Scene Simulation for Future Landsat Systems

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Outline

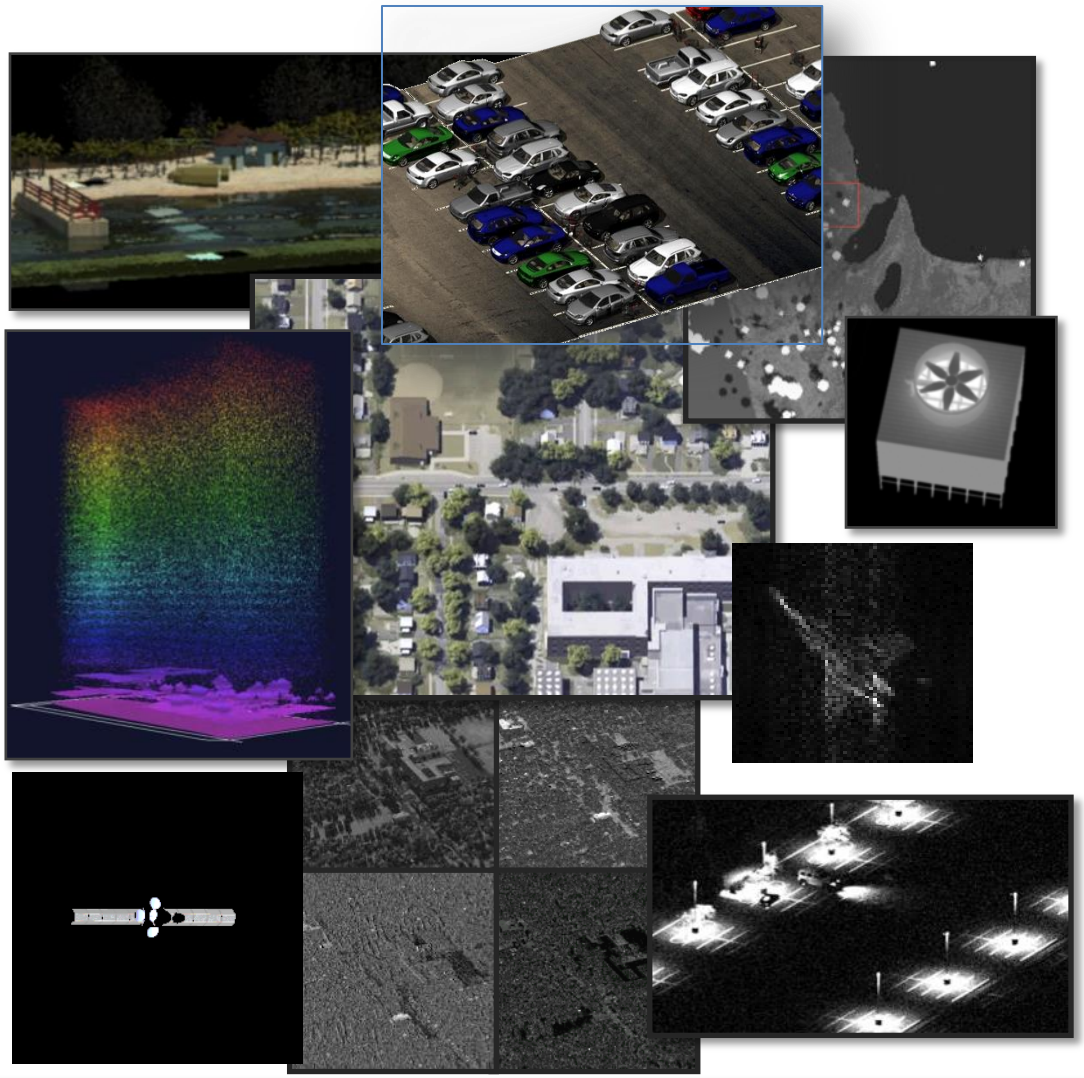
- Introduction and Objectives
- DIRSIG Modeling Tool
- Scene Construction Tool
- Initial Scenes
- Summary and Future Plans

Introduction and Objectives

- Physics-based scene simulation powerful tool for system studies
  - Explore impact on imagery and resulting products of requirements or design changes
  - Provide data with known truth for algorithm development and testing
  - Provide realistic imagery for testing of processing work-flow
- Objectives for Landsat program
  - Provide realistic synthetic scenes and imagery for a variety of biomes
  - Use scenes to explore quantitative impacts of future design concepts on imagery characteristics and science products
  - Assist in defining quantitative basis for system requirements

DIRSIG: Image and Data Simulation (www.dirsig.org)

- An image and data simulation tool for modeling remote sensing systems:
  - Pan and RGB
  - Multi/Hyper-spectral
  - Thermal
  - Video
  - Polarization
  - Low light/night
  - Plumes/Water/Clouds
  - LIDAR/LADAR
  - SSA*
  - SAR*



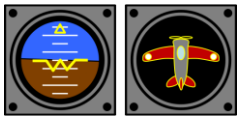
* Experimental application areas

DIRSIG: Creating Imagery

Instruments:
Imaging and
Non-Imaging Instruments

Modeling a Real-world Target

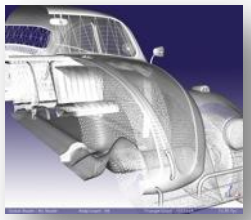
Platform Motion:
Dynamic location/orientation



Platform:
Attach multiple instruments

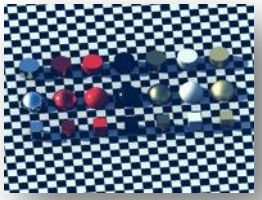
Collection Data:
Date and Time

Geometry:
Objects described by 3D CAD models; surface modeled by DEM



Atmosphere:
Radiative Transfer
(MODTRAN)

