A case study on the use of MODTRAN for atmospheric correction of satellite imagery obtained from high spatial resolution pointable sensors over agricultural study sites.

Atmospheric Transmission Models – Modeling in Remote Sensing 2018

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Presentation Objectives

- 1) Provide a methodology for the use of MODTRAN 5.3.3 for pointable sensors in deriving surface reflectance imagery.
    - WorldView-3 (WV3), SPOT 7
    - How important it is to account for off-nadir view angle of pointable sensors?

- 2) Provide an assessment of MODTRAN compared to FLAASH, SMARTS, and Py6S
    - How much do these radiative transfer models differ?

Background and Motivation (1)

- USGS & USDA using high spatial resolution imagery to study tillage (via. crop residue assessment)
  - Crop residue: SWIR
  - Live vegetation: VNIR

- Commercial satellite imagery like WorldView-3 (DigitalGlobe) and SPOT 7 (SPOT Image) offer spatial resolutions far finer than Landsat.

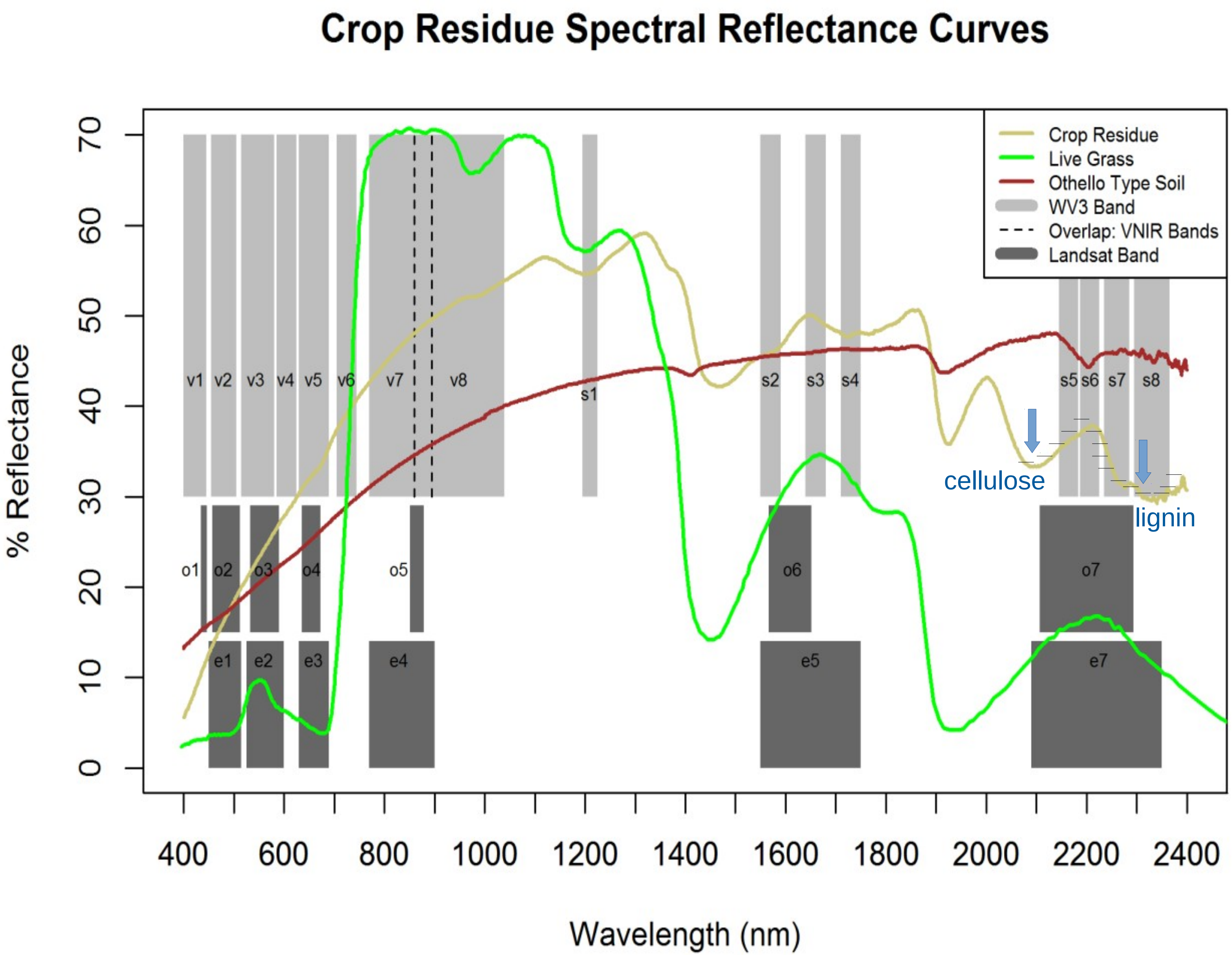
30 meter WV3 SWIR imagery (coarsened)

4 meter WV3 SWIR imagery (native resolution)

Eastern Shore, Maryland

Background and Motivation (2)

- Strategies for mapping crop residue with SWIR bands
- WorldView-3 has 4 bands between 2100-2400 nm
- Identifying cellulose and absorption features at 2100 nm and 2300 nm (blue arrows)
- Compare to reflectance differences of green vegetation from 700 to 900 nm



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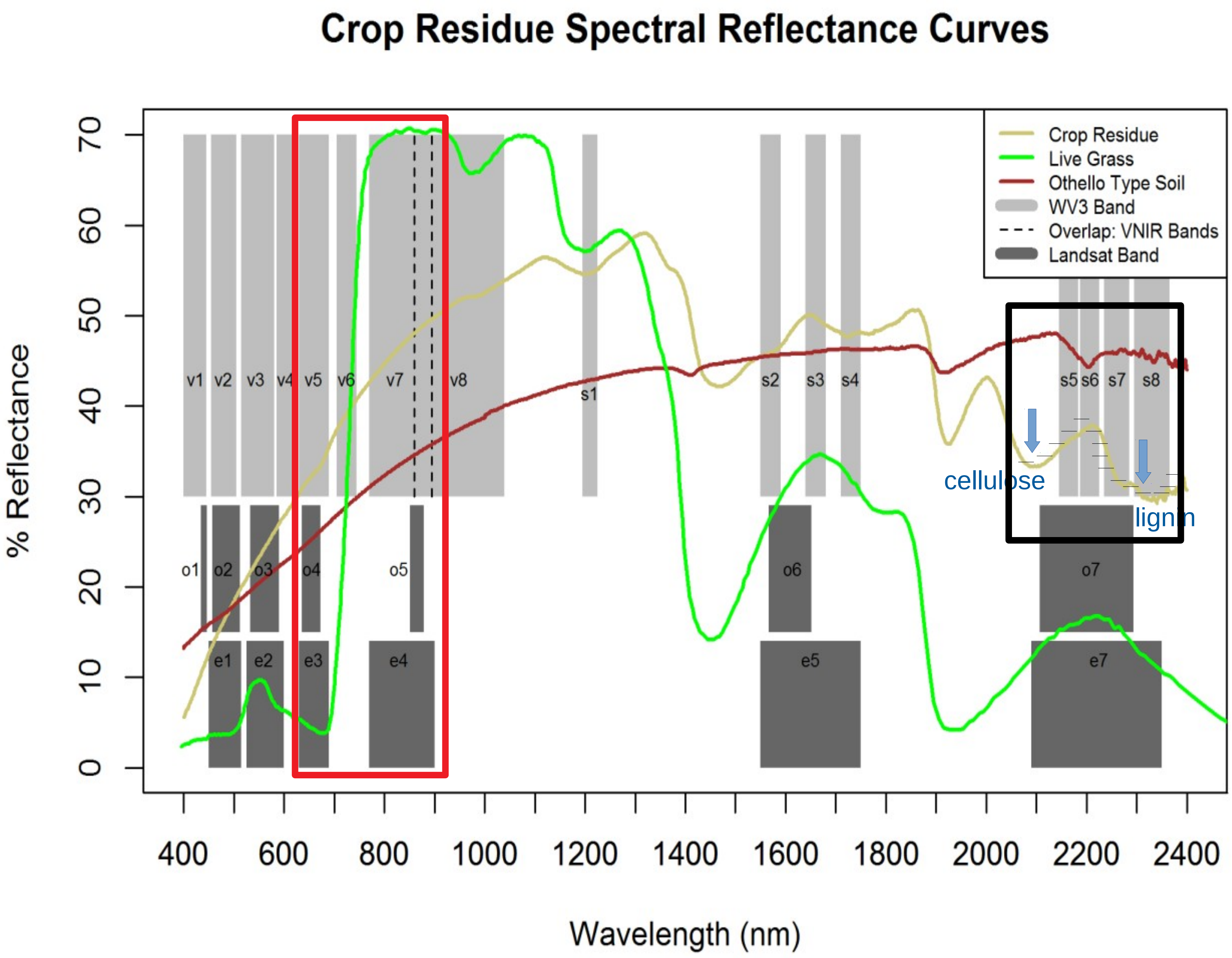


