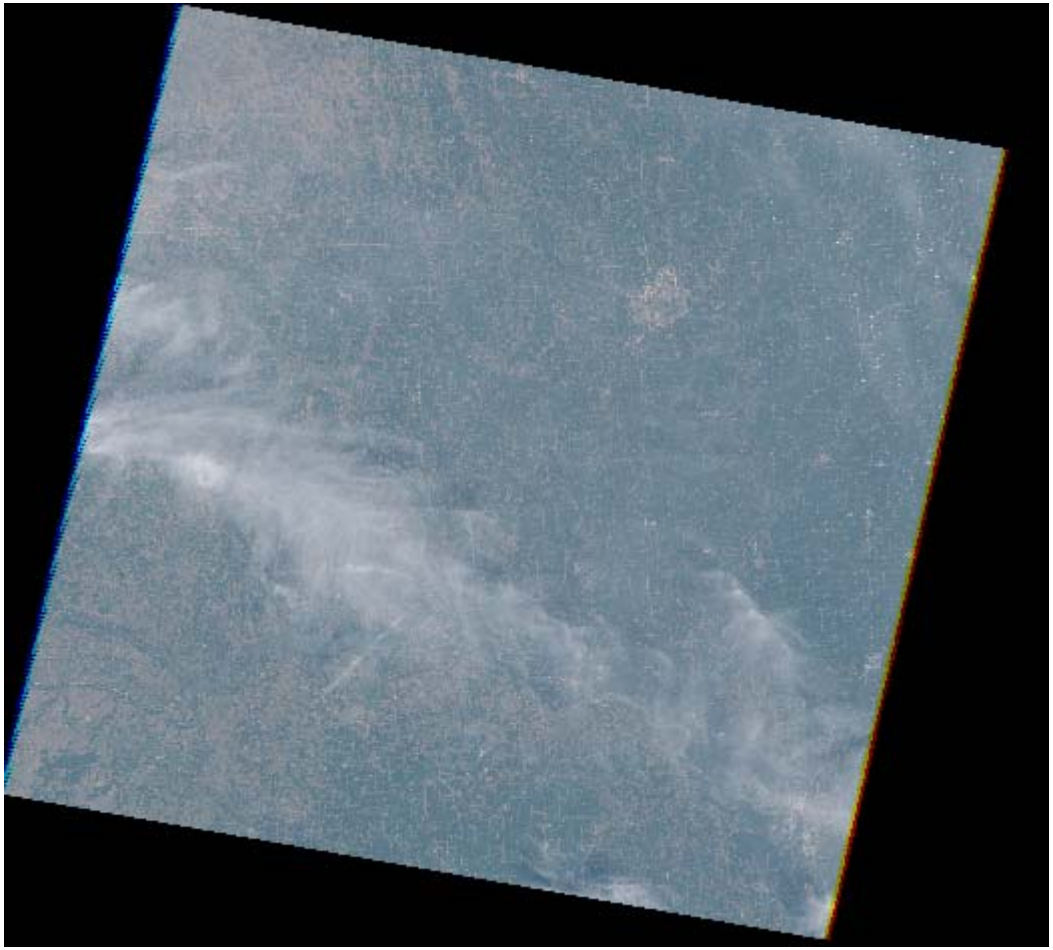




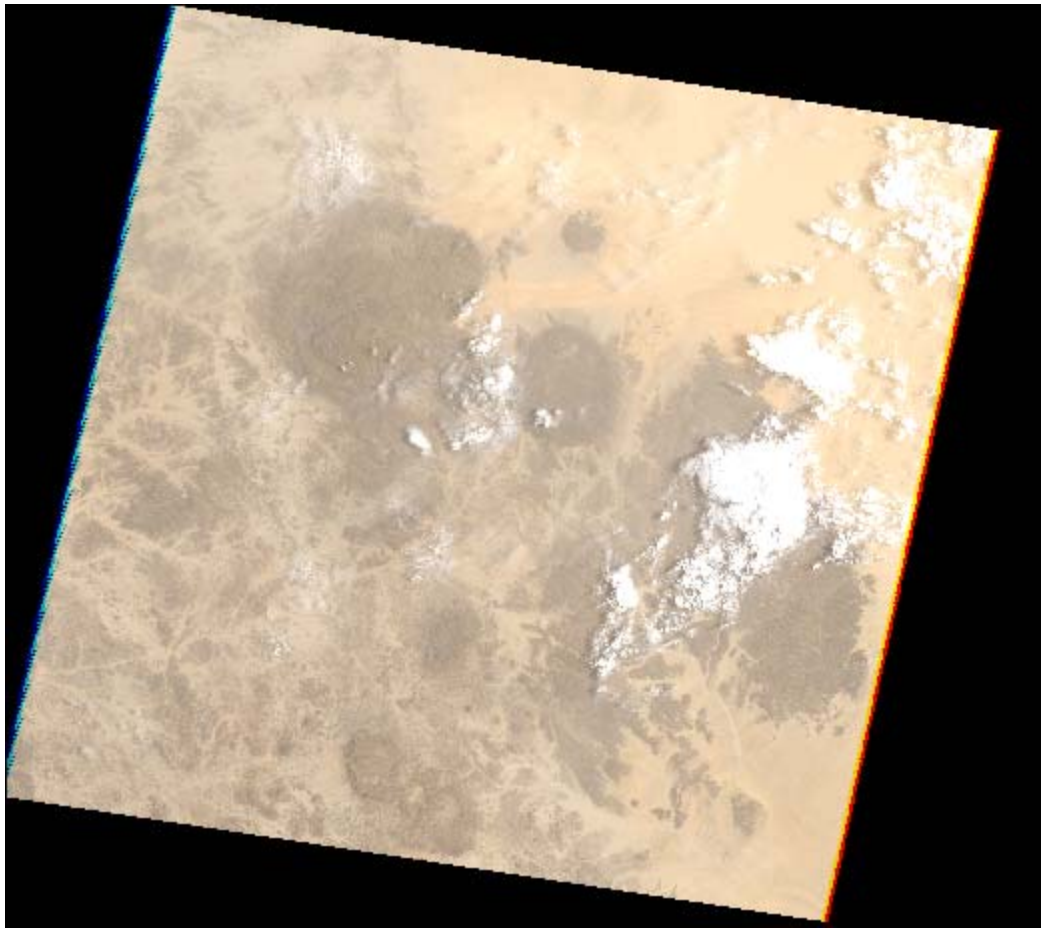


# ACCA



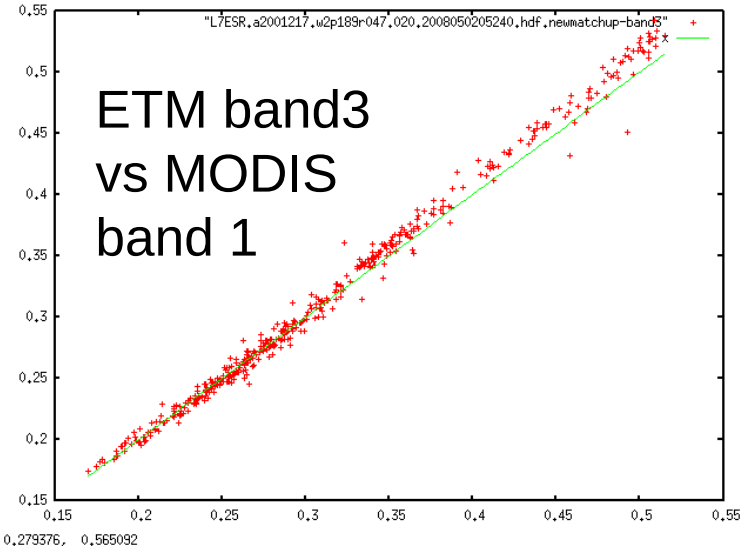


# Comparison to MODIS Terra (CMG)

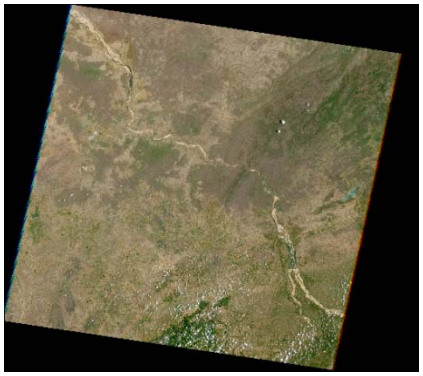
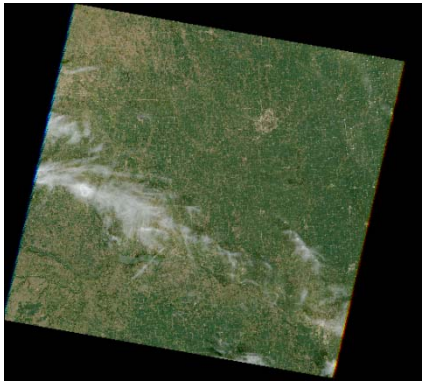
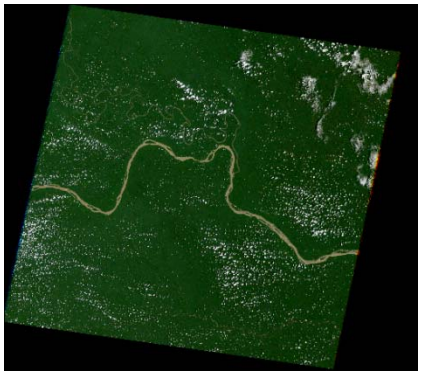