Materials:
Surface (Bulk) Optical Properties
Thermodynamic Properties



Material Attribution

Data Products:
Low-Level Imagery
Platform Ephemeris
Truth Maps

Object Database:
Different objects
Geometry variants
Material variants

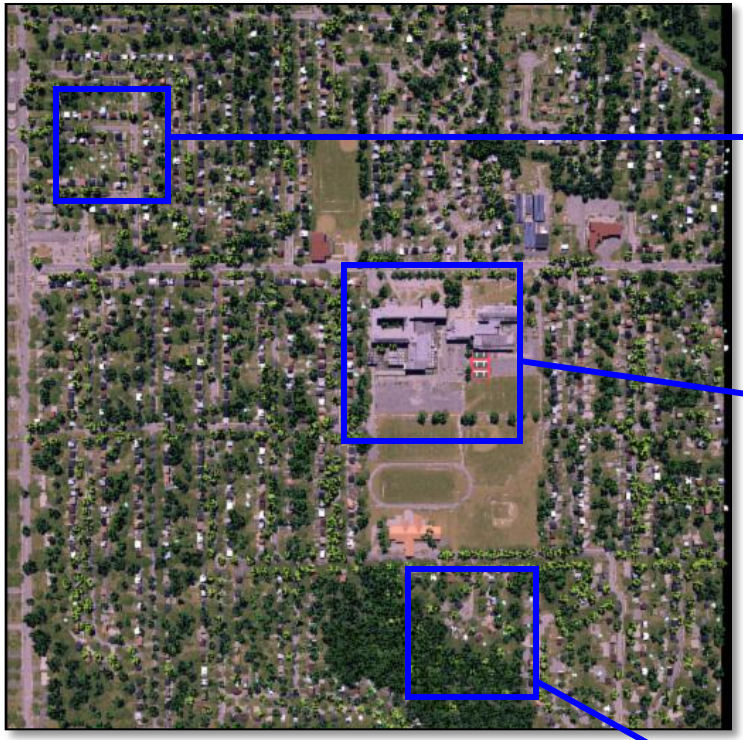
Scene Assembly

General Capabilities

- Image Modalities
  - Visible through thermal infrared (0.4 - 20.0 microns)
  - Passive Sensing
    - Broad-band, multi-spectral (MS), hyper-spectral (HS) imaging.
    - Polarization (usually limited by material properties)
  - Active Laser sensing
    - Topographic LADAR and atmospheric/gas LIDAR
  - Active RF sensing
    - Synthetic and real aperture RADAR (in development)
- Instruments
  - Single pixel, 1D arrays and 2D arrays.
  - Filter, diffraction/refraction or interferogram based photon collection.
- Platforms
  - Ground, air or space on static or moving platforms.
- Instrument/Platform Interfaces
  - Platform relative instrument scanning, simulated platform data recorders, etc.

MegaScene1:

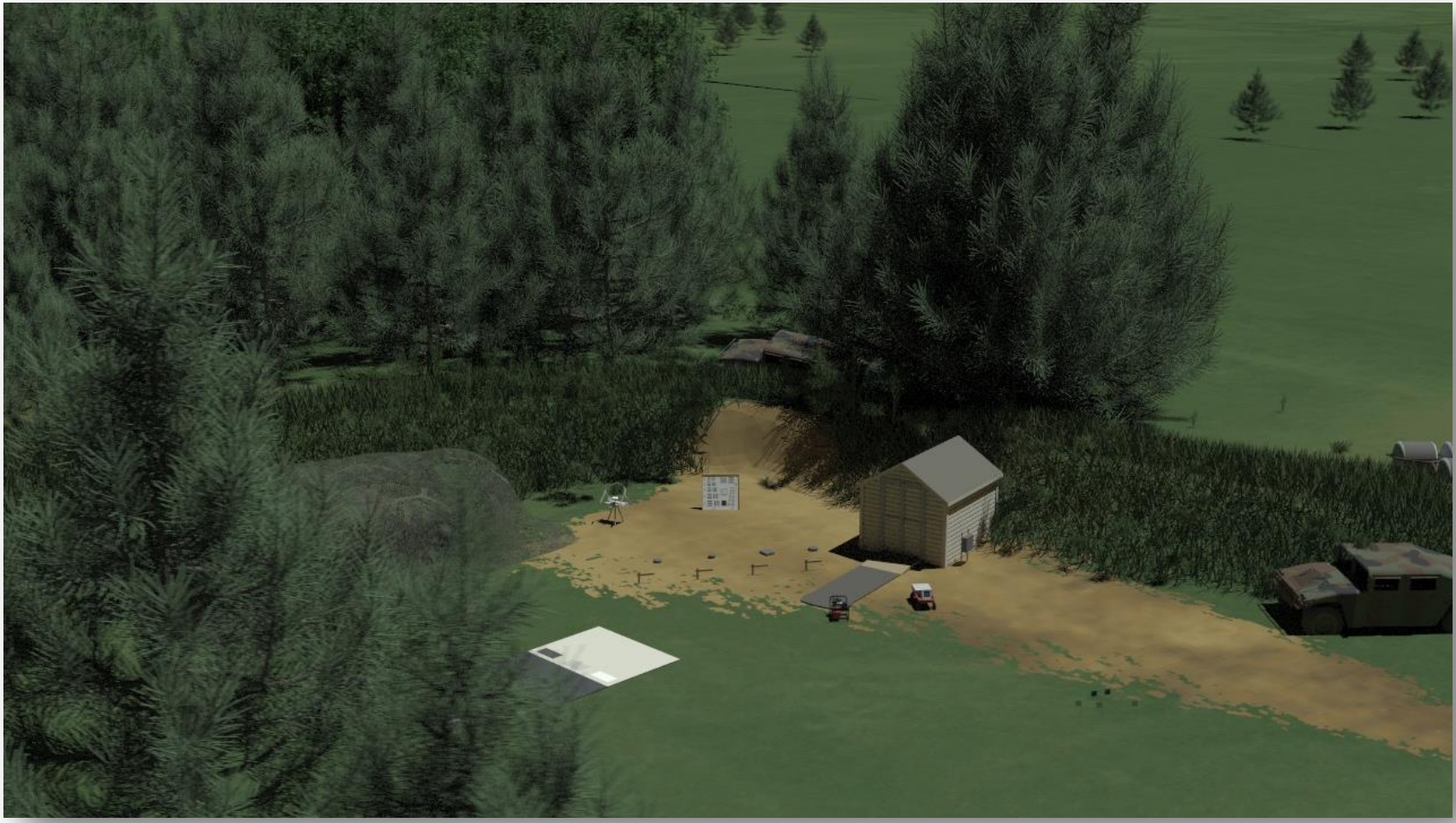
A Large Area, High Resolution Scene



A portion of an area approximately
3 km x 8 km in size.