Background and Motivation (3)

- Why we need atmospheric correction for SWIR
  - Strong H_20 absorption in the SWIR
  - Aerosols impact scattering and absorption in SWIR
  - Lower upwelling radiance signal for SWIR than VNIR
  - Surface reflectance needed for scene to scene comparability with Landsat SWIR band crop residue mapping (Gelder et al. 2009)

Implementation of MODTRAN (1)

- Converted WV3 DN imagery to radiance imagery (image date February 22, 2016)
  - Obtained gains, offsets, ACF, EBW from WV3 metadata
  - L ($W/m^2/um/sr$) = DN (ACF/EBW) * (2 - Gain) - Offset

- Obtained local station data for MODTRAN TP5 file modification:
  - Vertical temperature, pressure, and relative humidity profiles (NOAA RSL radiosondes)
    - Wallops, VA
    - ~100 km away from site (but best option)
  - Ozone: Environment Canada (modeled product)
  - Visibility: Aerosol optical thickness (NASA AERONET)
    - Easton, MD
    - Calculated AOT(550nm) by interpolating AOT(500nm) and AOT(670nm) observations
    - Visibility = exp(-Ln [AOT@550nm / 2.7628] / 0.79902)
    - 206 km

Implementation of MODTRAN (2)

- View angles accounted for in MODTRAN CARD 3 LINE-OF-SIGHT-GEOMETRY

- WorldView-3
  - Satellite lat/lon unknown, only image center lat/lon known
    - IPARM11 (H2ALT to H1ALT)
    - True Azimuth (TRUAZ = mean satellite azimuth from WV3 metadata) (e.g. 69.9)
    - Zenith Angle = (180 – off nadir view angle from WV3 metadata) (e.g. 150.9)

- SPOT 7
  - Satellite lat/lon and image center lat/lon known
    - IPARM1 (H1ATL to H2ALT)
    - True Azimuth (TRUAZ determined using Python script calculating satellite view direction from SPOT metadata)
    - Zenith Angle = (180 – off nadir view angle determined using Python script calculating satellite view direction and satellite elevation)

Implementation of MODTRAN (3)

- CO_2 Mixing Ratio: 390
- O_3: 325 DU
- Default values used for other trace gases

- Three albedo iterations
  - 0.0, 0.5, 1.0

- Spectral radiances from three albedo iterations were converted to coefficients for converting converting radiance to surface reflectance
  - Surface reflectance =
    (radiance – 0.0_albedo) / (A + S * (radiance – 0.0_albedo))

Assessing accuracy of MODTRAN

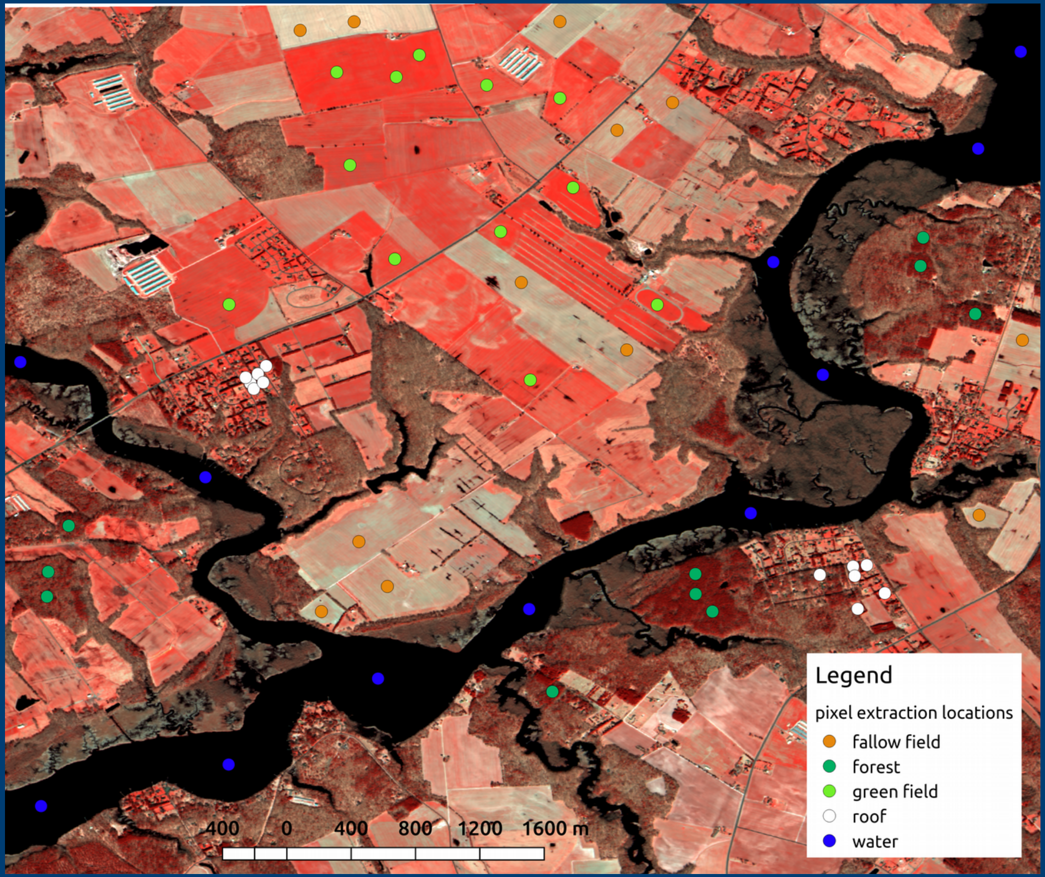
- Compare TOA reflectance with MODTRAN surface reflectance imagery

- Compare MODTRAN with other radiative transfer models, holding all models parameters constant when possible.
  - FLAASH (Fast Line-of-sight Atmospheric Analysis of Hypercubes)
  - SMARTS (Simple Model Atmospheric Radiative Transfer of Sunshine)
  - 6S (Second Simulation of the Satellite Signal in the Solar Spectrum)
    - Py6S (Python interface to 6S)

- Qualitative visual assessments of imagery
- Quantitative assessments of imagery differences