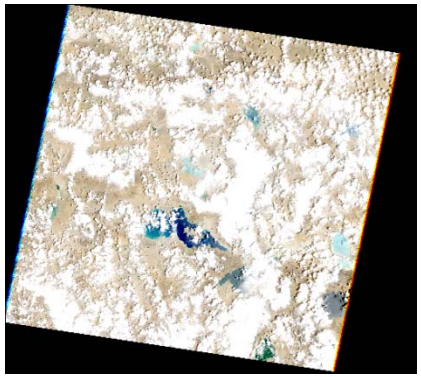
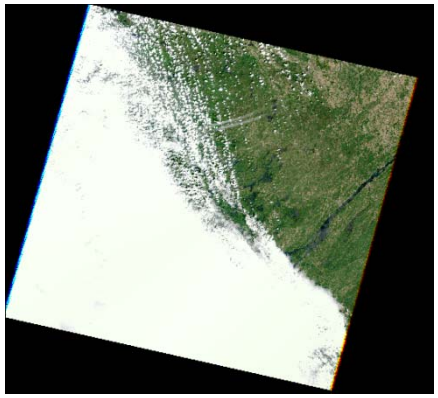
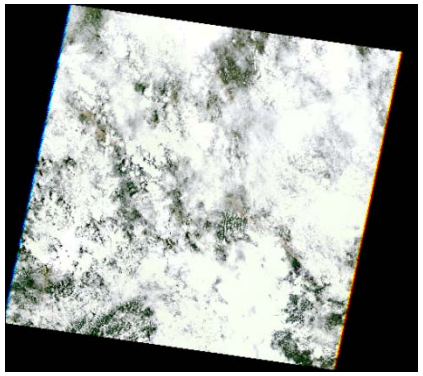
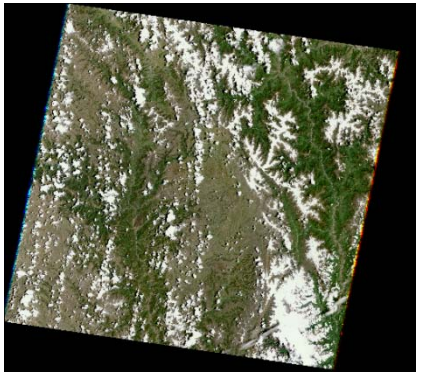
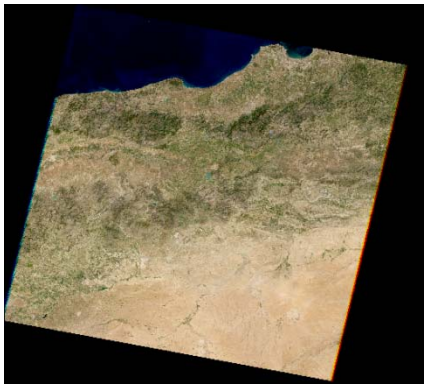
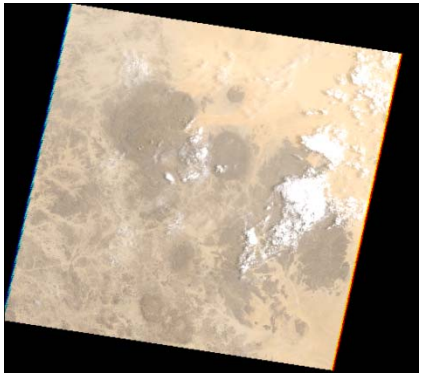
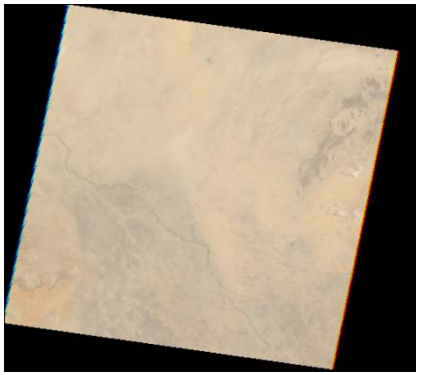


