SMACAA

SDSU's Modtran Atmospheric Compensation Anywhere Anytime

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Toulouse, France

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Overview

- Overview
- SMACAA description and current status
- SMACAA validation
  - Dark sites
  - Bright sites
- SMACAA application: A-PICS
- Conclusions

  - Much of the work in this project was performed by students Sudeep Karanjit, Subash KC, Romain Richard

Overview

- The objective of this project?
  - Originally came from the desire to correct desert sites for calibration work,
    - Locations where other processes failed,
    - but this approach works for any region of the globe,
- SMACAAA was developed to do the following.
    - To atmospherically correct VIS/NIR/SWIR satellite images
      - No limits on collection time (back through 1972)
      - No acquisition location limits
      - No limits on the sensor being used
    - In particular: atmospherically correct all Landsat sensors
      - ETM, TM and MSS.
    - Consistent solution through time.
    - Allow for better cross calibration work for all platforms through time via the use of atmospherically compensated PICS

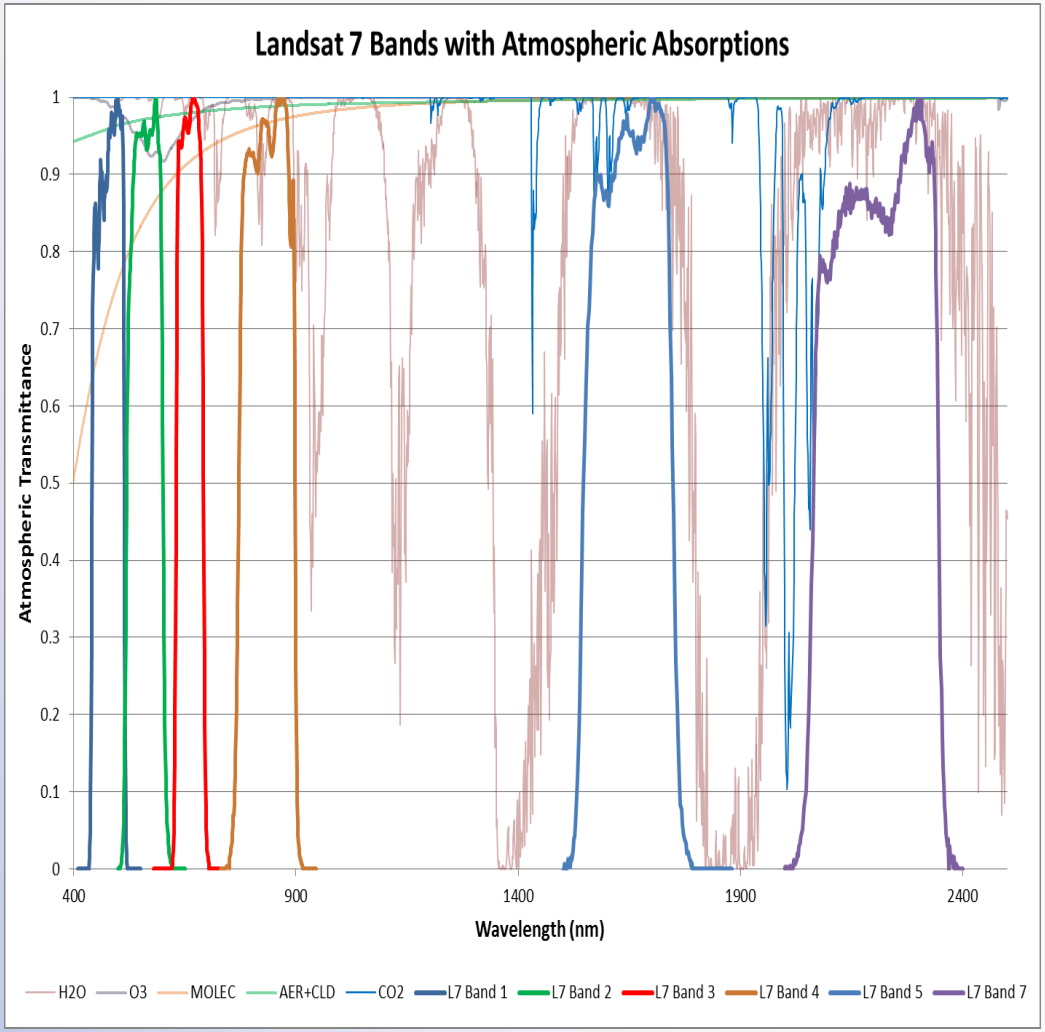
Overview

- In particular, the system needs to work for ETM+, TM, and MSS.
  - With the limited amount of atmospheric information available in the 4 bands of MSS. Ancillary data to perform a correction is needed.
  - One size fits all solution to correct imagery requires a atmospheric radiative transfer model: Modtran
- What do we consider to be the most important parameters for the atmospheric compensation?

Inputs

- Three key inputs for doing the atmospheric compensation:
  - Aerosol
    - Affects Bands blue, green, and red with decreasing intensity
  - Water vapor
    - Affects Bands SWIR1, SWIR2, and NIR with decreasing intensity
  - Ozone
    - Affects Bands green and red with decreasing intensity

With these 3 atmospheric effects causing most of day to day variability and affecting all bands to some level they become the key components under investigation



Inputs - Ingest Status

Current Status:

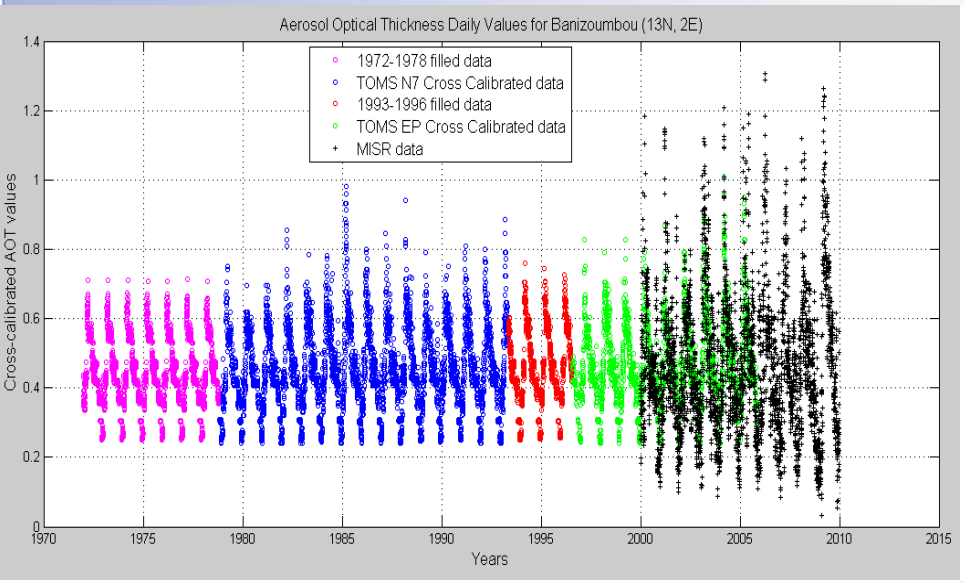
- All NOAA NCEP data (water vapor key)
  - **OPERATIONAL**: Automatic processing and ingest
- All OMI / TOMS Ozone ingested
  - **OPERATIONAL**: Automatic processing and ingest
- All MISR/TOMS Aerosol data ingested
  - **OPERATIONAL**: Automatic processing and ingest