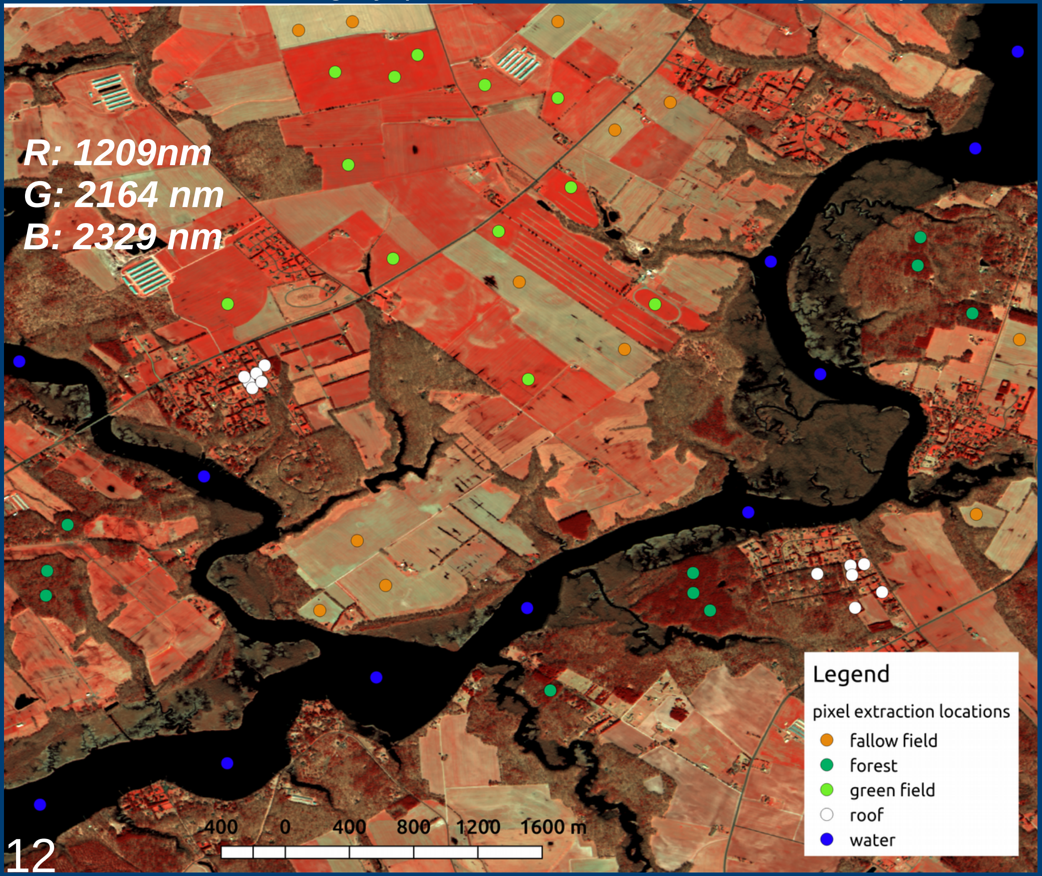
Assessing Reflectance Differences Over Different Landcover Classes

- 12 points identified for different landcover types:
  - Open water (blue points)
  - Forest (dark green points)
  - Roof (white points)
  - Green fields (light green points)
  - Fallow fields (tan points)
- Quantitative assessments of imagery differences

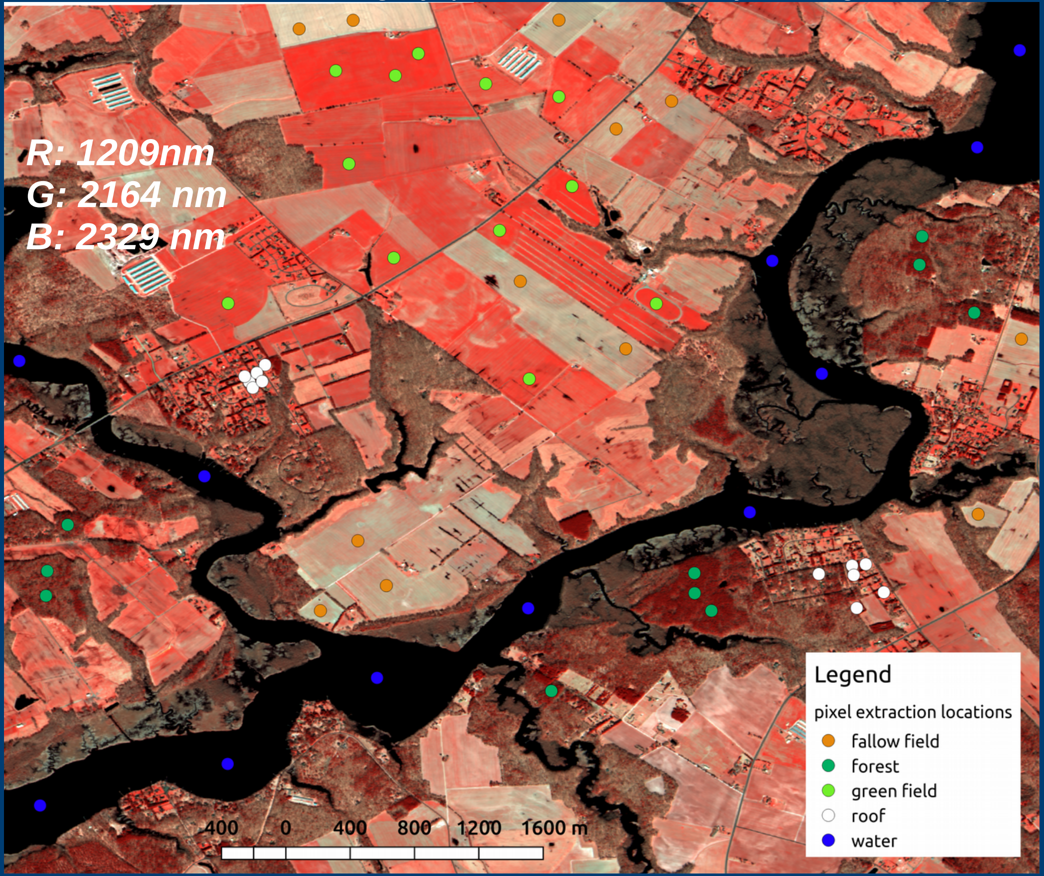


Qualitative Assessment of TOA reflectance imagery vs. MODTRAN surface reflectance

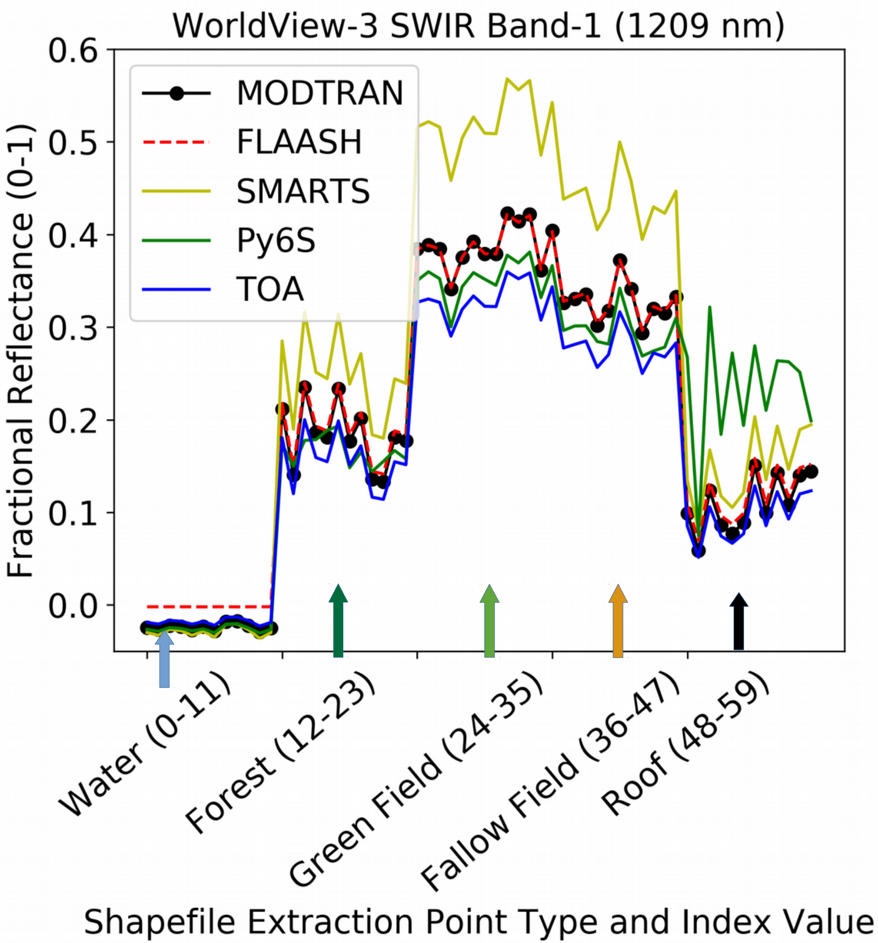
TOA Reflectance Imagery (Eastern Shore, Maryland Ag. Sites)