ETM+ Year 2001 Day 217 path  189 row 47

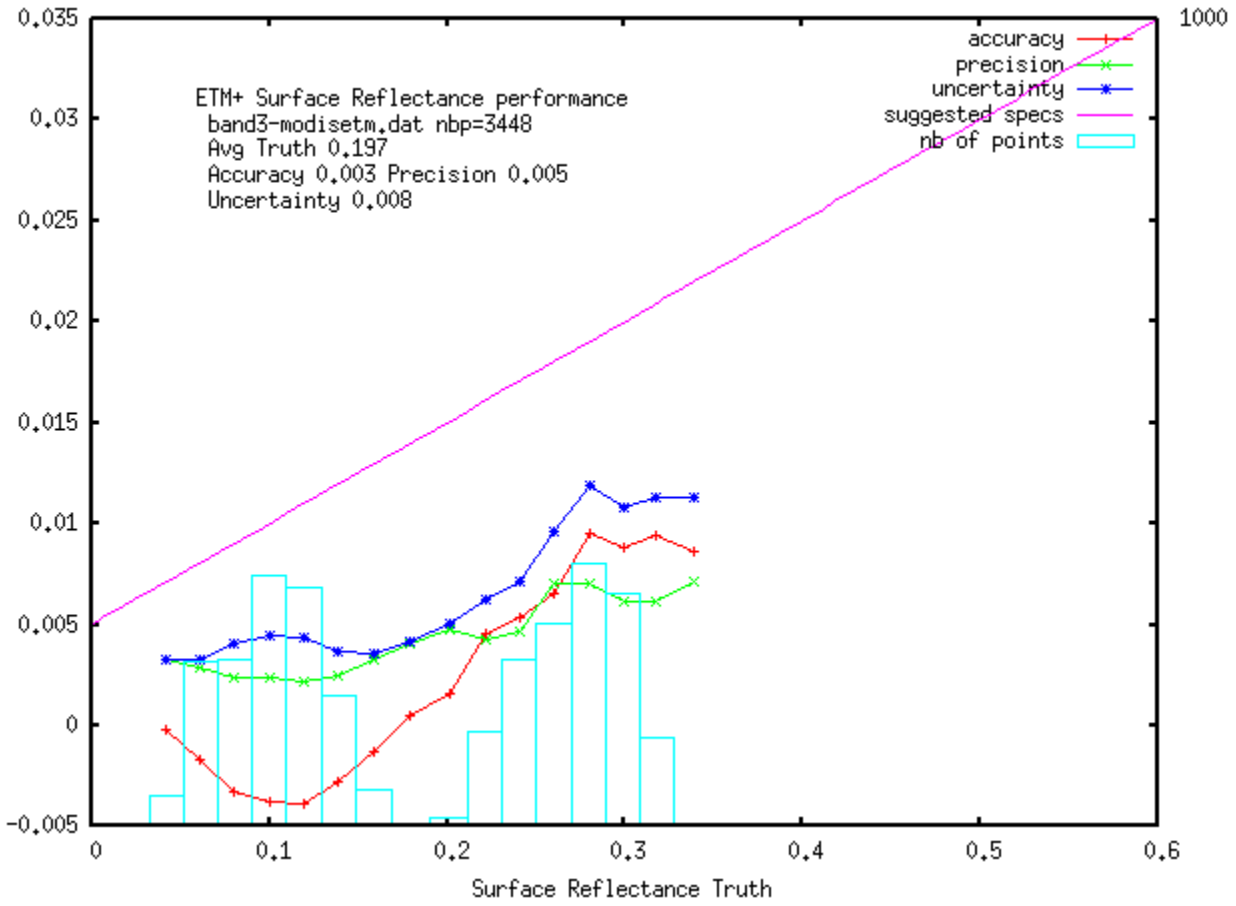
Terra CMG subset



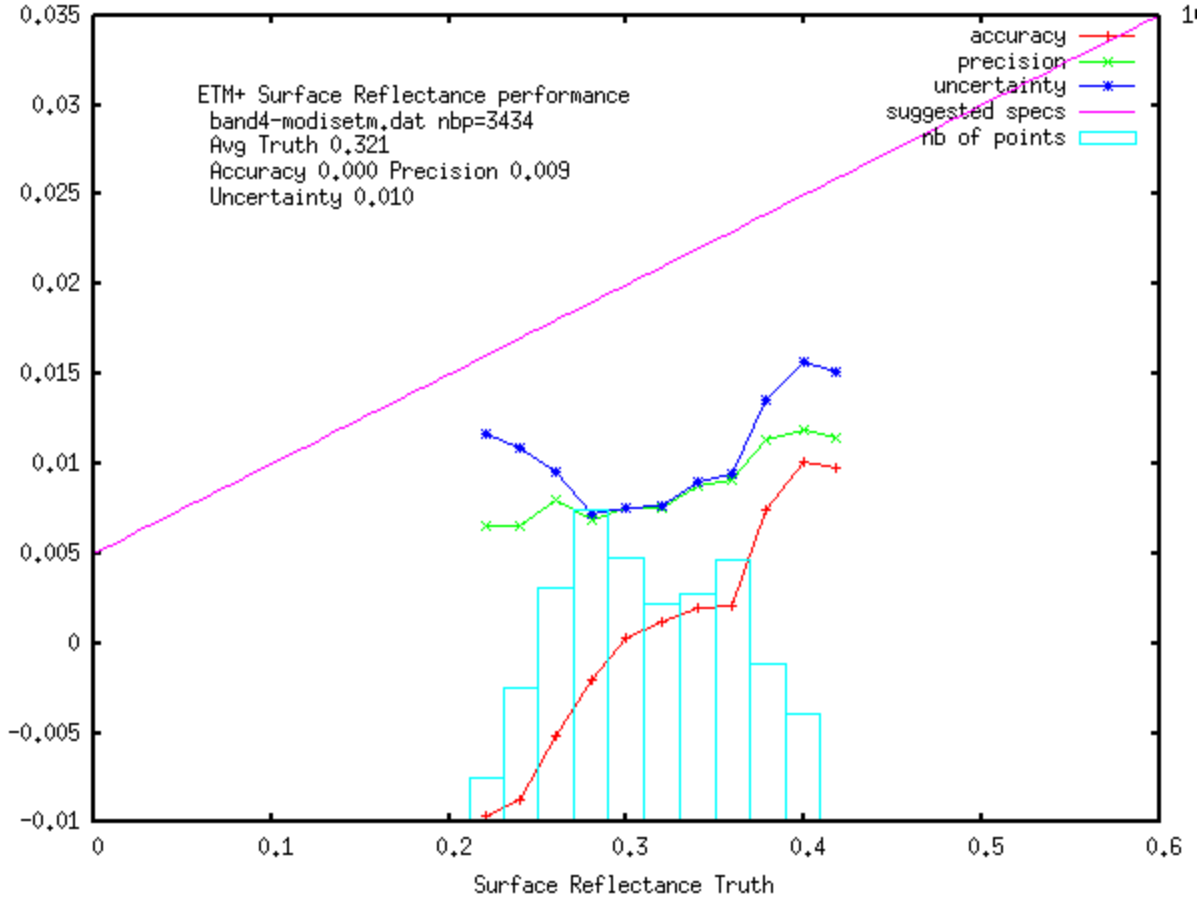