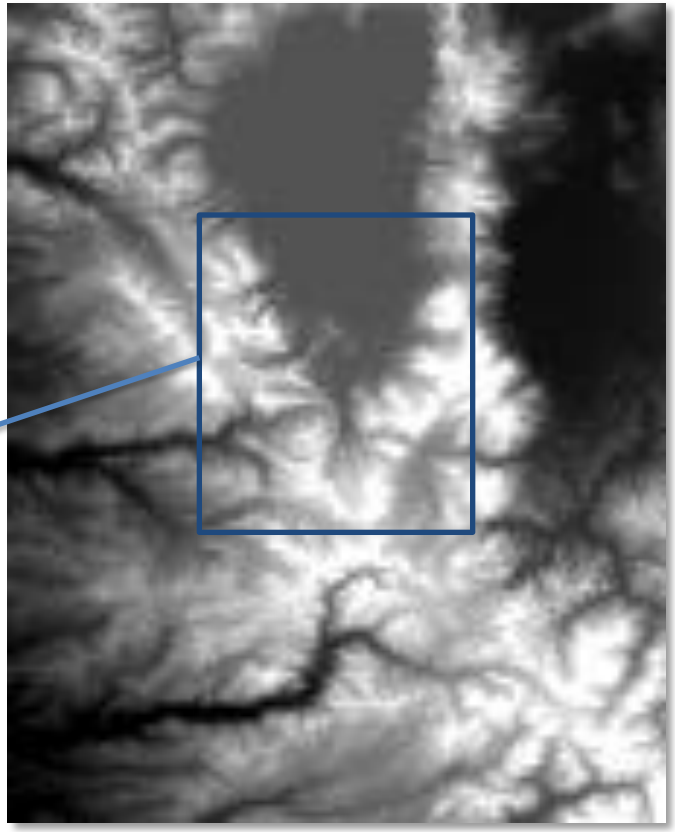
MicroScene1:

A Small Area, Very High Resolution Scene



Large-Area, Space-Based Simulations

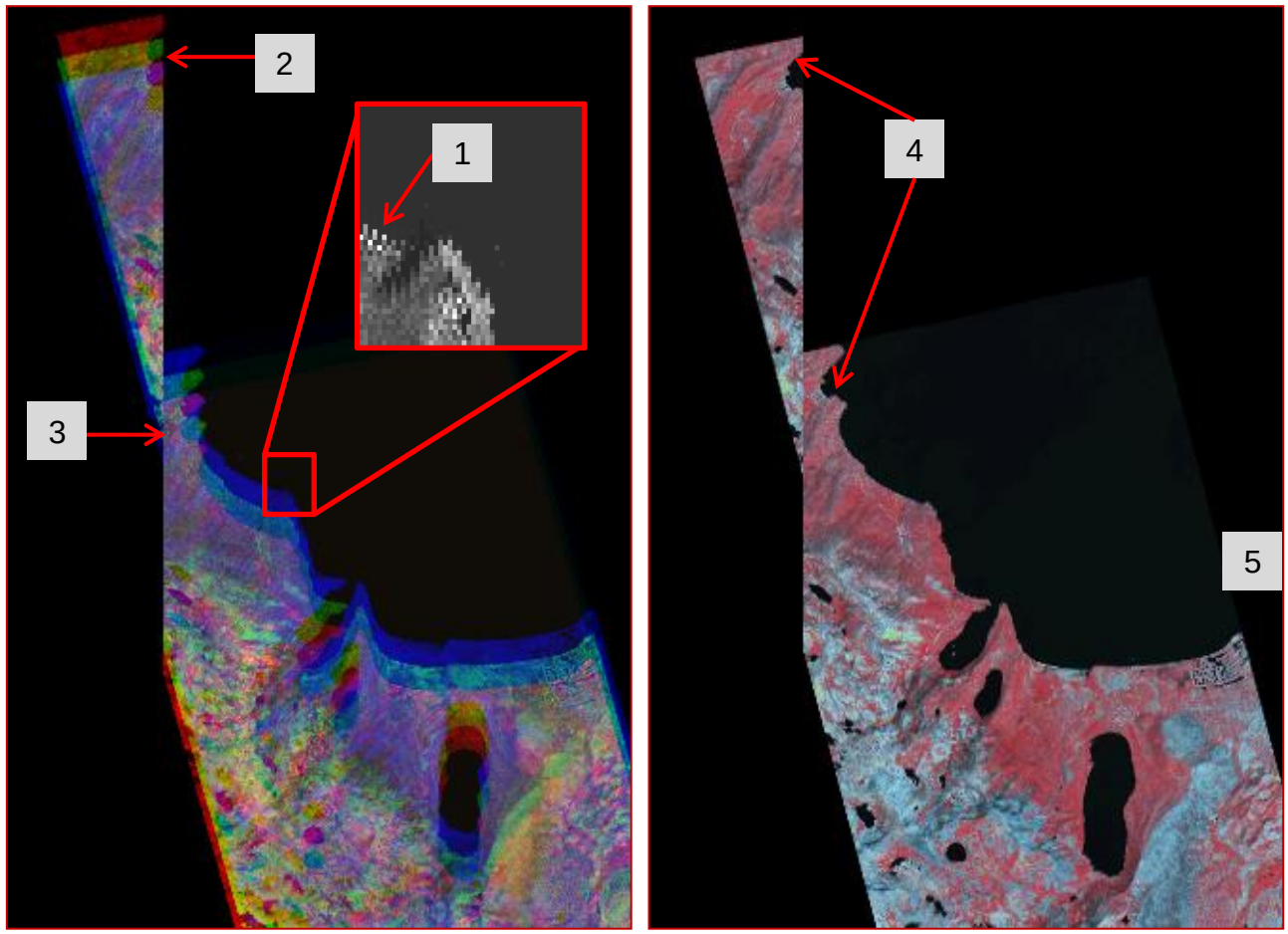
Landsat-8 (LDCM)



Lake Tahoe, CA
Large spatial footprint, vegetation heavy scene with extensive terrain relief