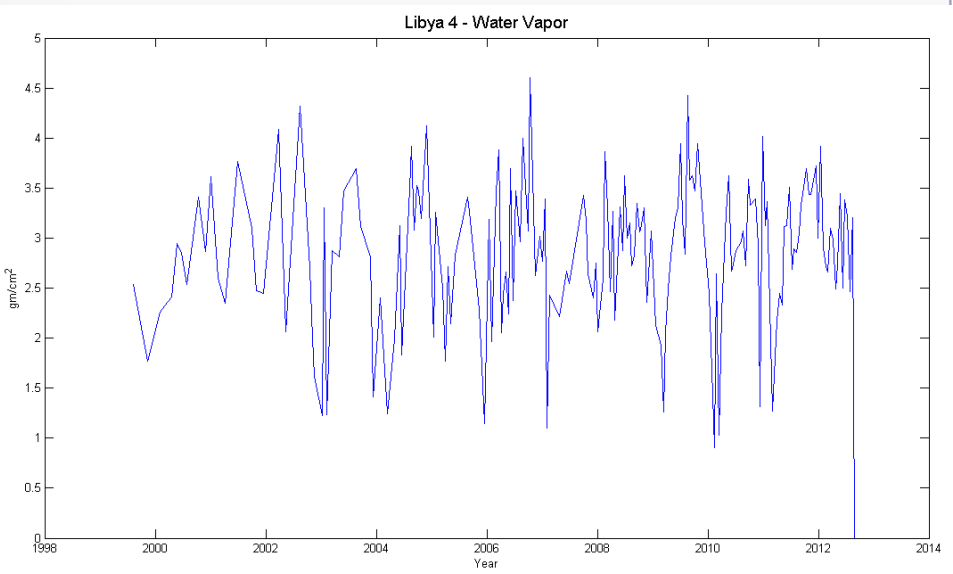
*Kalnay et al.,The NCEP/NCAR 40-year reanalysis project, Bull. Amer. Meteor. Soc., 77, 437-470, 1996

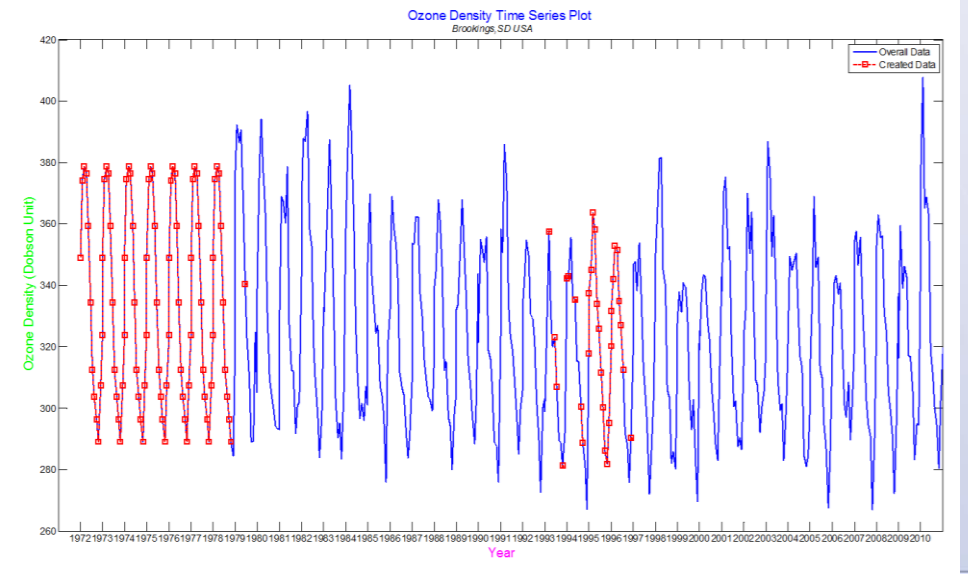
Input Storage and Status

- All Inputs placed in a MySQL database
- Currently the database is holding 46 x10^9 (as of 2014) entries (~2.5TB) with regular automated weekly updates.
  - Data is automatically screened and cleaned with uncertainty for each value being determined and assigned.
  - Data exists in MySQL database for local and remote access, used to drive SMACAA and other lab research projects

Inputs – Examples of Meteorological Data





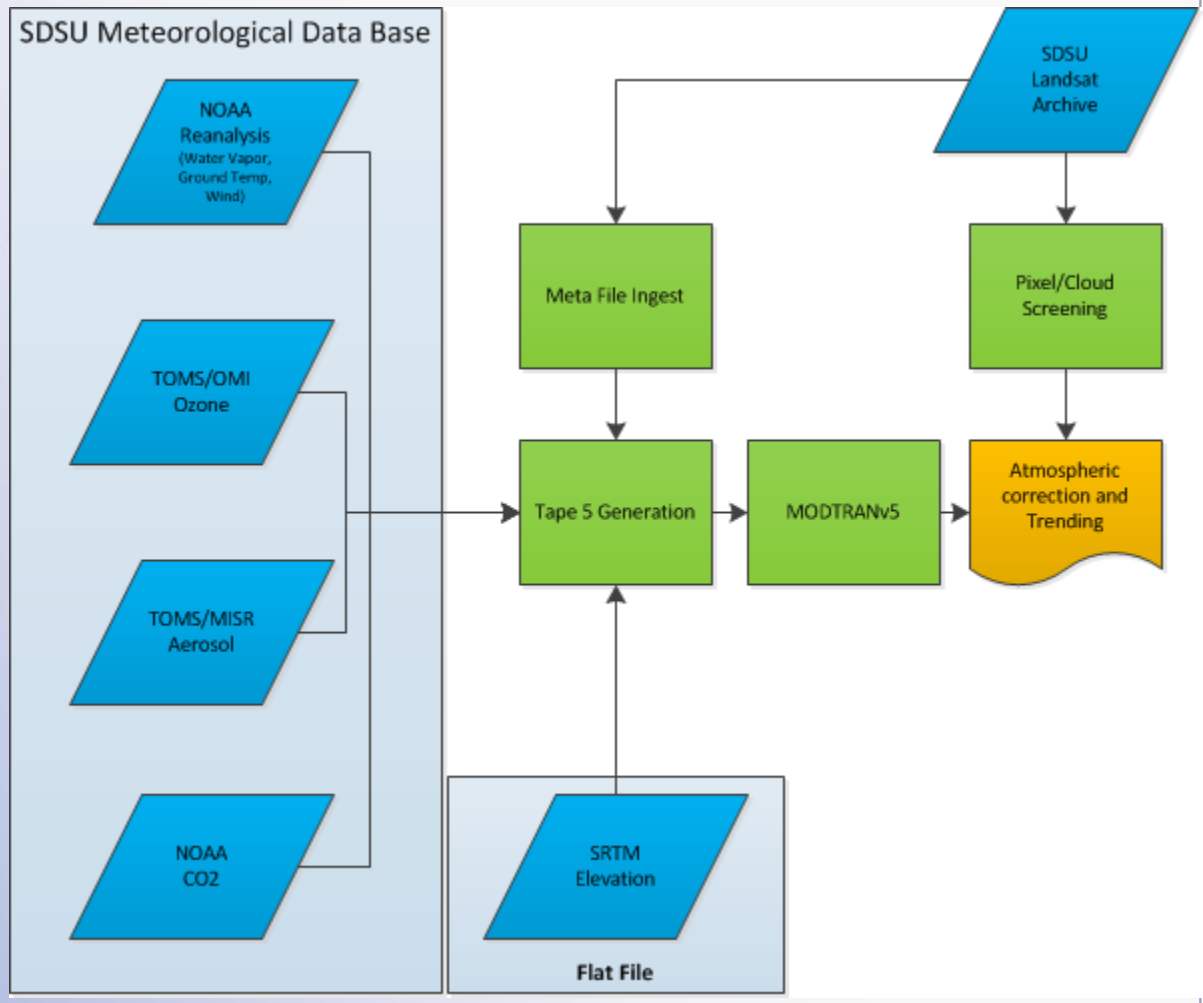


- Top Left: Example of Aerosol* Loading profile for 40 years over Banizoumbou
- Top Right: Water vapor loading for Libya 4
- Bottom Left: Ozone* Over Brookings, SD