# Scenes analyzed for APU

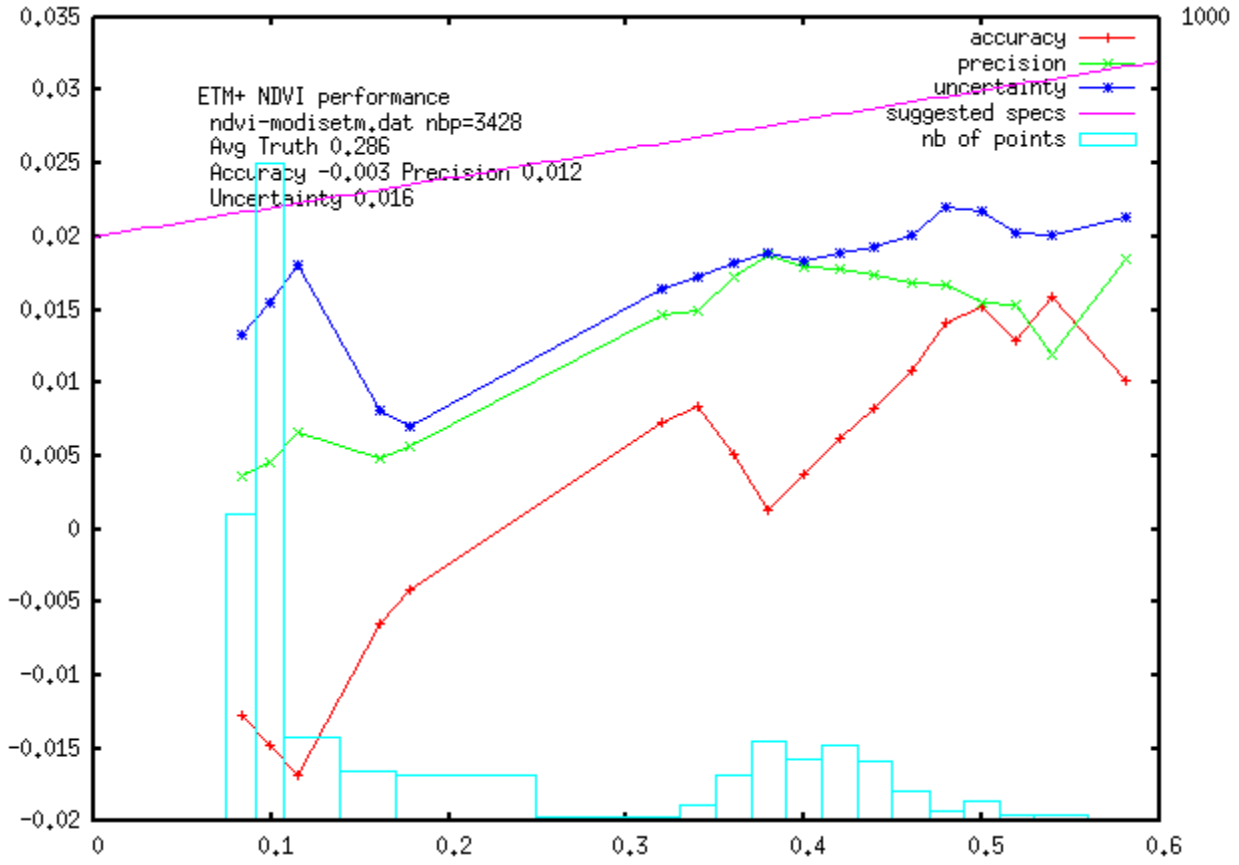
# ETM+ APU results: Band 3 (670nm)