OLI Simulation of Lake Tahoe Scene

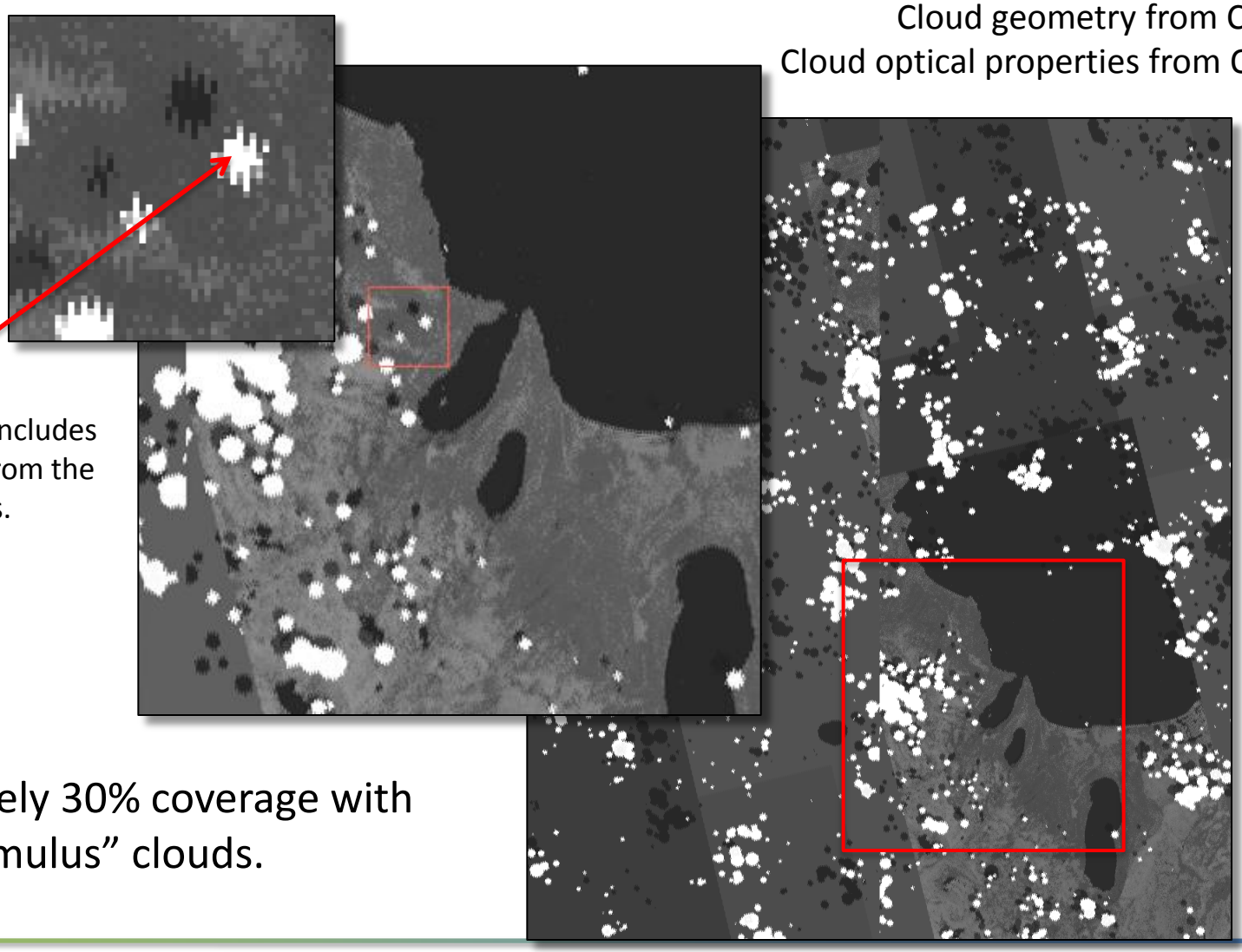
1. Even/Odd pixel offsets
2. Band offsets
3. Module offsets
4. Module overlap
5. Rotation of scene due to orbit



DIRSIG simulations of Lake Tahoe, California using OLI bands 3, 4 and 5

Simulated OLI Image with Cumulus Clouds

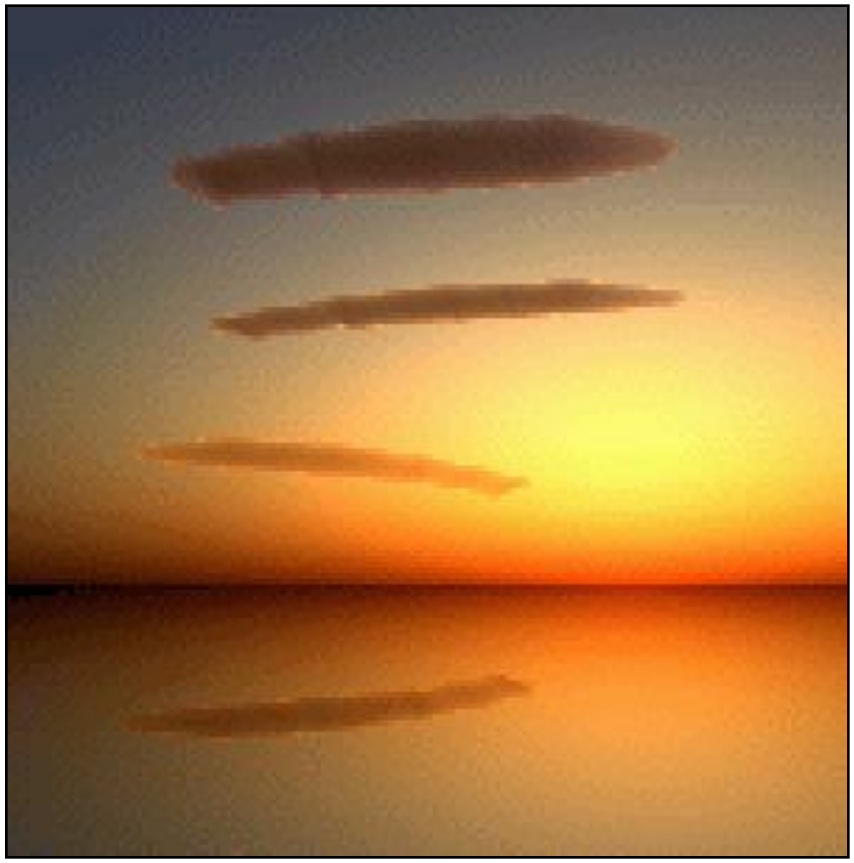
Cloud geometry from CSSM
Cloud optical properties from OPAC



Uncorrected imagery includes pixel-to-pixel offsets from the even/odd arrays.