*Multi data source and sensors used to develop the entire history and to cover the entire globe

Automated Process - Flow Chart

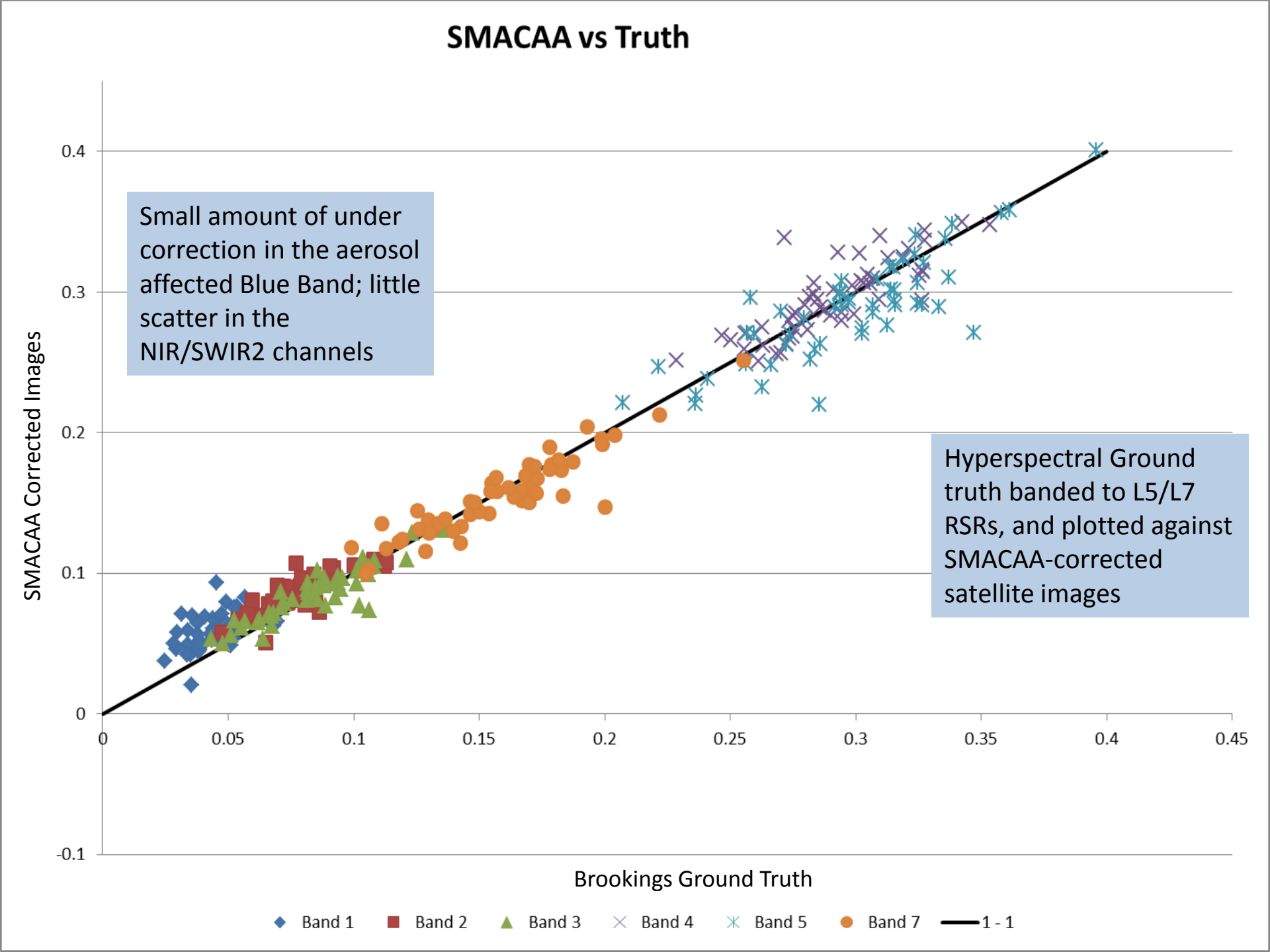
- Local MYSQL Databases are actively being updated via external links
  - NASA & NOAA
- All data is automatically pulled via Matlab scripts from the database
- Images local to the SDSU Archive are ingested in bulk or individually, screened and processed.
- Finally all inputs are passed through Modtran, with the results being applied to the imagery.