# ETM+ APU results: Band 4 (870nm)

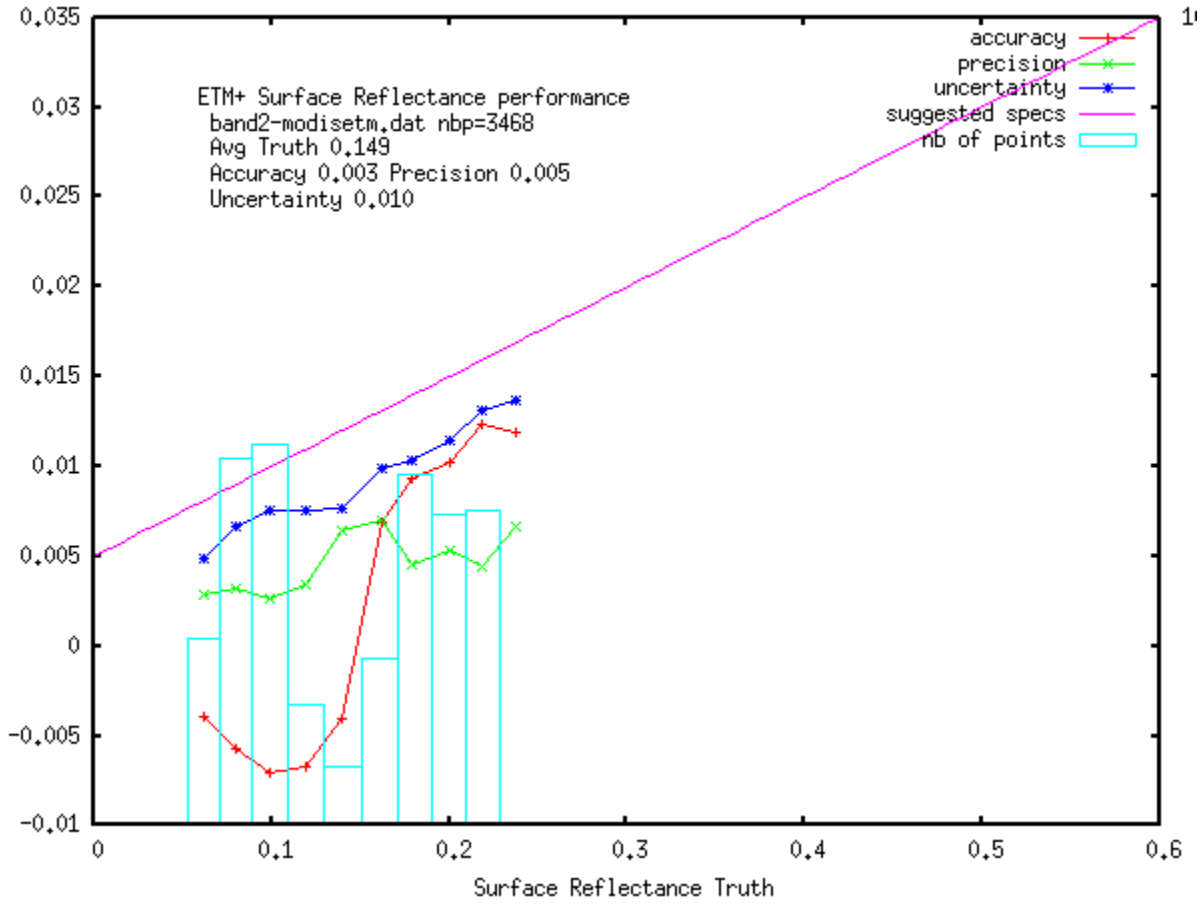


# ETM+ APU results: NDVI