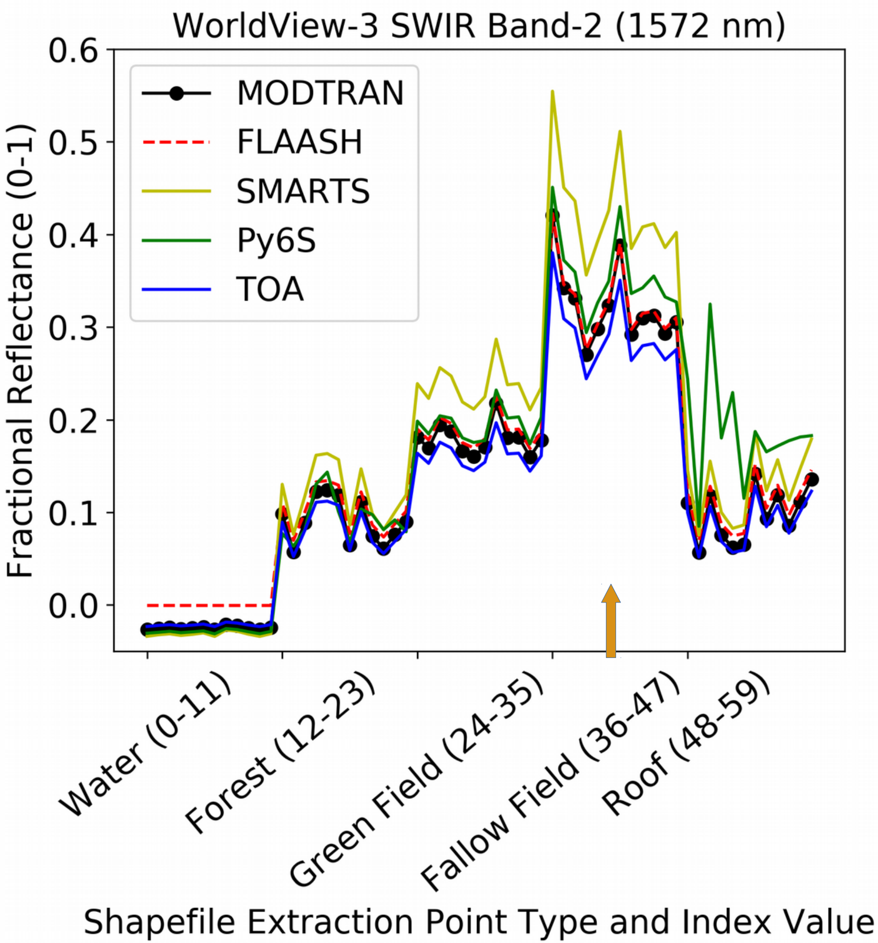


Surface Reflectance Imagery (Eastern Shore, Maryland Ag. Sites)

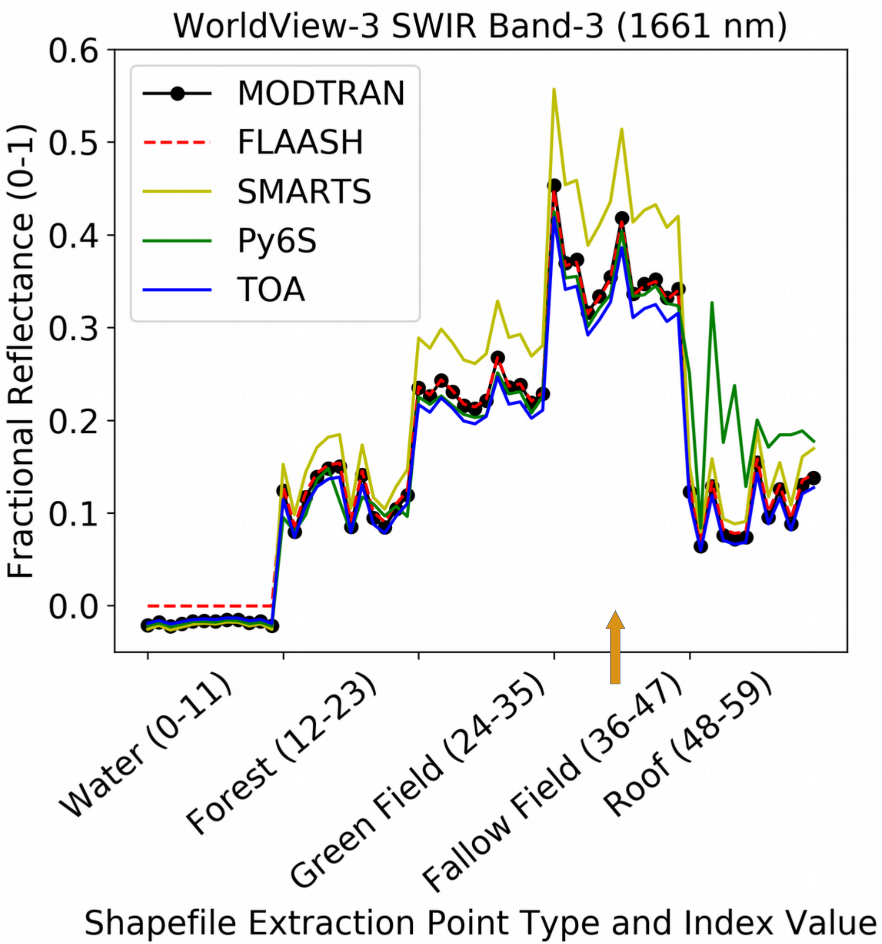


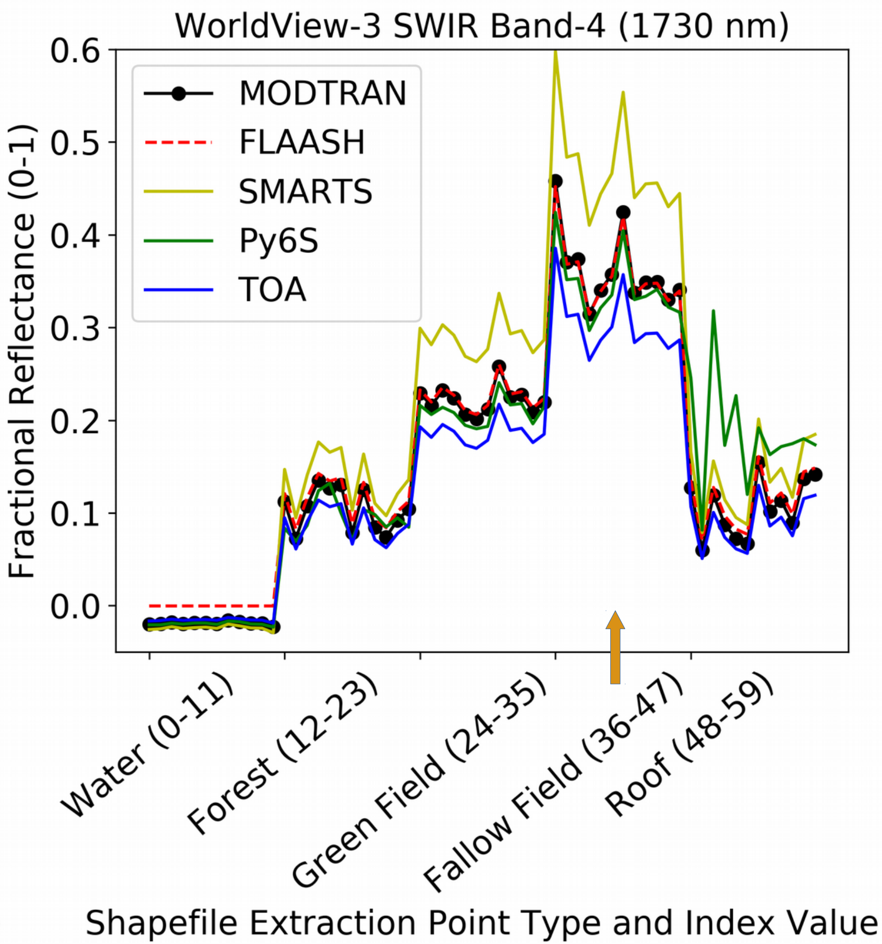
Comparison of atmospheric correction approaches (SWIR Bands 1-2)