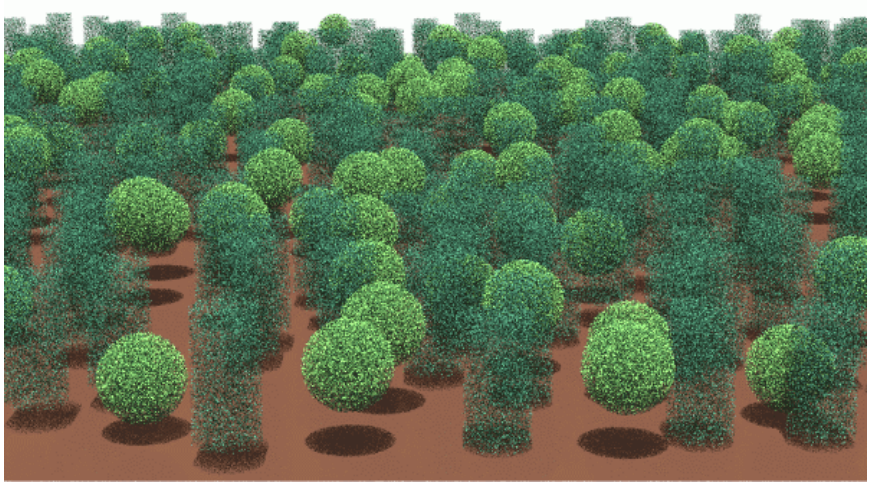
Approximately 30% coverage with "cumulus" clouds.

The Benefits of First Principles Based Modeling

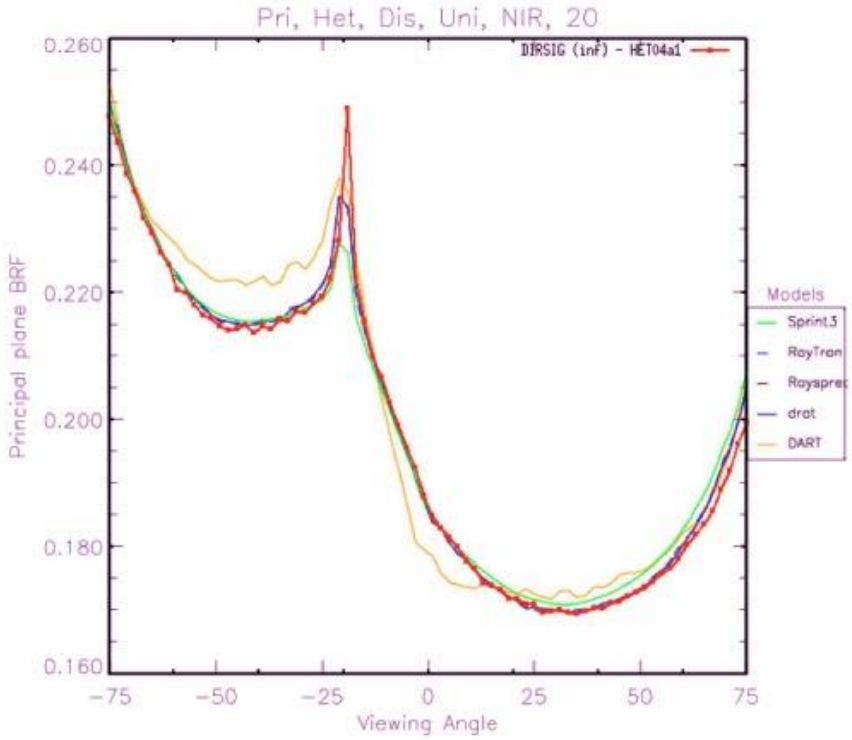


DIRSIG Ray-tracing Validation[1]

- DIRSIG radiometry solver was validated using RAdiation transfer Model Intercomparison (RAMI) III test cases
  - For both homogeneous and heterogeneous test scenes
  - In the red and NIR spectral region for both single and total scattering scenarios
- DIRSIG BRDF results are consistent with most models evaluated by RAMI studies



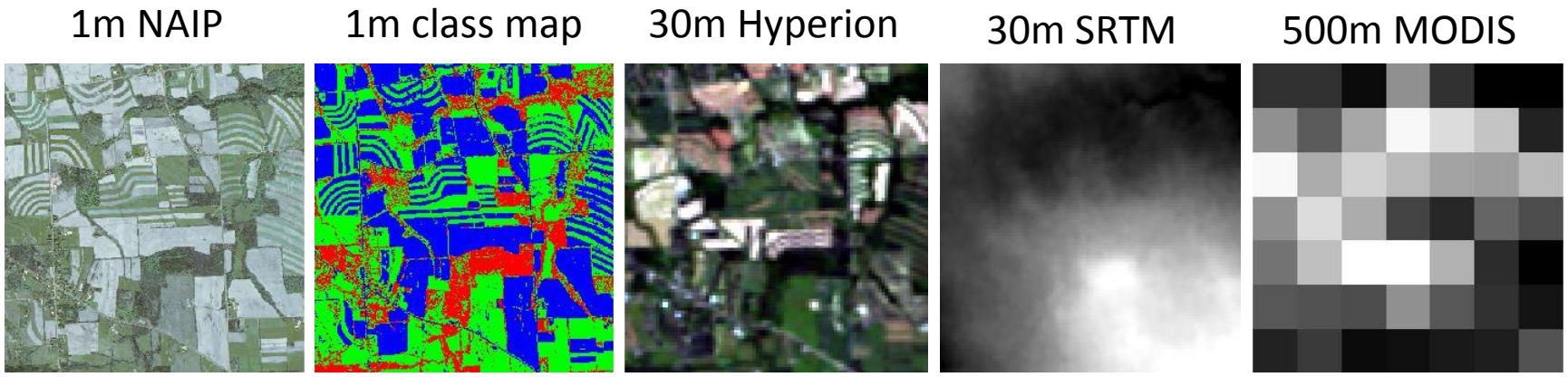
Heterogeneous experiment



[1]Goodenough, A. A. and Brown, S. D. (2015), "Development of land surface reflectance models based on multiscale simulation," Proceedings of Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XXI, SPIE volume 9472, pp. 1-8.