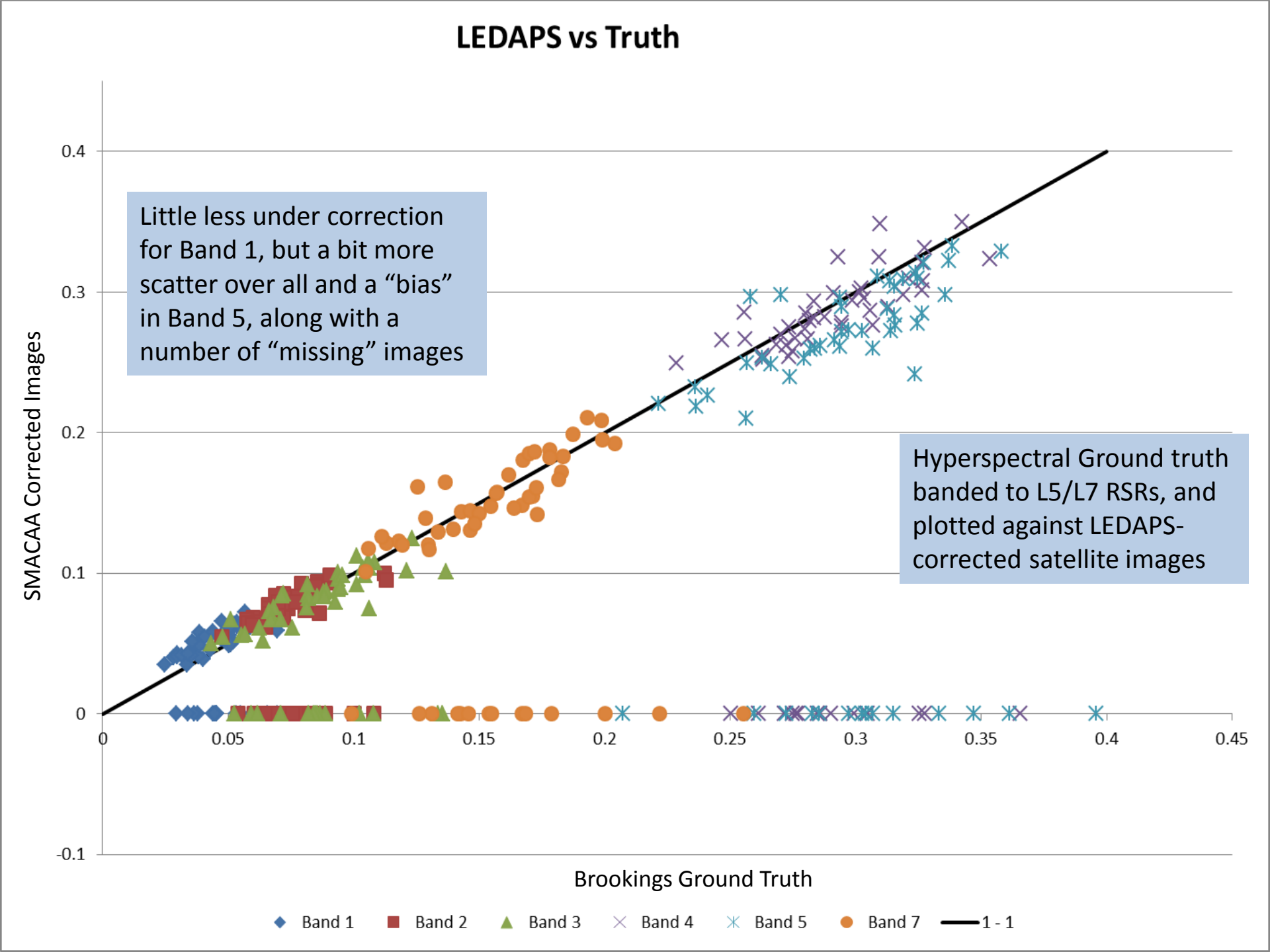


SMACAA Validation - Dark Site

SMACAA versus LEDAPS versus ground truth @ SDSU Test Site

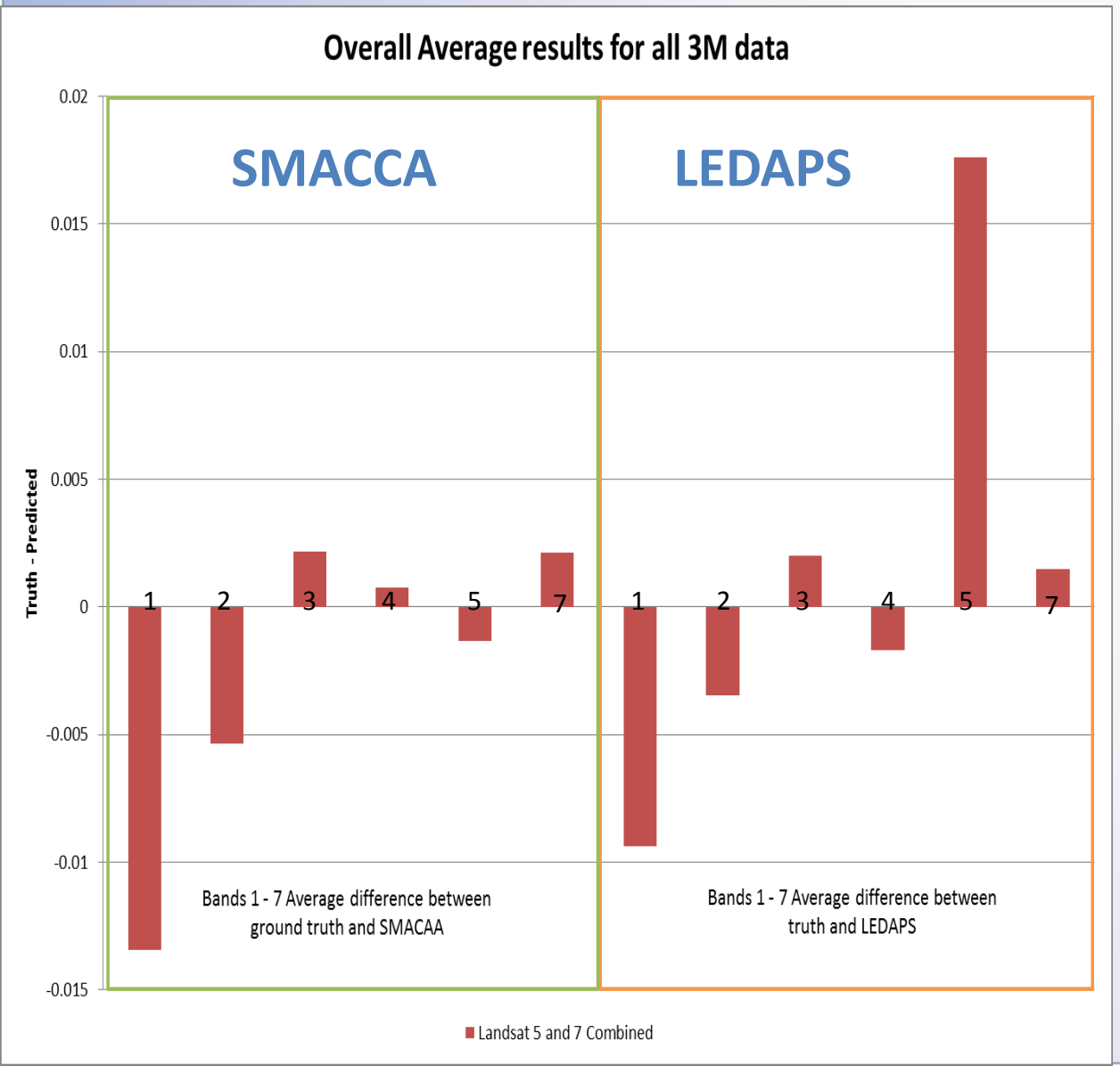
- Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS)—default atmospheric correction code for Landsat
- A comparison of SMACAA and LEDAPS to ground truth was performed using the SDSU Test site
  - Compare the capability to a “known” correction
  - Validate the atmospheric understanding for a known site.
- Ground truth comprised 63 field hyperspectral reflectance measurements covering the summer months for the years of 2004 – 2014, these include L5, L7 and L8 acquisitions.
  - L1T Images were collected for the 63 dates, and processed with SMACAA,
  - 41 LEDAPS reflectance images collected and ROIs extracted
    - Only 41 of the 63 scenes in LEDAPS acquired; unknown why the other 22 images and not available.


SMACAA vs Truth
Small amount of under correction in the aerosol affected Blue Band; little scatter in the NIR/SWIR2 channels
Hyperspectral Ground truth banded to L5/L7 RSRs, and plotted against SMACAA-corrected satellite images
SMACAA Corrected Images
Brookings Ground Truth
0.4
0.3
0.2
0.1
0
-0.1
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
Band 1
Band 2
Band 3
Band 4
Band 5
Band 7
1 - 1


LEDAPS vs Truth
Little less under correction for Band 1, but a bit more scatter over all and a "bias" in Band 5, along with a number of "missing" images
Hyperspectral Ground truth banded to L5/L7 RSRs, and plotted against LEDAPS-corrected satellite images
SMACAA Corrected Images
Brookings Ground Truth
0.4
0.3
0.2
0.1
0
-0.1
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
Band 1
Band 2
Band 3
Band 4
Band 5
Band 7
1 - 1

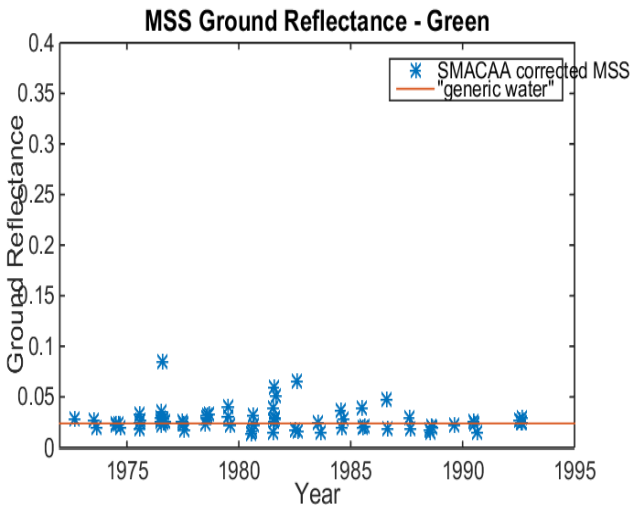
SMACAA Validation:

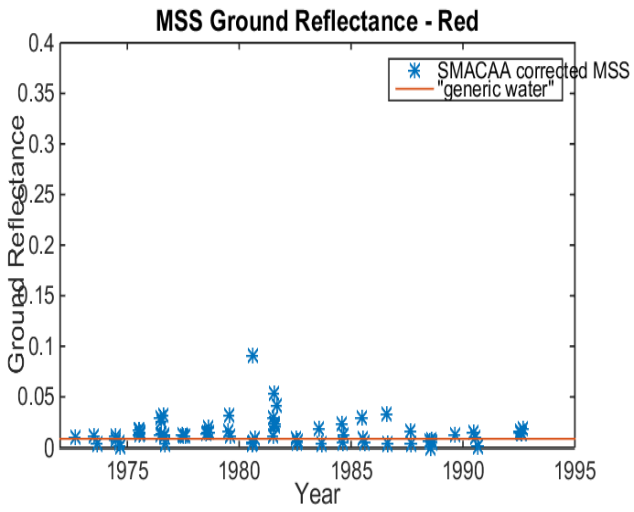
SMACAA versus LEDAPS versus ground truth @ SDSU Test Site

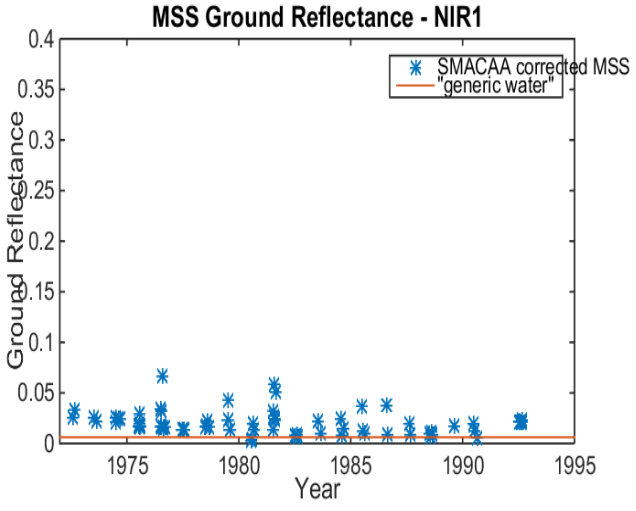


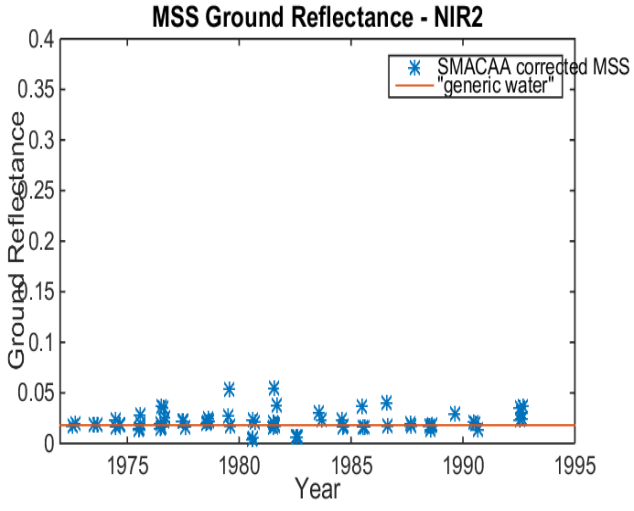
- SMACAA: On average, Band 1 is off by 0.014 units of reflectance and the rest are under 0.005 units
- LEDAPS: Less under correction for band 1, but as seen a bit of over correction for band 5, too much “water” being removed?

SMACAA Validation - Dark Site
MSS 1-5 SMACAA Reflectance for Crater Lake









- Due to some work over darker forest sites, with MSS we wanted to make sure the calibration / correction at the low end was correct as well
- “Truth” is just standard water reflectance level and does not represent actual ground measurements.
- Check on the atmospheric understanding back through a longer time span ~ 80 images for 20+ years

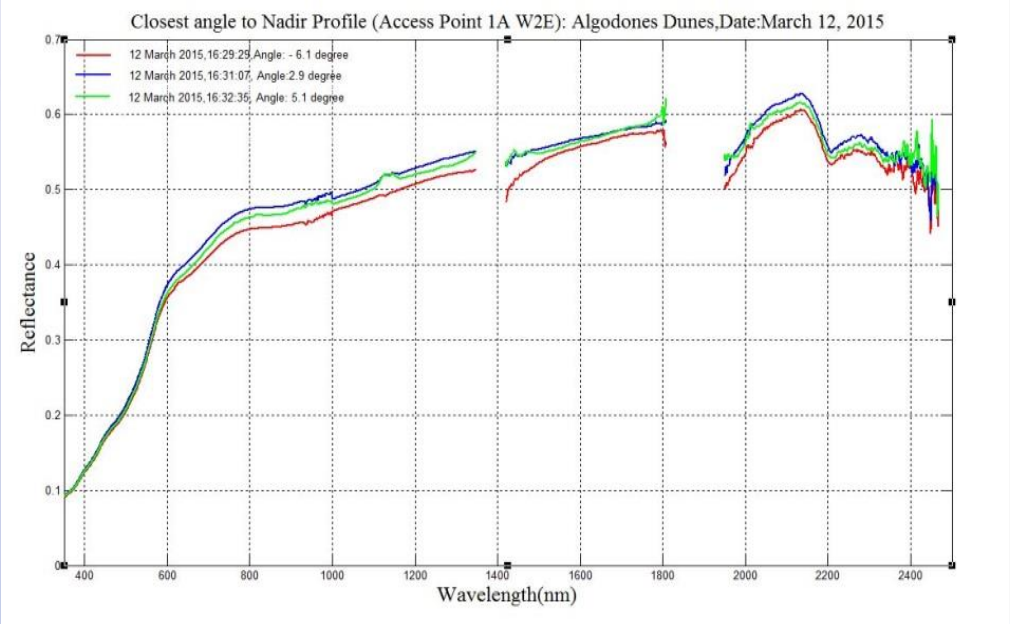
SMACAA Validation - Bright Site

SMACAA versus Ground truth @ Algodones Dunes

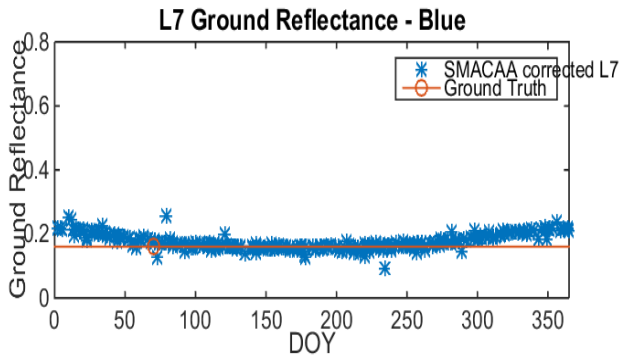
- With a dark comparison completed, a bright target was chosen. The only bright target we have "truth" for is Algodones Dunes (AD).
  - Only have very limited (temporally) measurements of AD, but the assumption is it's invariant.