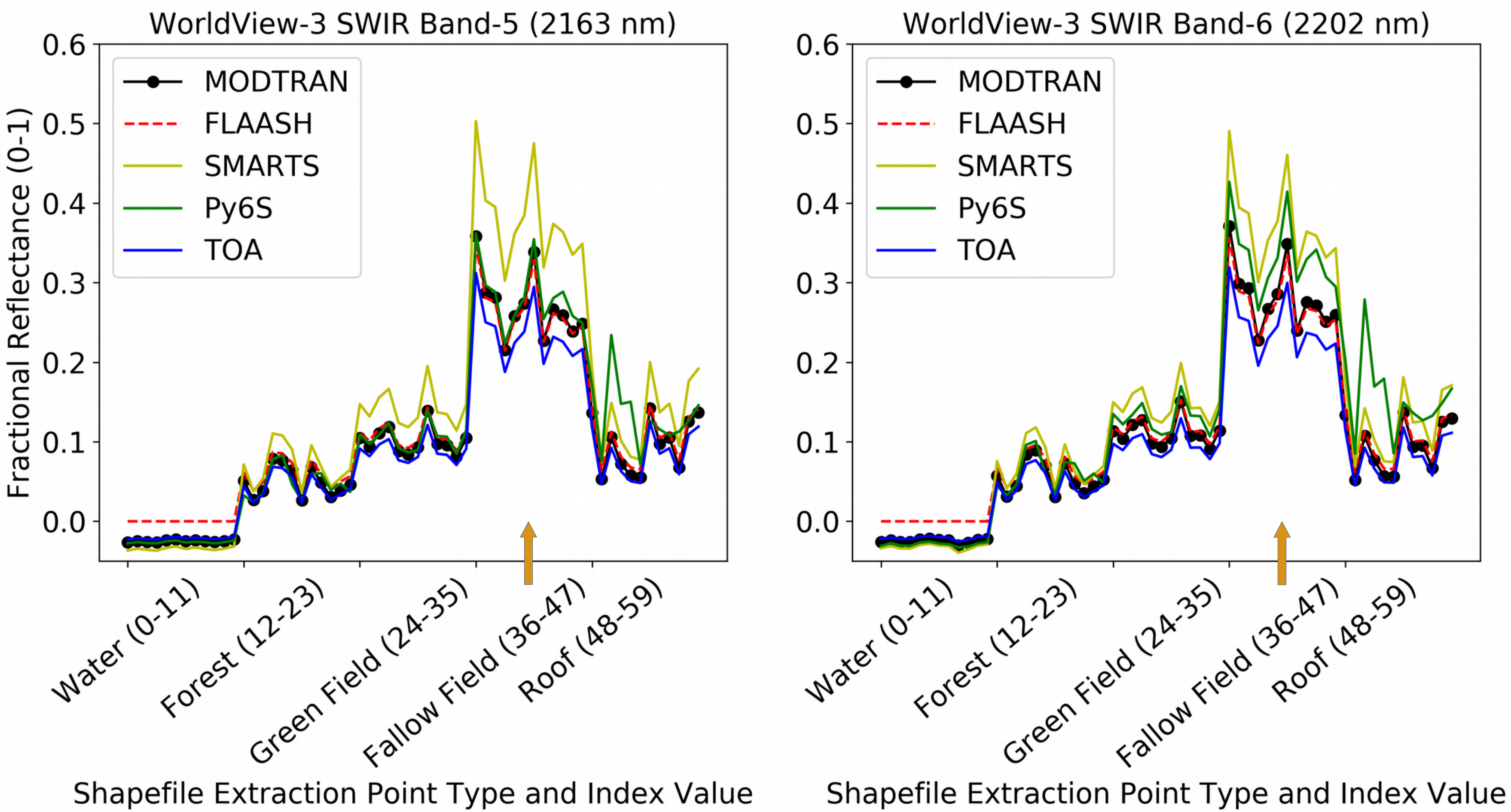


Comparison of atmospheric correction approaches (SWIR Bands 3-4)

