Investigation of Atmospheric Attenuation and Influences for Interpreting MSI Imagery Using Sentinel-2

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GEOG 596A
30 April 2018

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Agenda

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- Project Description
- Introduction to electromagnetism
- Overview of Sentinel-2
- Sen2Cor Algorithm Description
- Data Sources
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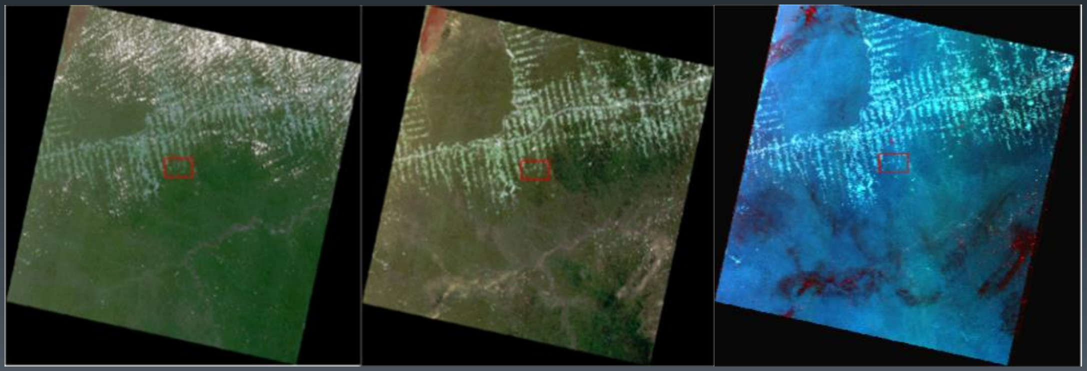
- Conference Venue

Project Background

- Penn State GEOG 883 – Remote Sensing with Object Based Image Analysis
- Detecting deforestation in the Amazon using spectral indices
- Problem: Imagery not atmospherically corrected - using the same spectral indices for different images resulted in different classifications
- Happens for all electro-optical imagery – some bands are effected more than others