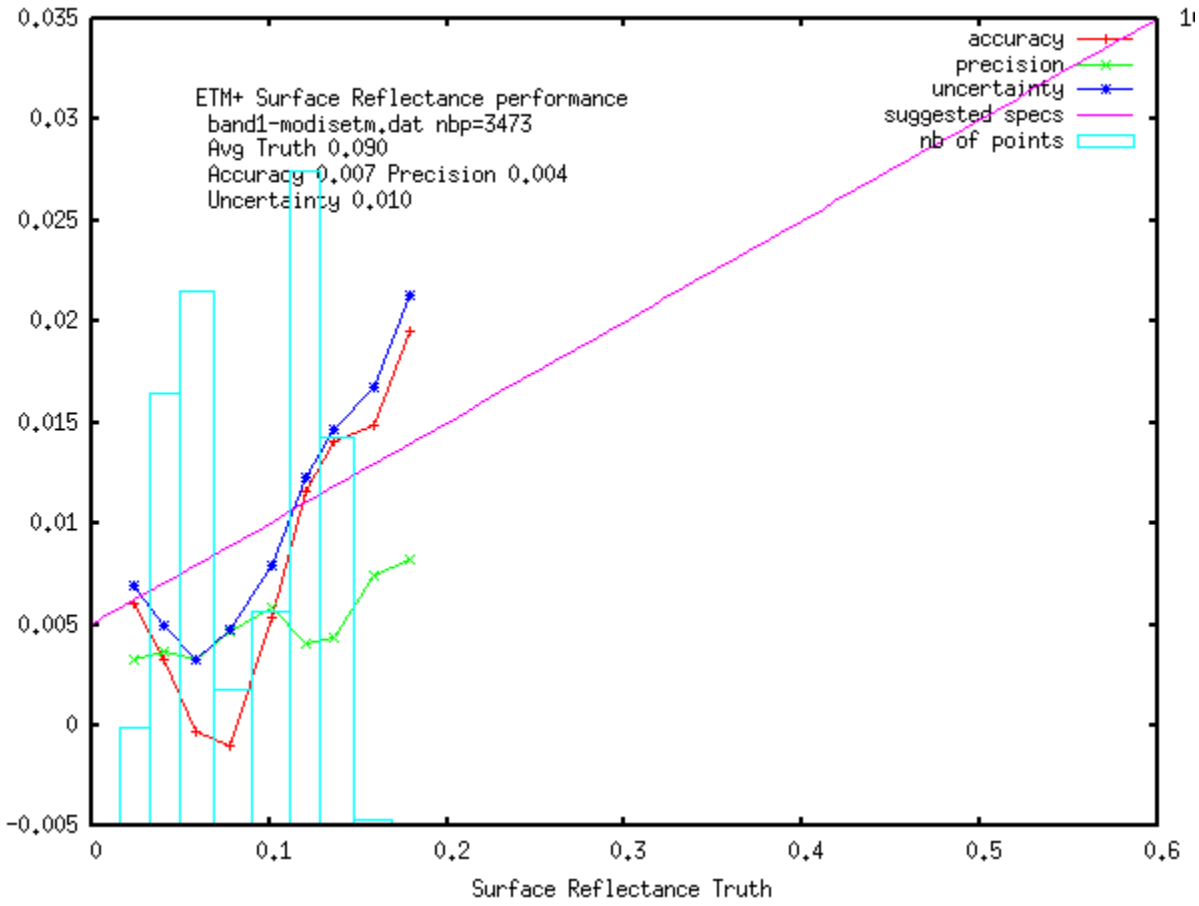



NDVI Truth

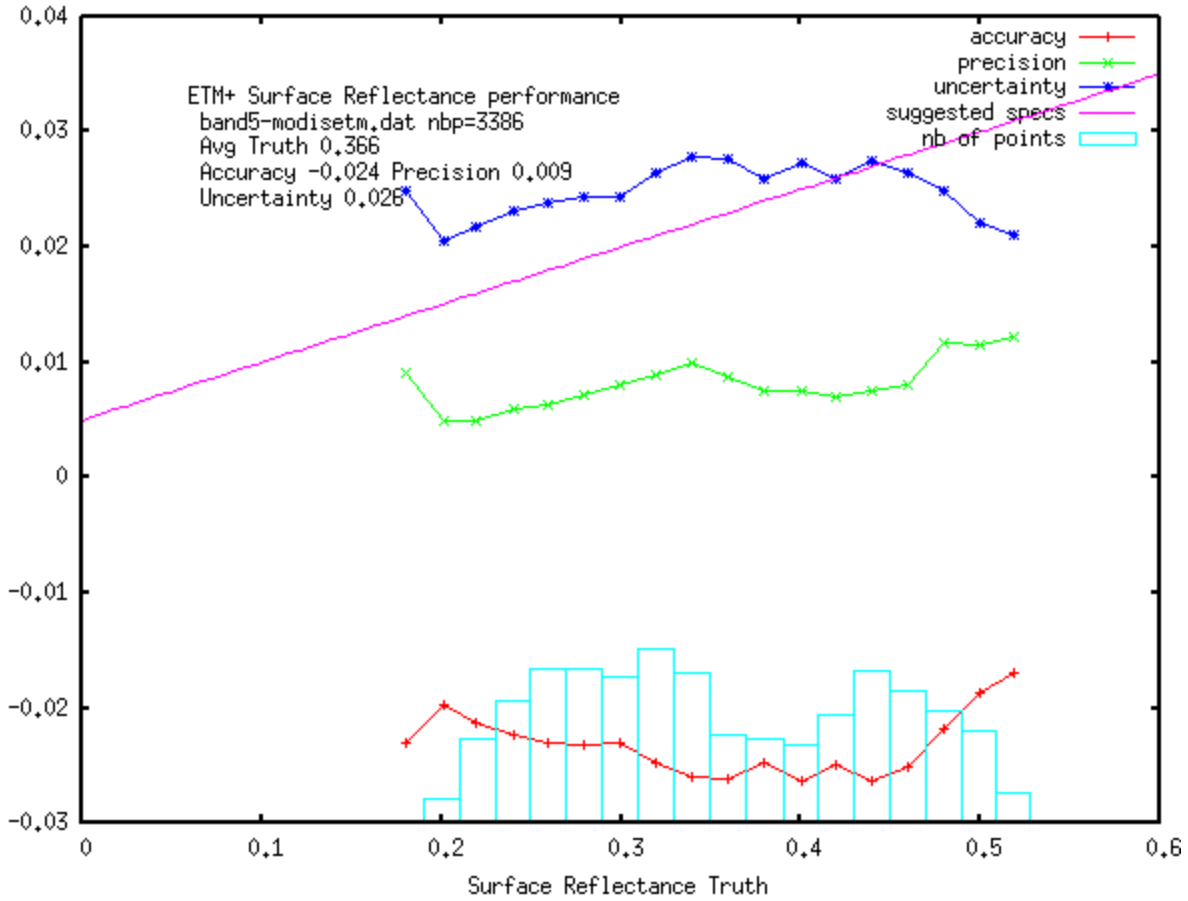
# ETM+ APU results: Band 2 (550nm)