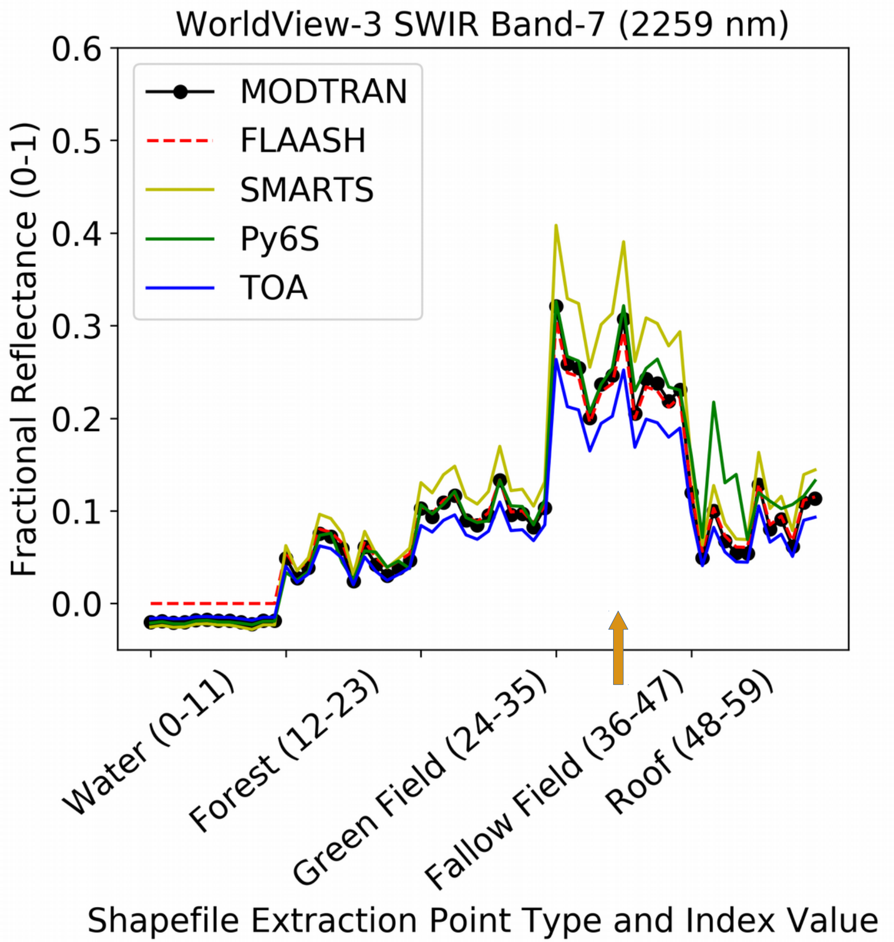


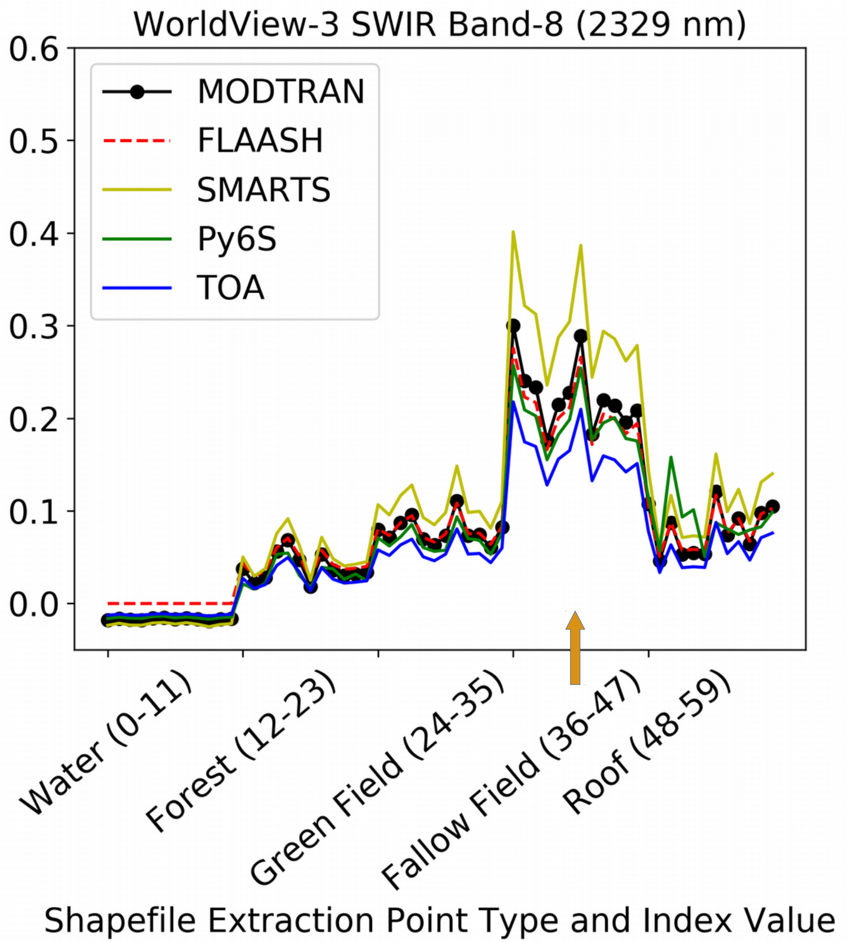


Comparison of atmospheric correction approaches (SWIR Bands 5-6)

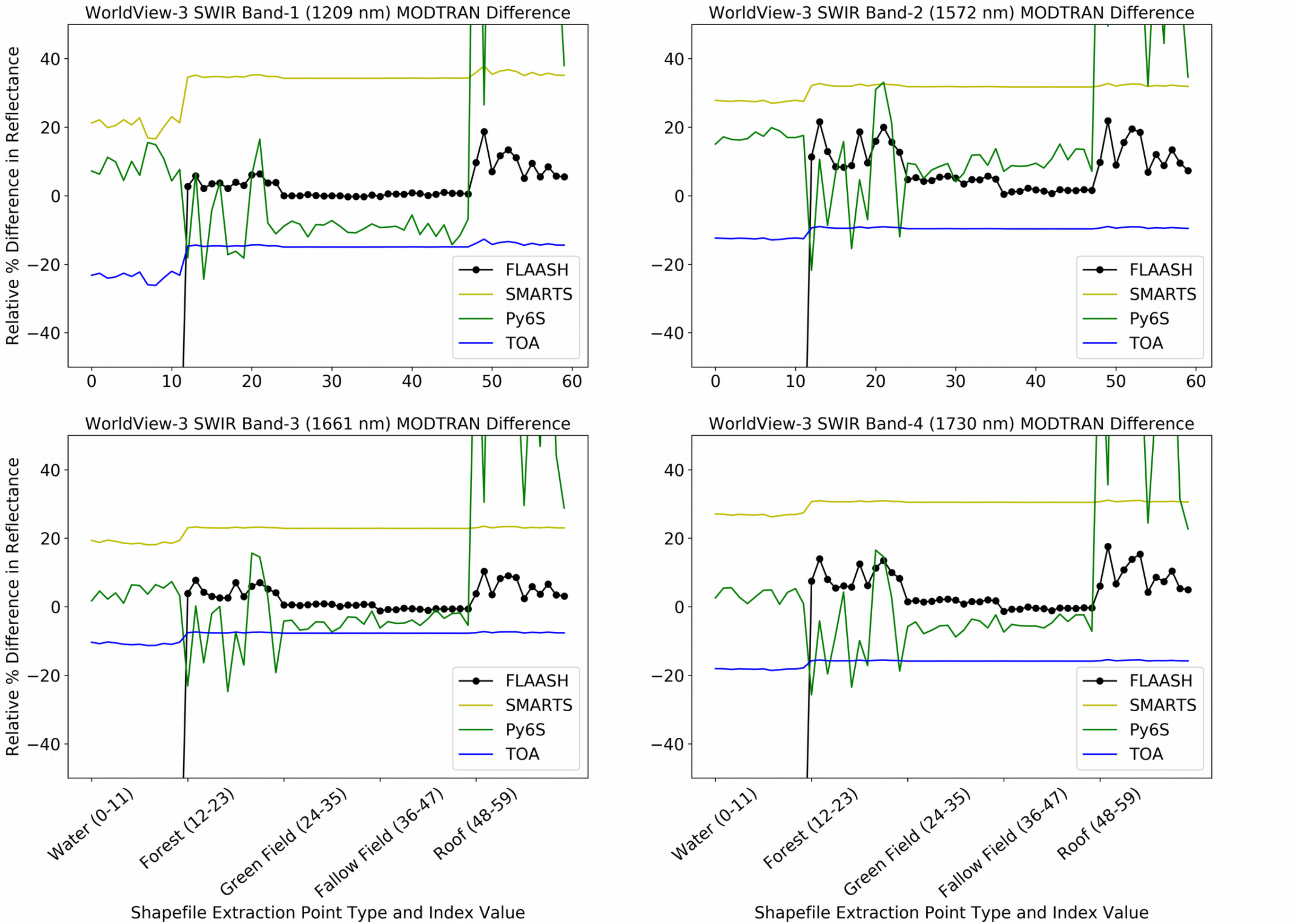


Comparison of atmospheric correction approaches (SWIR Bands 7-8)