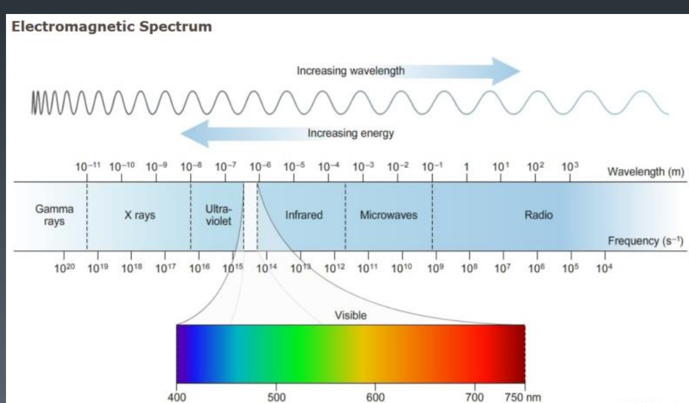
July 2014 July 2015 July 2015

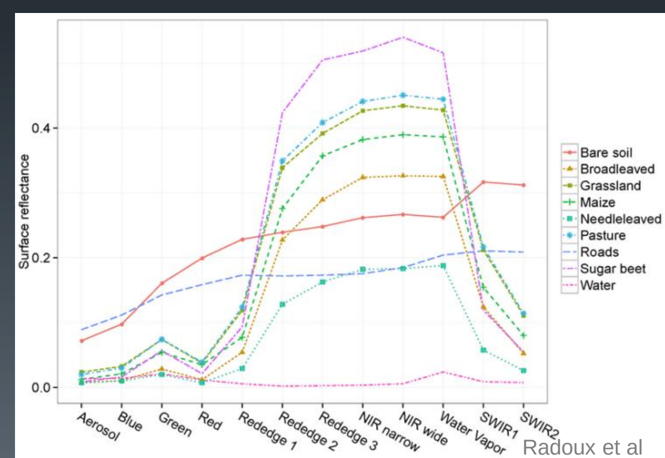
Project Description

- Goal: investigate how the atmosphere impacts remotely sensed imagery and impacts for interpretation
  - Manual interpretation – signature analysis of
    - Crops health/agriculture
    - Atmospheric pollutants
  - Automated image analysis – change detection
    - Inaccurate atmospheric compensation may “fool” algorithms
- Palm Springs, CA; 3 types of land cover
  - Water/Urban/Desert
- Two Image Products: Top of Atmosphere (TOA) and Bottom of Atmosphere (BOA)
- Near Infrared (NIR) / Blue – quantifies attenuation (signal degradation)
- Time Series Analysis
  - Opportunity to find indicators for images which should filtered from consideration due to poor atmospherics or seasonality
- Expected Result – Seasonality/Water Vapor/Pollutants will be found in time series analysis

Introduction to EM Spectrum

- Humans see in only a very small portion of the spectrum
  - Generally like to view imagery that is similar to how we visually perceive the world
  - To get many different colors, we combine separate images of different colors, called “bands” in Multi-Spectral (MSI) imagery
- Energy (light) is reflected, absorbed, scattered off of different materials
- Energy (light) carries information about the material that it is reflected from
  - Water vapor and other aerosols in the atmosphere act as a lens and cause changes to reflected light
  - Leads to false interpretations of what materials are
- Math and physics based models can be used to correct for some changes to the energy