Scene Construction Tool Block Diagram

Objective is to create large area scenes for moderate resolution imagery

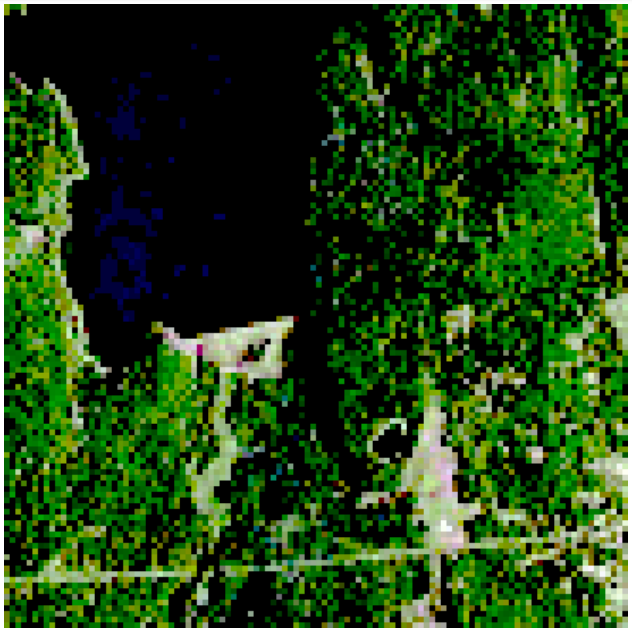


Initial Scenes

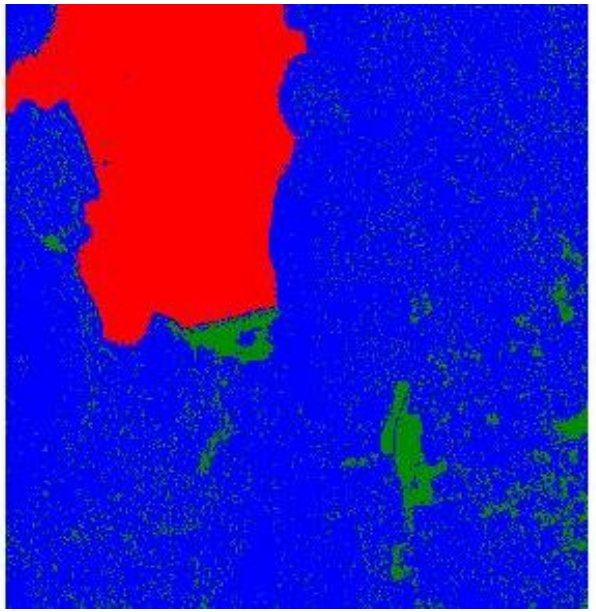
- Harvard Forest (forest)
- Bondville (cropland)
- Mount Rainier (alpine/snow)
- Virginia Coast Reserve (littoral)

Harvard Forest

- Biome: Forest
- Input data
  - Hyperion (15 July 2012)
  - NAIP CIR 1 m imagery (9 July 2012)
  - MODIS BRDF Product (13 July 2012)
- Size: 3.6 km x 3.7 km
- Spectral Coverage: 355 – 2577 nm
- Application metric
  - Classification
  - Leaf Area Index



Simulation of OLI visible (432) bands



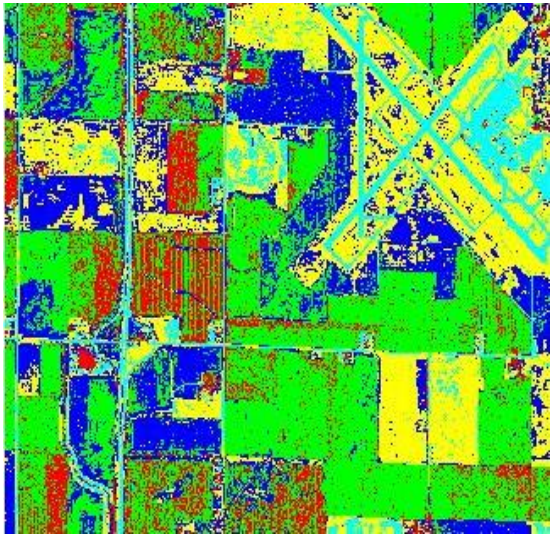
1 m Class Map
Red: water
Blue: forest
Green: soil/asphalt

Bondville

- Biome: Cropland
- Input data
  - Hyperion (27 July 2012)
  - NAIP CIR 1 m imagery (19 June 2012)
  - MODIS BRDF Product (27 July 2012)
- Size: 4.2 km x 4.2 km
- Spectral Coverage: 355 – 2577 nm
- Application metric
  - Classification
  - NDVI

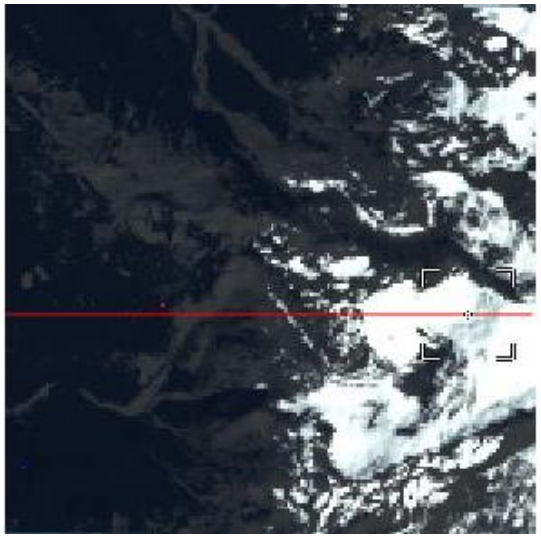
Simulation of OLI visible (432) bands

1 m Class Map
green/blue/red: different species /period crops.
yellow: soil/grass
cyan: asphalt



Mt. Rainier

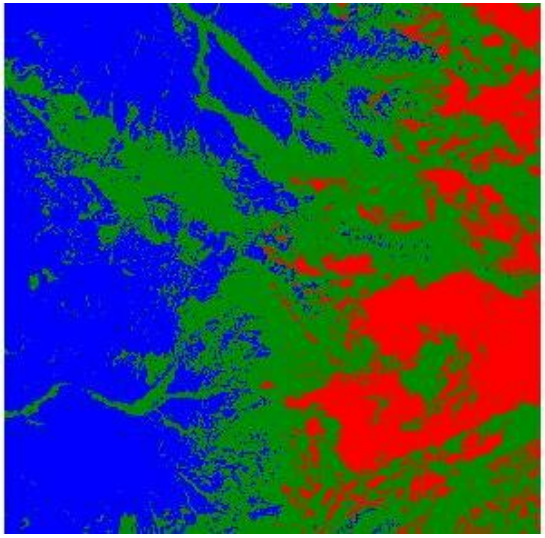
- Biome: Alpine/Snow
- Input data
  - Hyperion (8 August 2003)
  - NAIP CIR 1 m imagery (3 September 2009)
  - MODIS BRDF Product (5 August 2013)
- Size: 4.9 km x 4.8 km
- Spectral Coverage: 355 – 2577 nm
- Application metric
  - Classification
  - NDVI