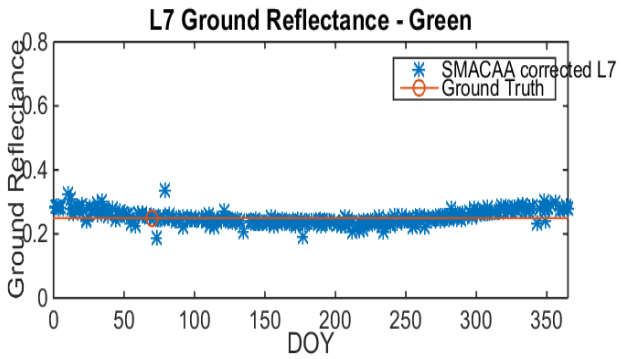
Took all available AD images for ETM+ (348 Images) and OLI(45 Images)

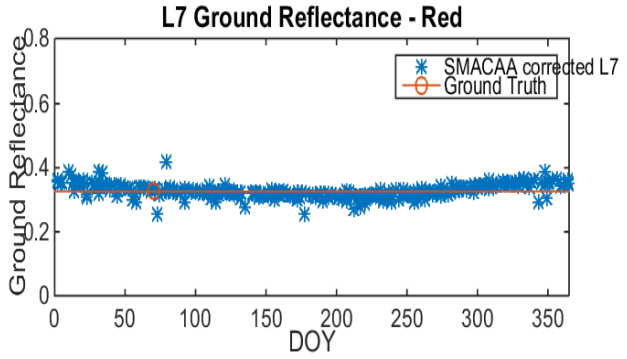
Corrected them with SMACAA and compared to the ground truth.

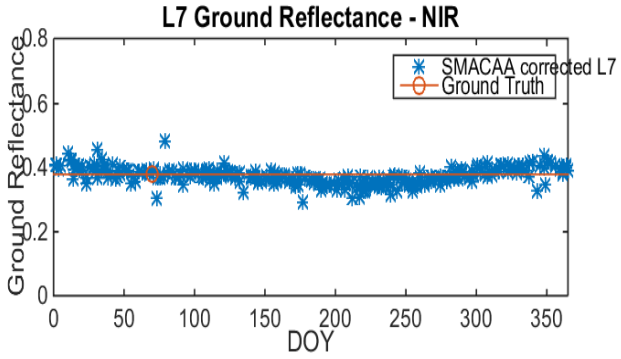


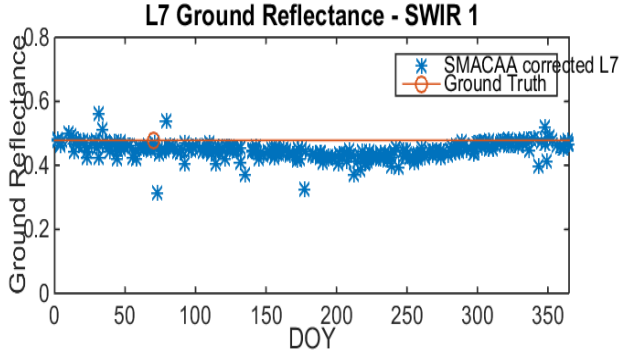
SMACAA Validation - Bright Site
L7 ETM+ SMACAA Reflectance for Algodones Dunes

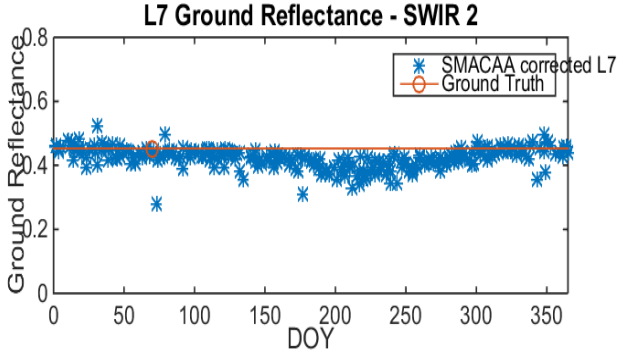










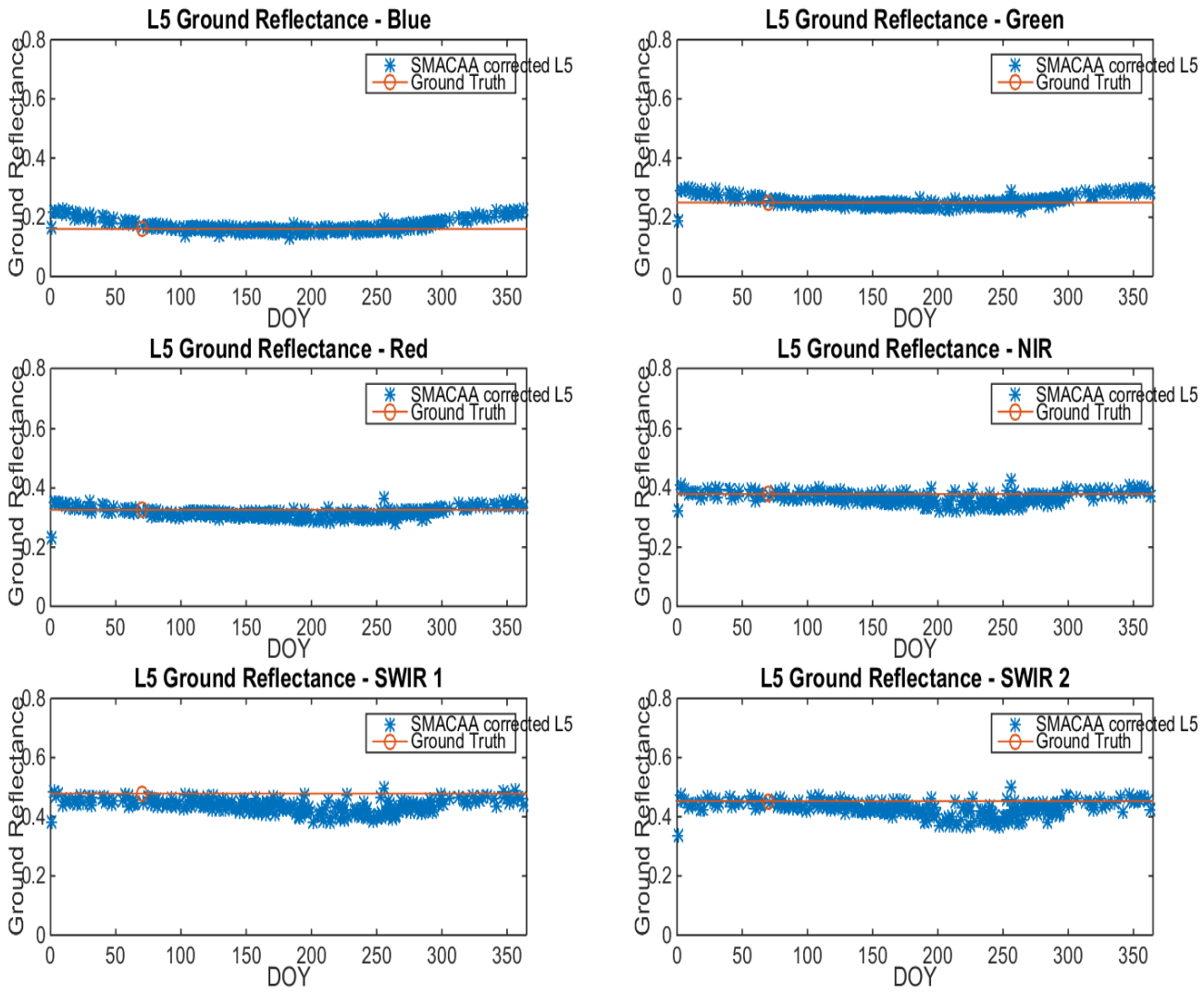


The red circle around DOY 70 represents the ground truth.