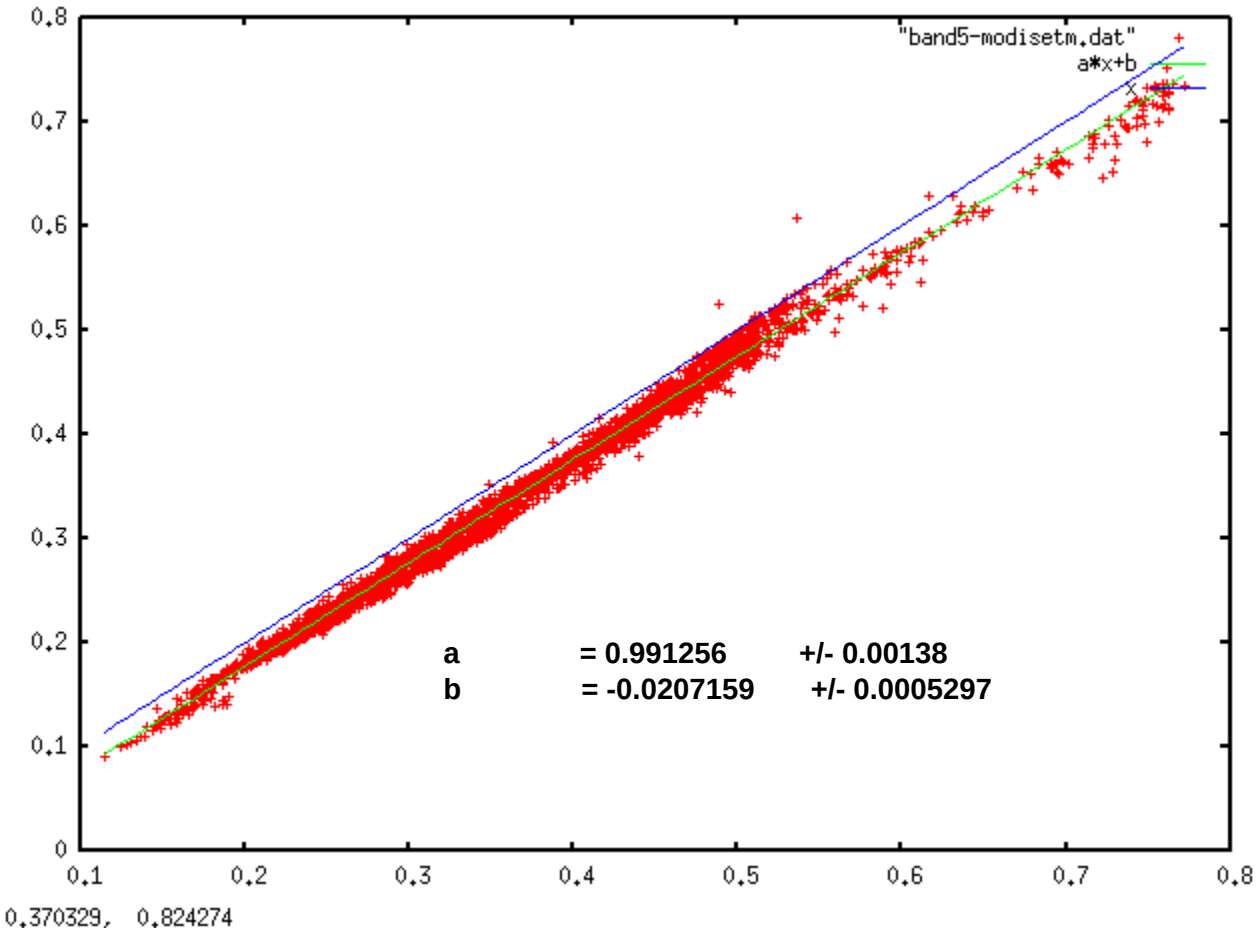
# ETM+ APU results: Band 1 (480nm)



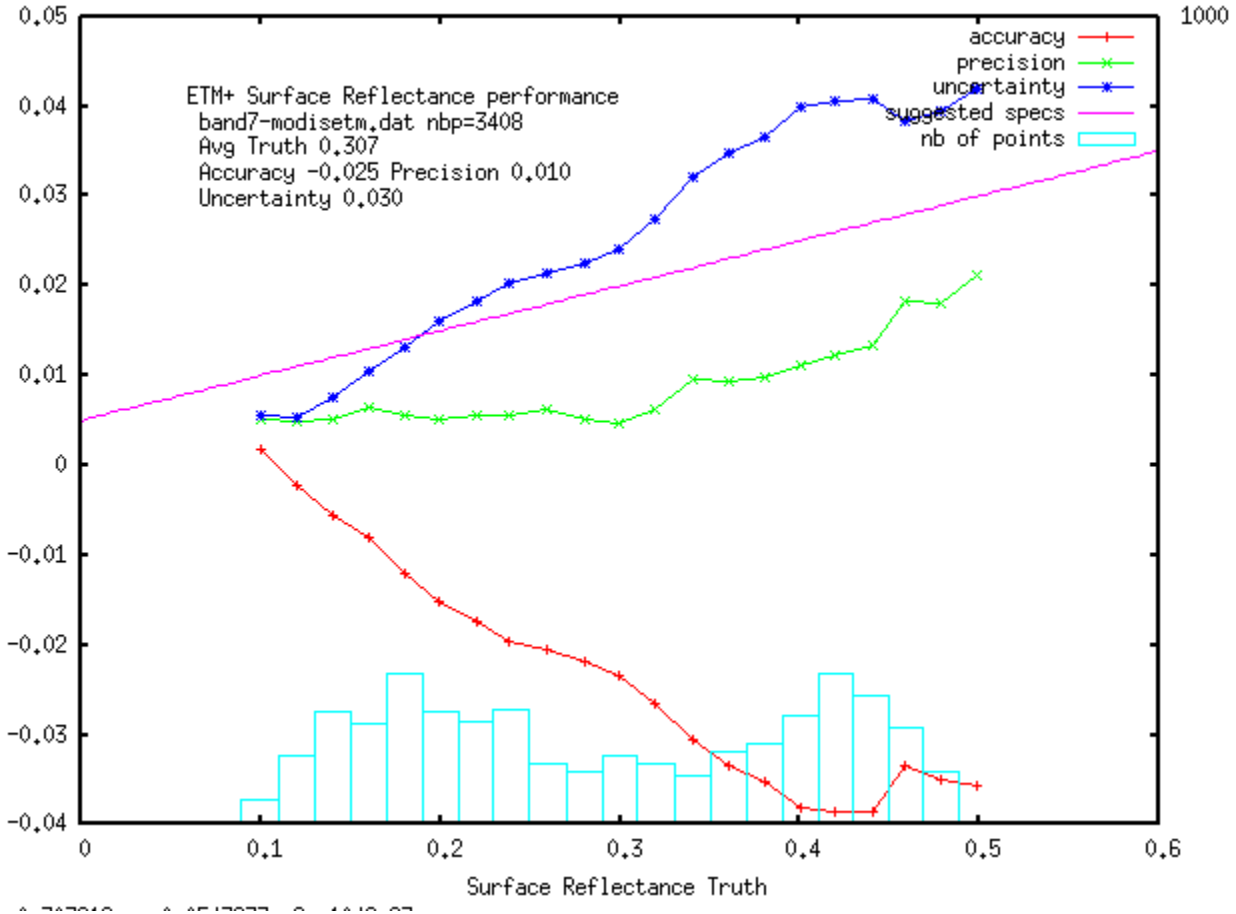
# ETM+ APU results: Band 5 (1650nm)