Simulation of OLI visible (432) bands

1 m Class Map

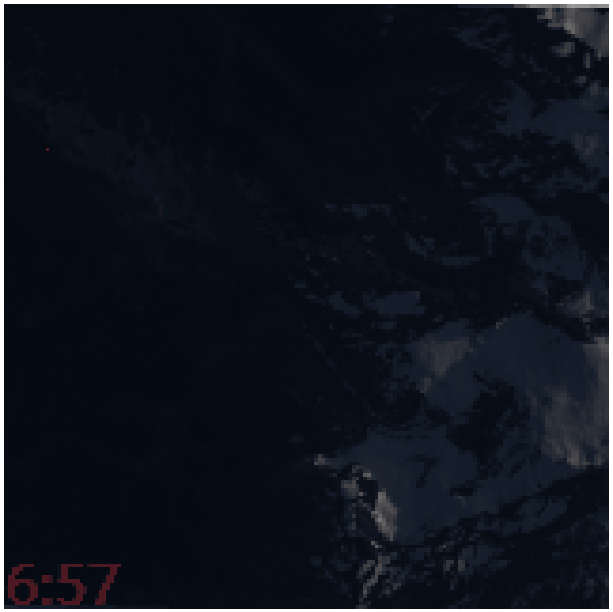
Red: snow
Green: soil
Blue: alpine forest