As before a little under correction for shorter wavelengths

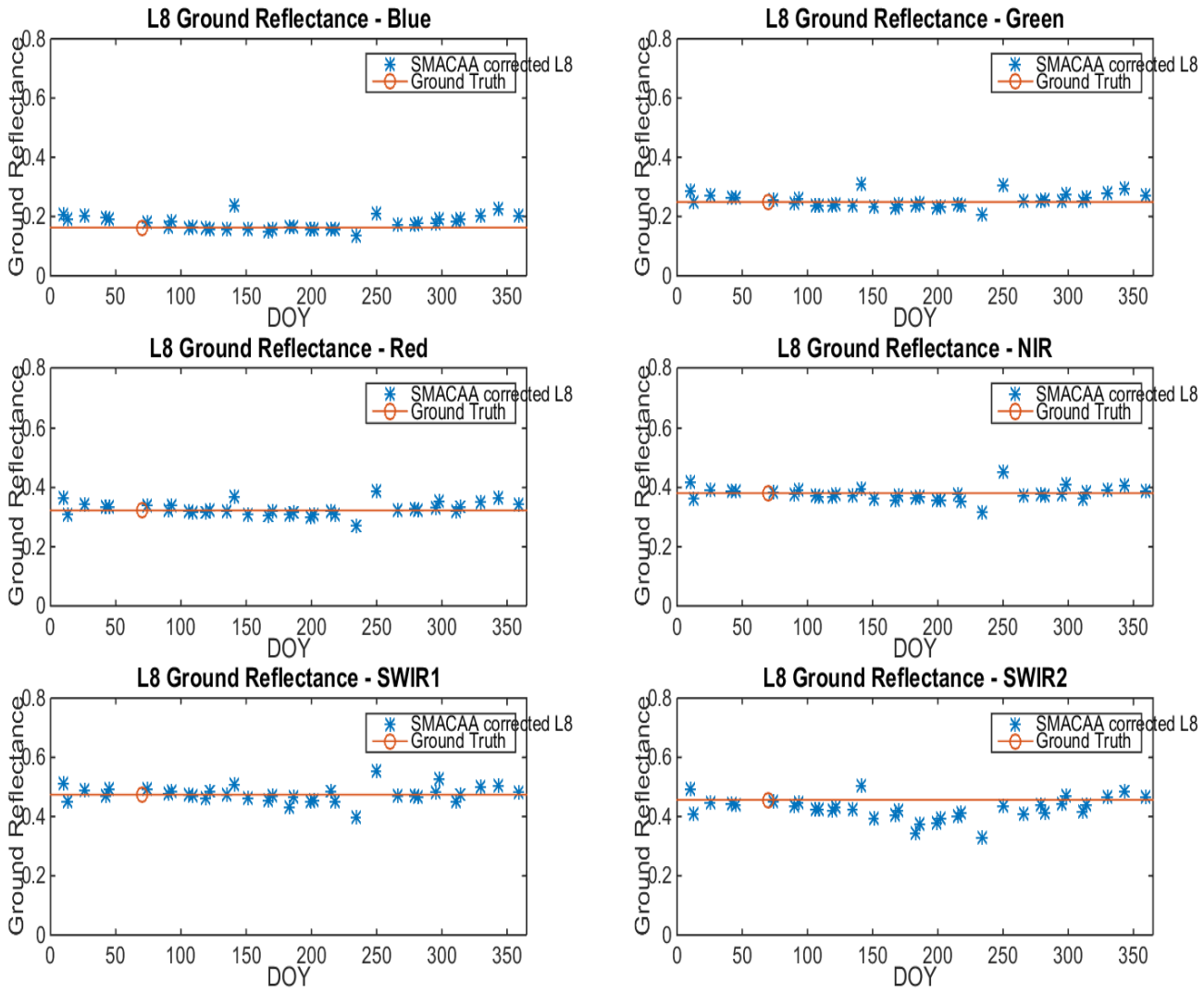
Yes there is a “smile” to the data – BRDF

SMACAA Validation - Bright Site
L5 TM SMACAA Reflectance for Algodones Dunes



- The red circle around DOY 70 represents the ground truth.
- Same over all shape, little more variation in longer wavelengths

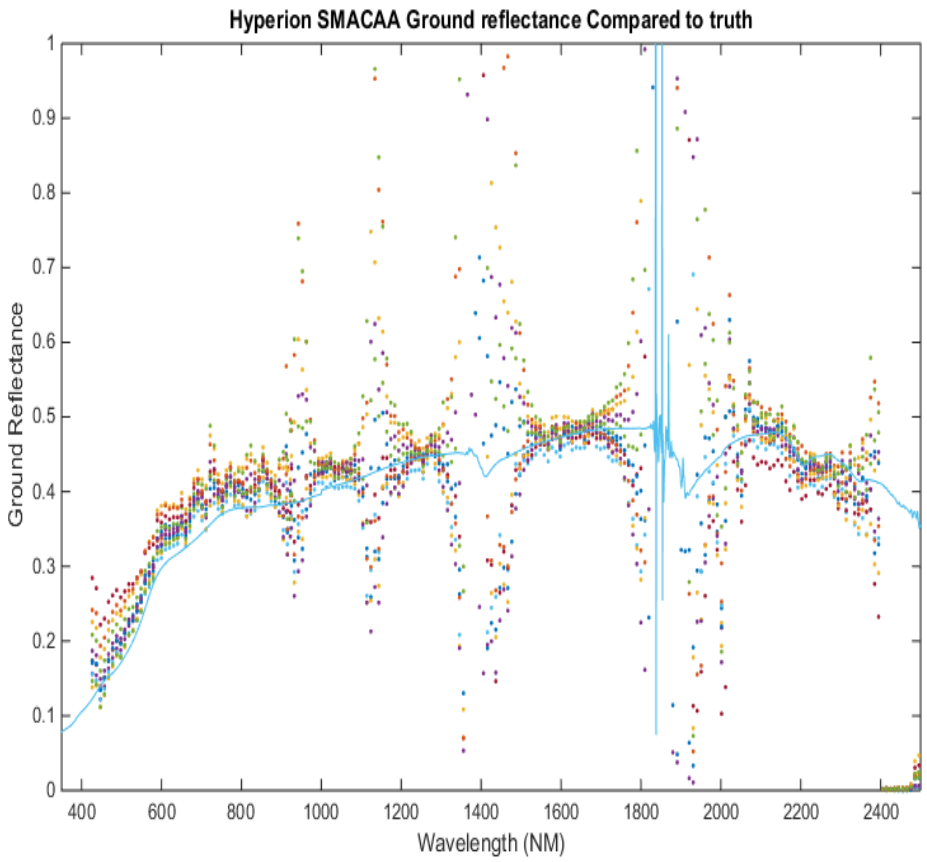
SMACAA Validation - Bright Site
L8 SMACAA Reflectance for Algodones Dunes



- The red circle around DOY 70 represents the ground truth.
- Same over profile, with just a fewer more points

SMACAA Validation - Bright Site

Hyperion Hyperspectral Ground Reflectance of AD Vicarious Site



- Dots represent the 12 Hyperion collects from 2011-2015.
- Solid line represents ASD taken from Vicarious area in AD from March 9, 2015
- No BRDF correction to the data, and most Hyperion data was collected off-Nadir.
- Still some under-correction in the shorter wavelengths.