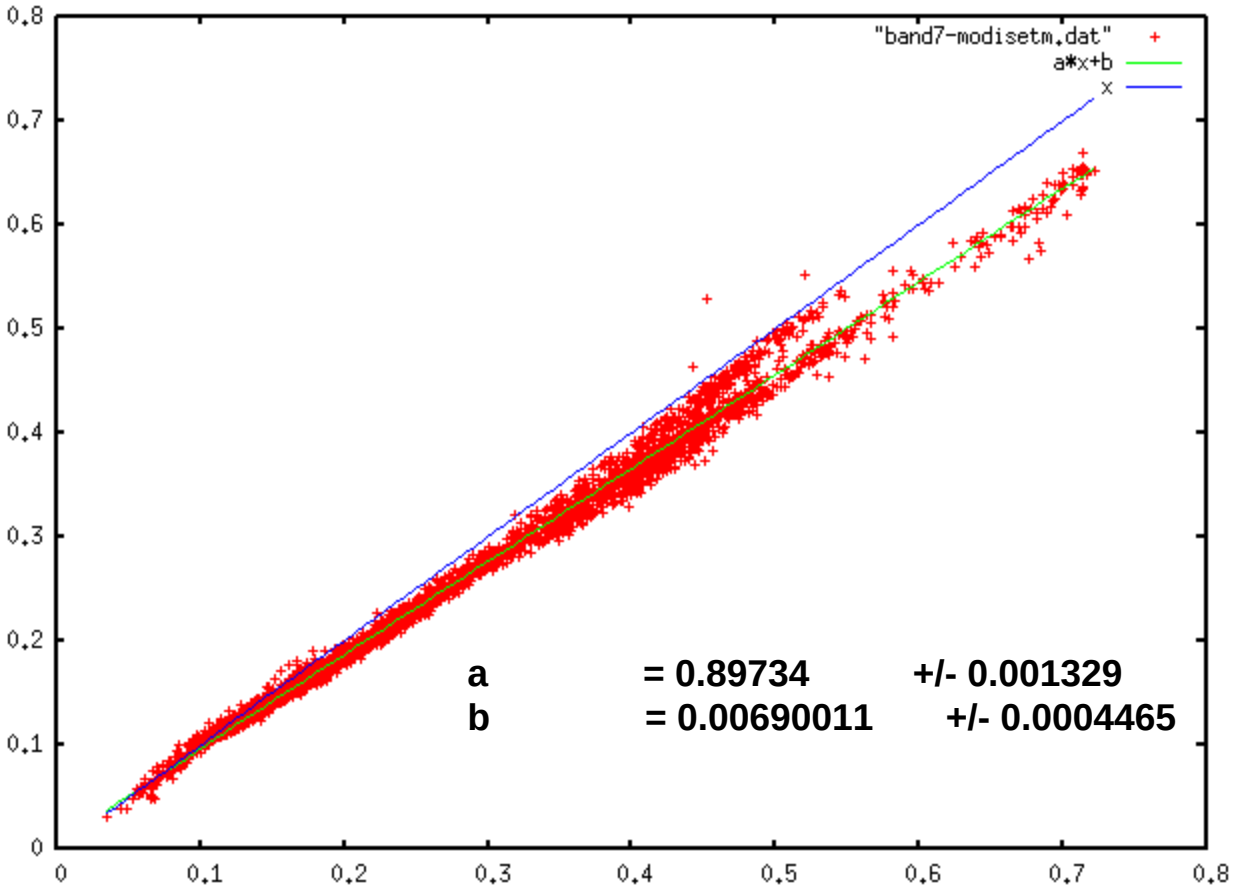
# Band 5 analysis



# ETM+ APU results: Band 7 (2130nm)



# Band7 analysis



# Next Steps

- Further Evaluation Landsat SR product
  - Deriving APU from MODIS and AERONET
- Evaluation of Cloud Mask
  - Further comparison with ACCA and MODIS
- Paper to summarize error budget and performances
- Continued Refinement
  - Determine need for solar angle correction/BRDF effects
  - Development of an improved (LUT based) faster processing code
  - Evaluate use of MODIS aerosol models for Landsat
  - Coastal regions/water
  - Adjacency effect

# Way forward

- Learn from the past record, database of observations will benefit development of standard products
  - Ex MODIS surface climatology makes possible decent cloud mask for AVHRR
  - Focus on change/deviation from normal rather than “analyzing everything”
  - Needs to understand how to “normalize” data for phenology effect (start of growing season for example)
- Educate the community about the accuracy of the product. Please be aware of error budget.