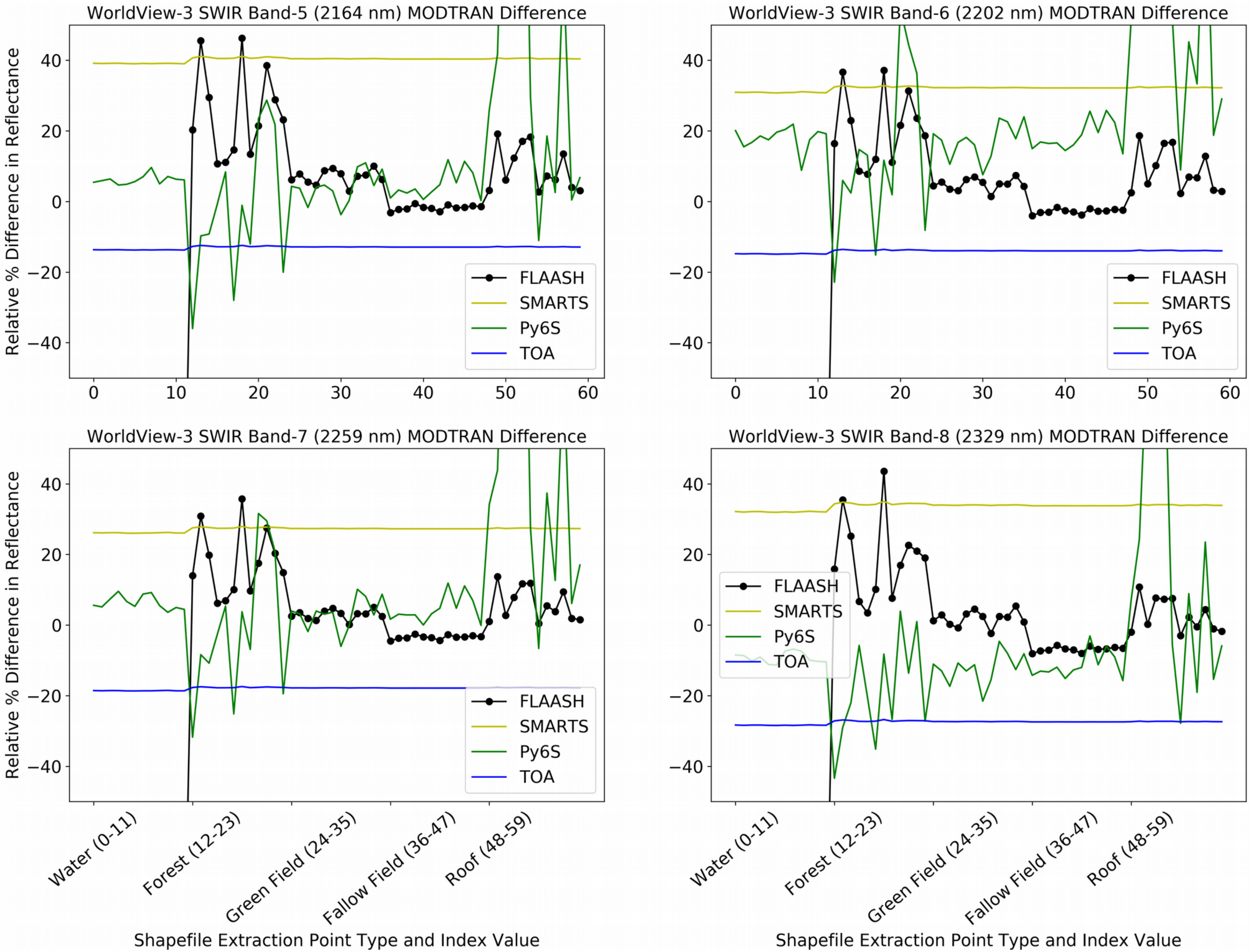




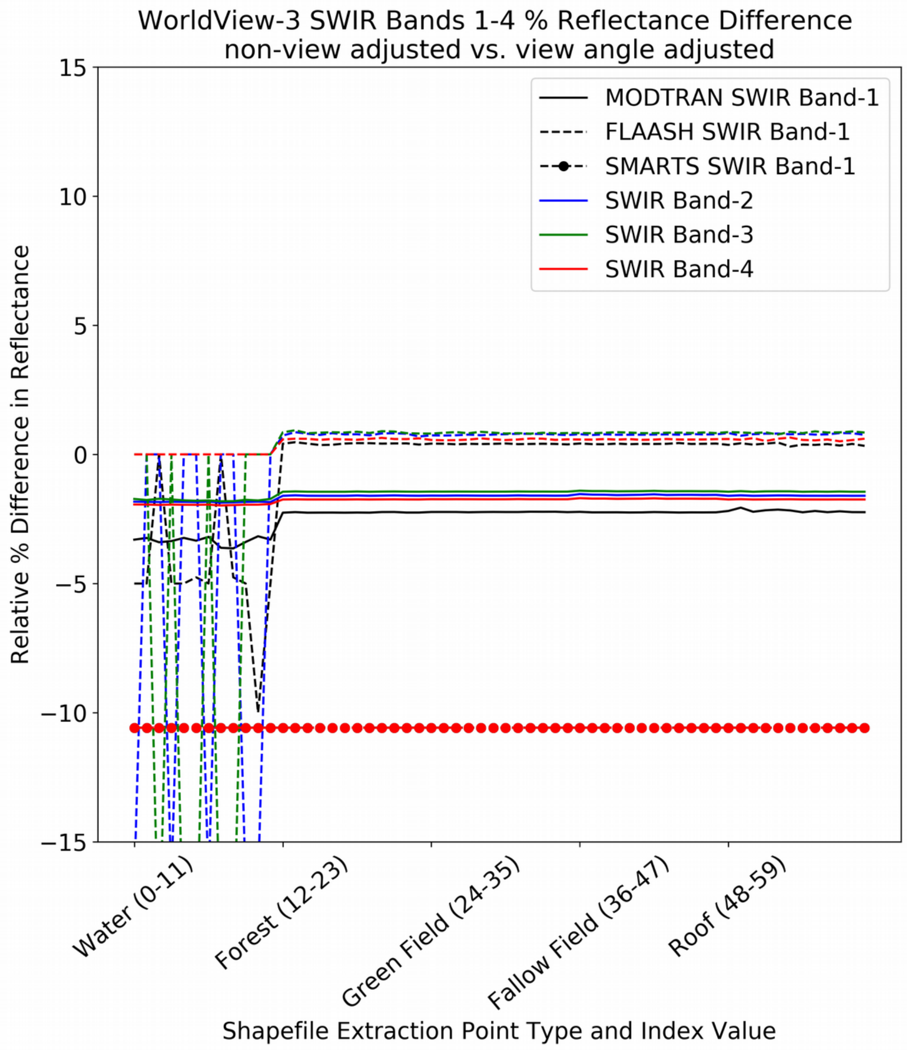
Relative % difference between MODTRAN and other atmospheric correction approaches (SWIR Bands 1-4)

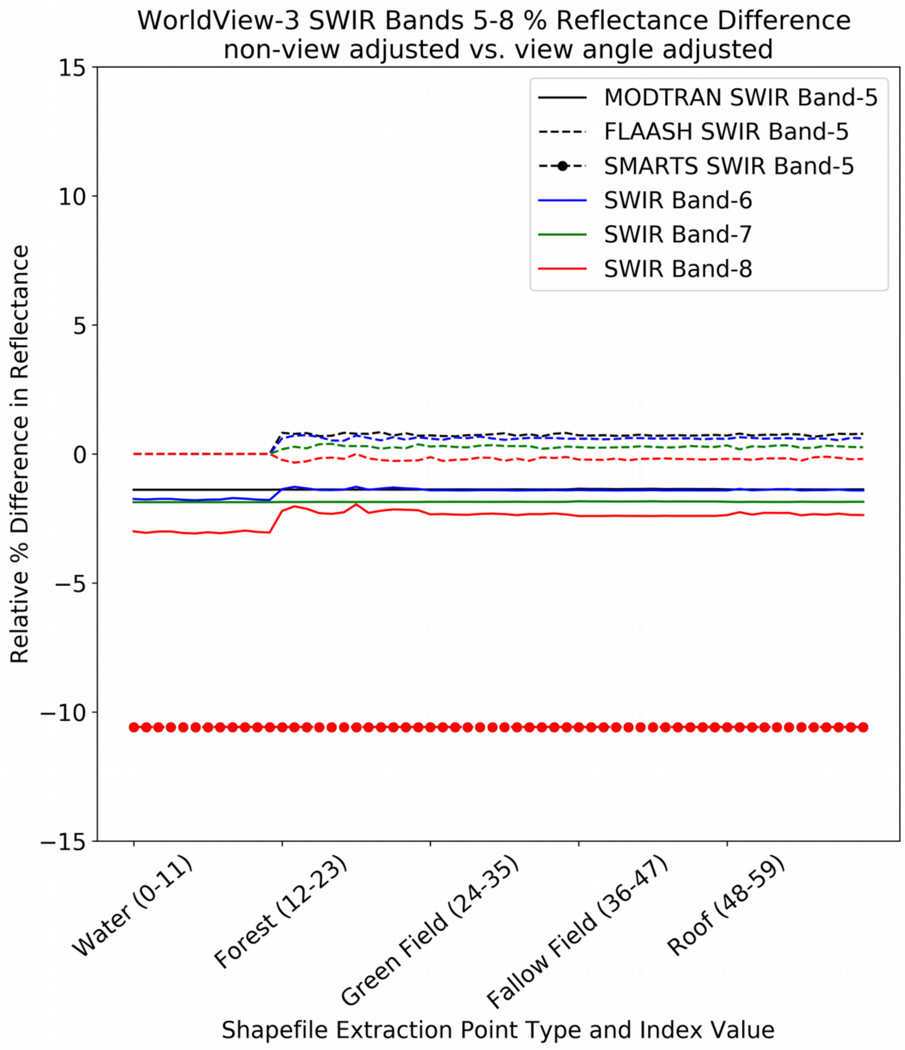


Relative % difference between MODTRAN and other atmospheric correction approaches (SWIR Bands 5-8)