Sub-Conclusion: SMACAA Atmospheric Model

- Via different sites, where the understanding of the ground is high, a check on the performance of the atmospheric correction was evaluated.
- Results indicate some under correction for shorter wavelengths, meaning an under-estimation of aerosol is presenting an absolute error of ~ 1.5 reflectance units.
- Longer wavelengths appear better than 1.0 reflectance units.
- Over all the database is accurate and capable of understanding worldwide optical atmospherics for 1972- current.

Example of SMACAA Usage

→A-PICS*

*Absolute Pseudo Invariant Calibration Sites

Overview A-PICS

- The desire is to transform relative calibration using PICS sites into absolute. Such that any sensor can fly over the site, and an absolute radiance / reflectance can be predicted.
  - Two key components need to be understood to make this happen
    - Atmospheric
    - Ground reflectance / Bi-Directional Reflectance Distribution (BRDF)
- These two areas have been worked from each end and are meeting in the middle, this talk will present how this data / analysis is meeting in the middle to create a validated end to end model

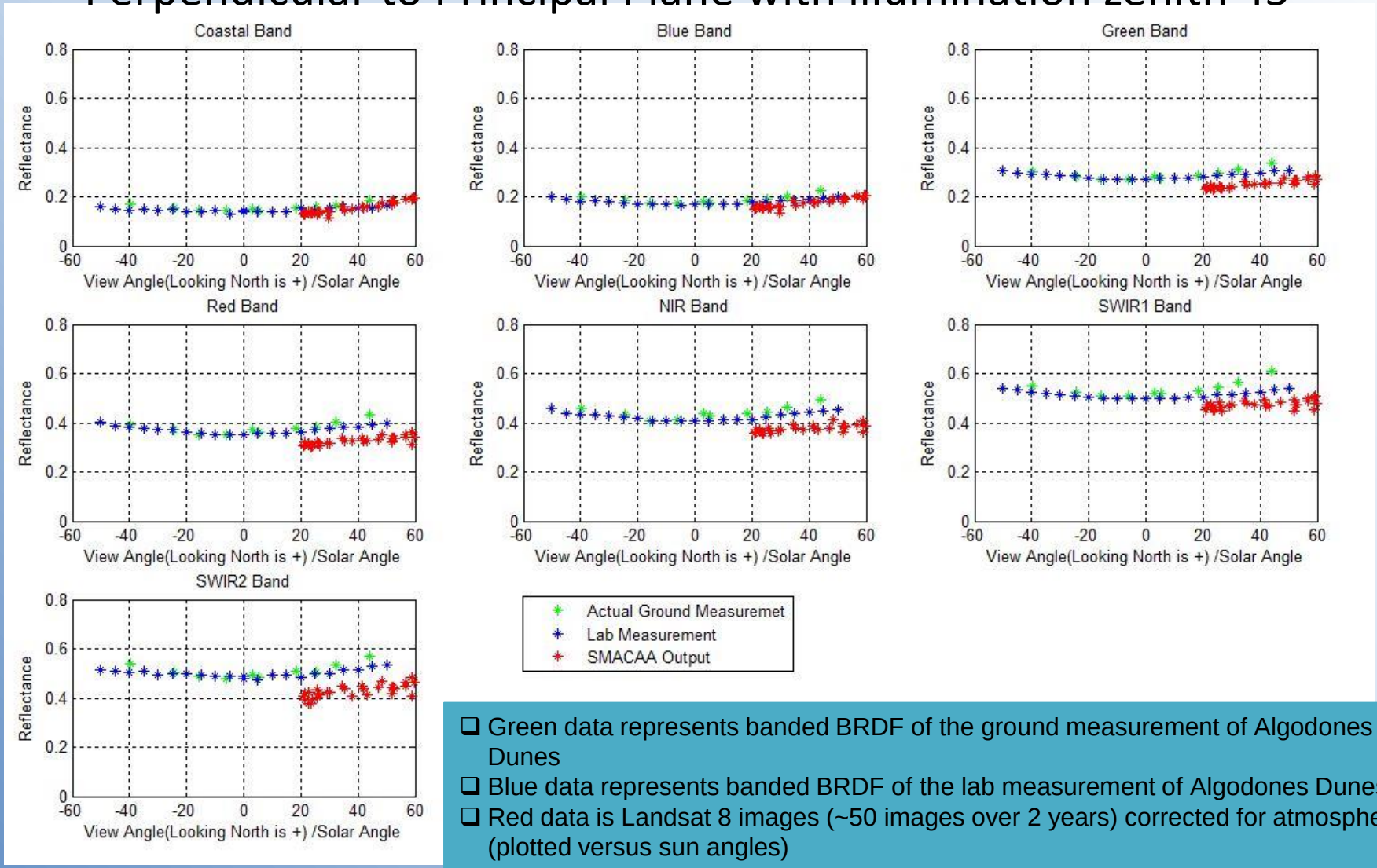
A-PICS Ground Side:
Algodones Dune Overview / Status

- March 8 – 14th Trip to Algodones dunes to acquire validation / model data of the surface reflectance and its BRDF
  - In field spectral data has been processed for a limited number of sites achieved in the field.
  - Atmospheric data processed
  - Sand samples acquired at larger area of interest being processed to validate in-situ measurements and determine larger area variation

A-PICS Ground Side: Algodones Dunes BRDF Data

- SDSU collected BRDF from a number of "different" sand categories around base camp (tops / sides / bottoms of dunes).
- The measurements where taken in the principle plane and 90 degree off principle plane.
- Data is used to "drive model" generation
- Data is also used validate results.
- Key to all this – methodology that can be replicated for other PICS that are "less accessible"

Comparison of Ground Measurement and Lab Measurement of Sand of Algodones Dunes with output of SMACAA for Site 1A Perpendicular to Principal Plane with illumination zenith 45^0



- Green data represents banded BRDF of the ground measurement of Algodones Dunes
- Blue data represents banded BRDF of the lab measurement of Algodones Dunes
- Red data is Landsat 8 images (~50 images over 2 years) corrected for atmosphere (plotted versus sun angles)

- **This data is not "apples to apple" the Blue and Green data represent the same "area" of the dunes, while the red data is from an adjacent site, that did appear to be "different". Work in progress to put everything to a "apples to apples" comparison.**

Sub-Conclusion A-PICS Ground

- Field data to understand surface BRDF behavior is captured; lab measurements agreeing with field data.
- SMACAA provides the atmospheric component to complete the A-PICS model.
- Need to combine the results of all team members in a consistent “story”. This will hopefully lead to production of a A-PICS site for Algodones Dunes.
- Started applying some of the methodology to Libya 4.

Conclusion

- SMACAA database and processing system are complete from a prototype and in-house use perspective
  - Global Coverage
  - Temporal coverage to 1972 (for Landsat MSS)
  - Sensor independent
  - Consistent with other atmospheric correction systems (LEDAPS)
- Usage of SMACAA for Algodones Dunes campaign providing consistent results
- Provides key atmospheric capability for A-PICS effort
- Currently finishing initial test case of processing all archived CONUS MSS data to surface reflectance