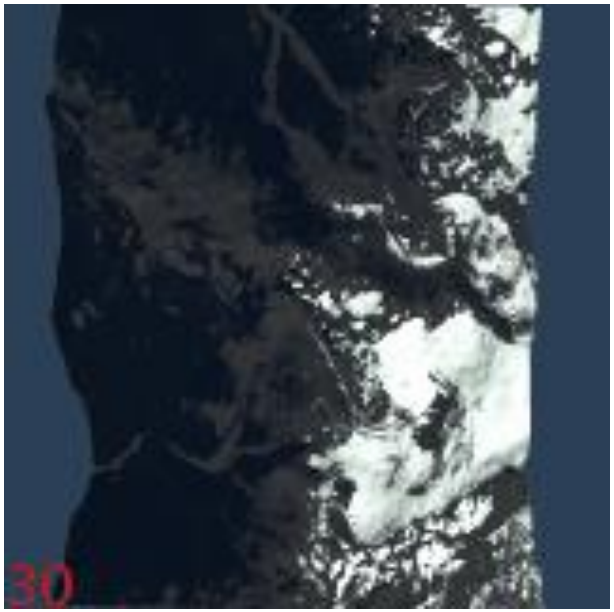
Mt. Rainier BRDF Effects

Landsat 8 OLI
local time: 11:57

DIRSIG OLI
Multiple acquisition times
6:57 to 19:57

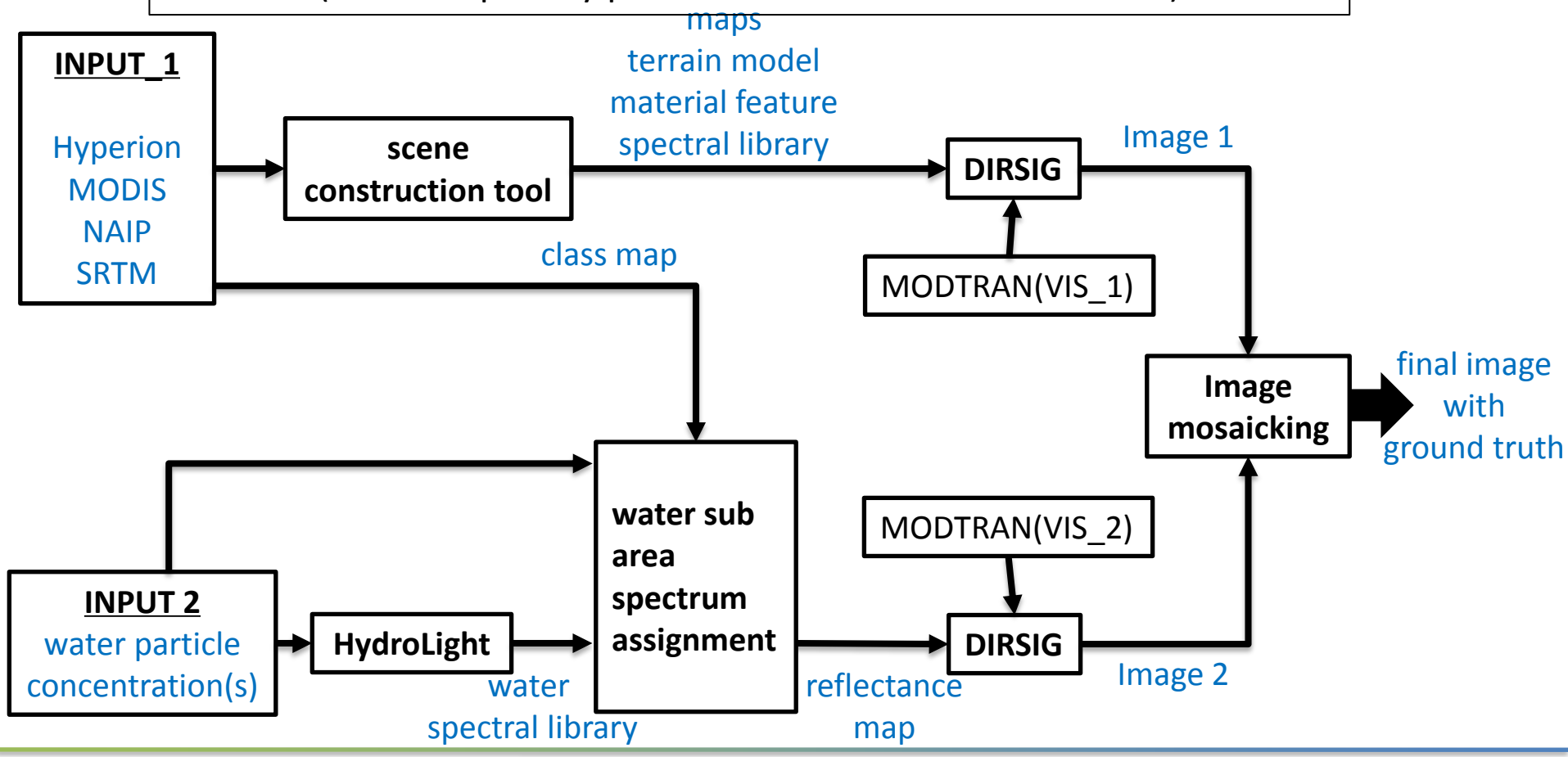


DIRSIG OLI
Multiple zenith angles
-30 to 30 degrees



Water Simulation Mosaicking Block Diagram

Hybrid simulation using HydroLight model spectra with known constituents for the water spectral library, together with other sources (similar capability possible with PROSPECT leaf model)

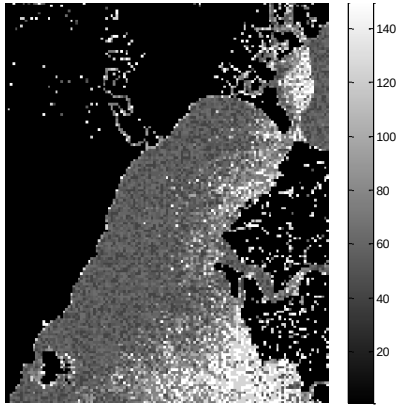


Virginia Coast Reserve

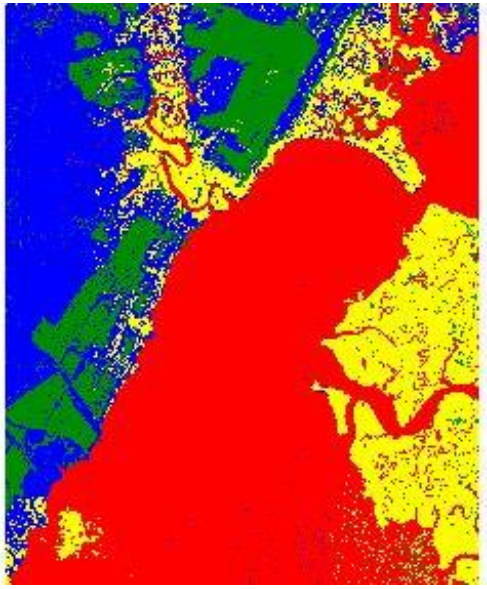
- Biome: Littoral
- Input data
  - Hyperion (22 May 2015)
  - NAIP CIR 1 m imagery (12 May 2012)
  - MODIS BRDF Product (17 May 2015)
  - HydroLight water spectra
- Size: 3.9 km x 4.8 km
- Spectral Coverage: 400 – 900 nm (limited by HydroLight)
- Application metric
  - Water Properties
  - Classification

Simulation of OLI visible (432) bands

Chlorophyll Concentration Map



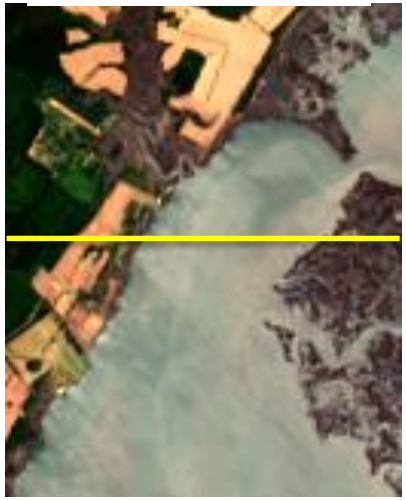
1 m Class Map



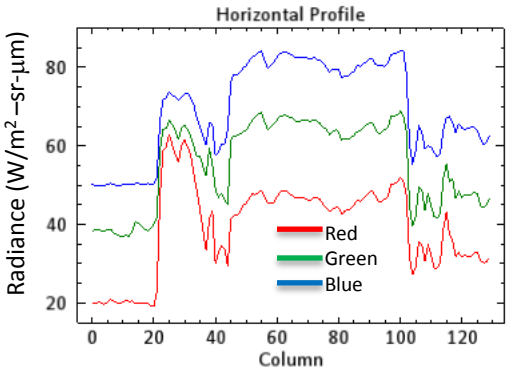
Landsat OLI – DIRSIG OLI VCR Comparison

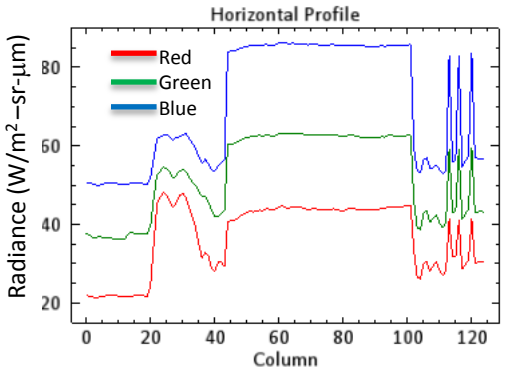
- Landsat 8 OLI acquired same date as Hyperion (22 May 2015)
- Hyperion spectra used for both land and water areas
- Acquisition time matched
- Found best match using different atmospheric visibilities for land and water
  - Land: 23 km vis
  - Water: 5 km vis
- Simulation compares well

Landsat 8 OLI



DIRSIG OLI





Summary and Future Work

- Physics-based scene simulation powerful tool for system studies
  - Explore impact on imagery and resulting products of requirements or design changes
  - Provide data with known truth for algorithm development and testing
  - Provide realistic imagery for testing of processing work-flow
- RIT's DIRSIG creates scenes from empirical data sources
  - Reflectance spectra from Hyperion, models, spectral libraries, etc.
  - Class maps derived from high resolution imagery
  - BRDF coefficients from MODIS or other sources
- Initial scenes created and OLI renderings produced
  - Four biomes: forest, cropland, alpine/snow, and littoral
  - Data contain realistic variation and known ground truth
- Invite further discussions and collaborations on use of data for instrument trade studies with product performance as metrics