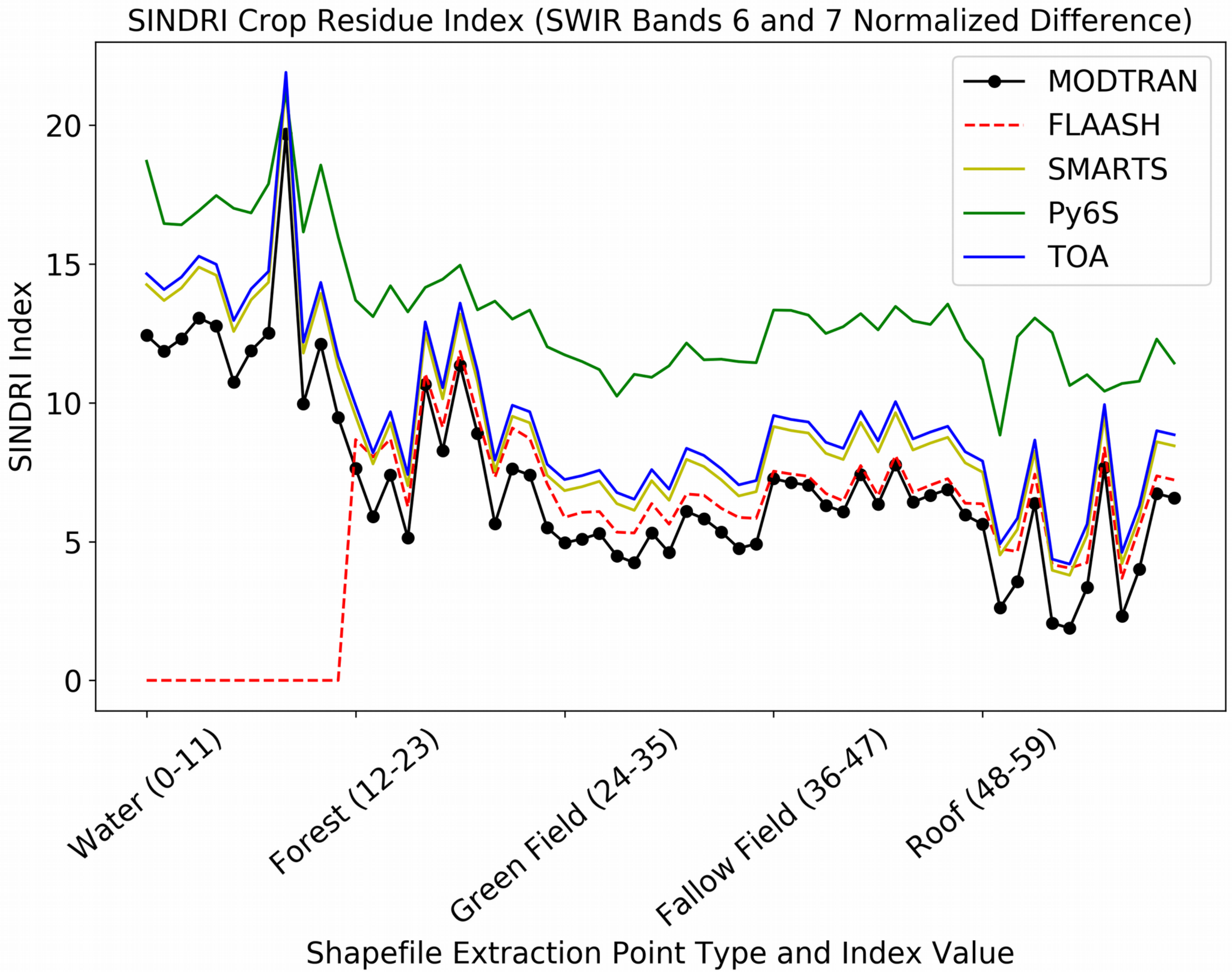


Accounting for view angle: Relative % difference between atmospheric correction with adjusted view angle and nadir view

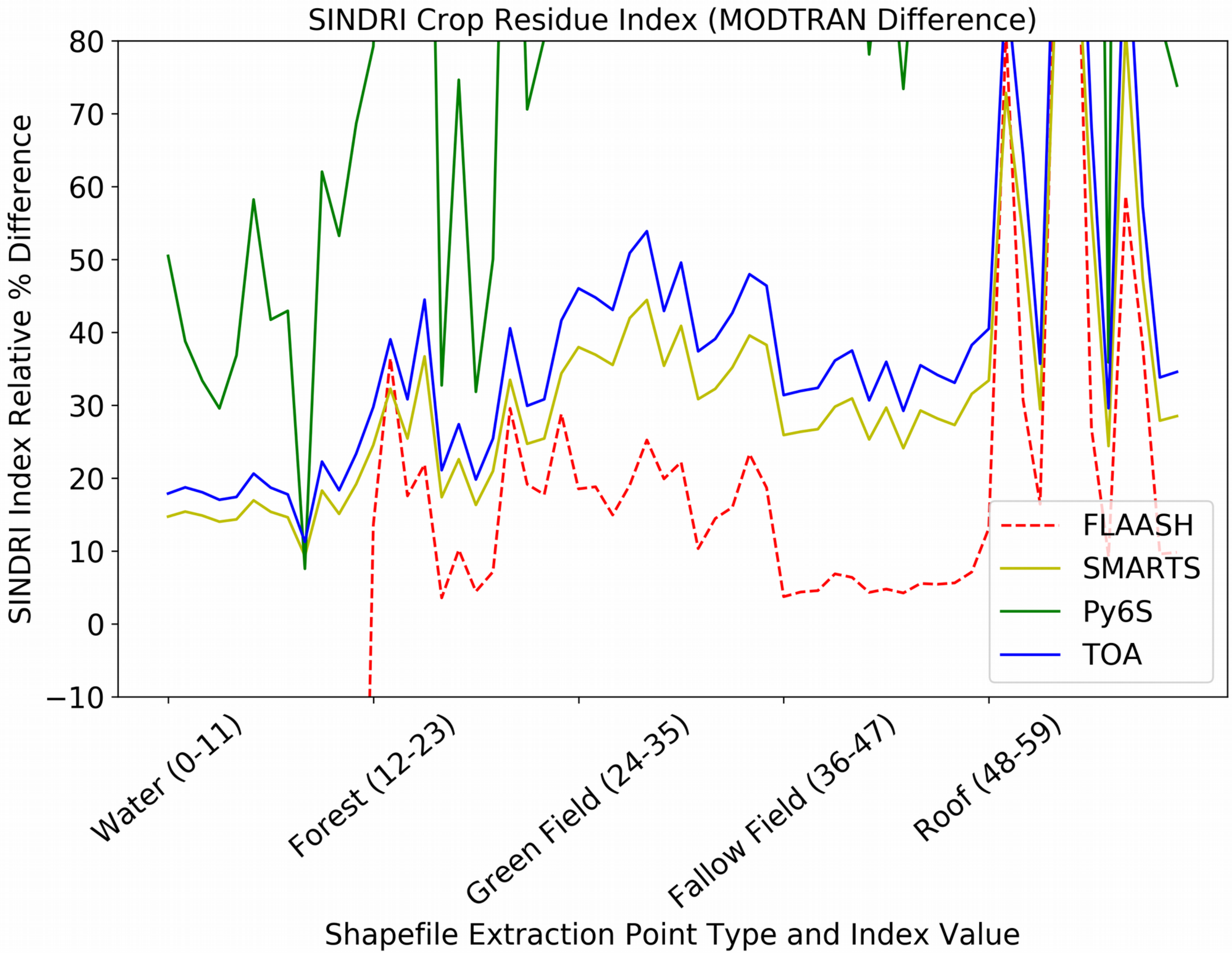




Crop residue index derived from surface reflectance imagery from different models



Crop residue relative % differences



Conclusions

- Different atmospheric correction methods produce greater differences in percent reflectance than accounting for view angles (zenith and azimuth)
- Relative % differences between MODTRAN and FLAASH reflectances were less than 10% for all SWIR bands over agricultural sites.
  - TOA, SMARTS, and Py6S all exceeded 10% relative difference in reflectance
- For fallow fields, crop residue indices (SINDRI) differed by less than 10% when comparing MODTRAN and FLAASH, and differences were otherwise >10% for other cover types and atmospheric correction types
- Ground-based spectral measurements need to further assess atmospheric correction performance
  - We know the models are different, we don't know which is "right".