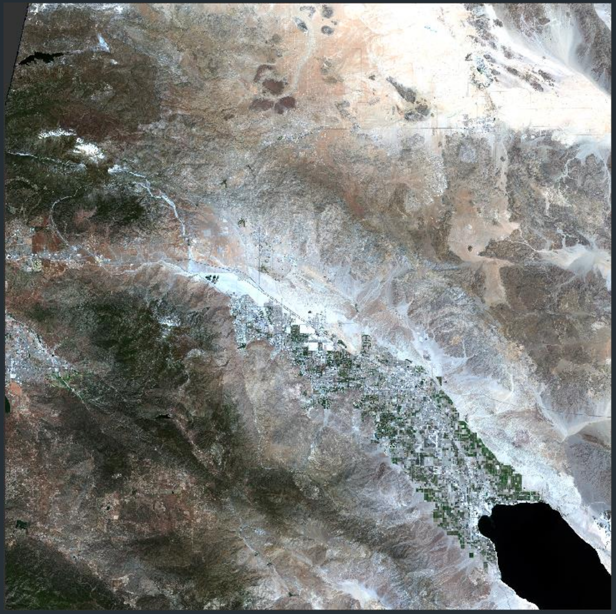


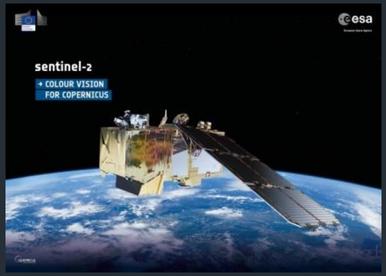


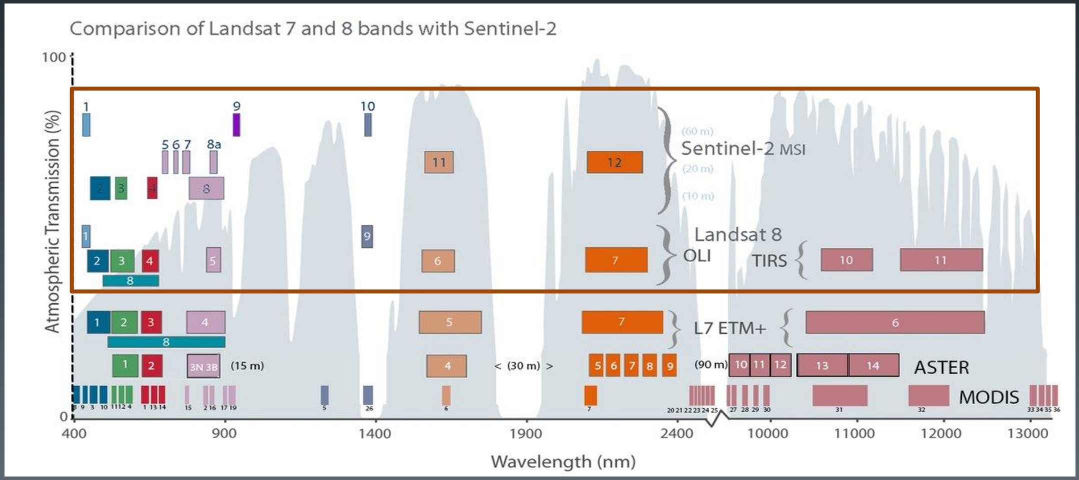
Radoux et al

Sentinel – 2A Overview

- Sentinel – 2 is a constellation of two satellites: 2A and 2B
- Revisit 5 days using both
- Revisit 10 days using just one
  - My project only uses 2A imagery
- 13 Spectral Bands
  - 10-meter
  - 20-meter
  - 60-meter
- Tile size: 10,000km^2
- Processing Levels – ESA
  - 1A – Raw data (Radiance)
  - 1B – Geometrically corrected Radiance
  - 1C – TOA Reflectance
- Processing – User
  - 2A – BOA





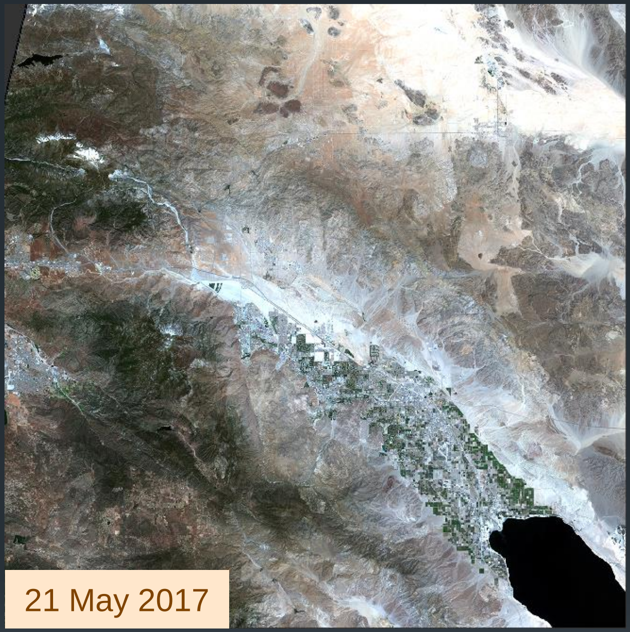


Atmospheric Correction Algorithms

- Sen2Cor – part of the Sentinel-2 Toolbox – LIBRADTRAN
  - Input: 1C TOA
  - Output: 2A BOA
- Bands are sub-sampled to 10m
- LIBRADTRAN is run, generating a Look Up Table (LUT) accounting for atmospheric conditions
  - Path radiance, transmittances, solar flux, spherical albedo
  - Elevations and solar geometries
    - Mid-Latitude Summer
- Aerosol Optical Thickness Derivation
  - Dark Dense Vegetation (DDV)
- Water Vapor identification - band ratio 8a and 9.
  - Cirrus cloud detection
- Caveat: Sen2Cor assumes Lambertian surfaces for all parts of the scene– that they are equal reflectors

Data Sources: Sentinel 2A

1C – Top of Atmosphere



2A – Bottom of Atmosphere

Image Dates:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	20	2	1	1	1	10	19	9	8	7	7
11		12	11	11	20	20	29	18	18	17	17
31		22	21	21		30			28	27	

Methodology

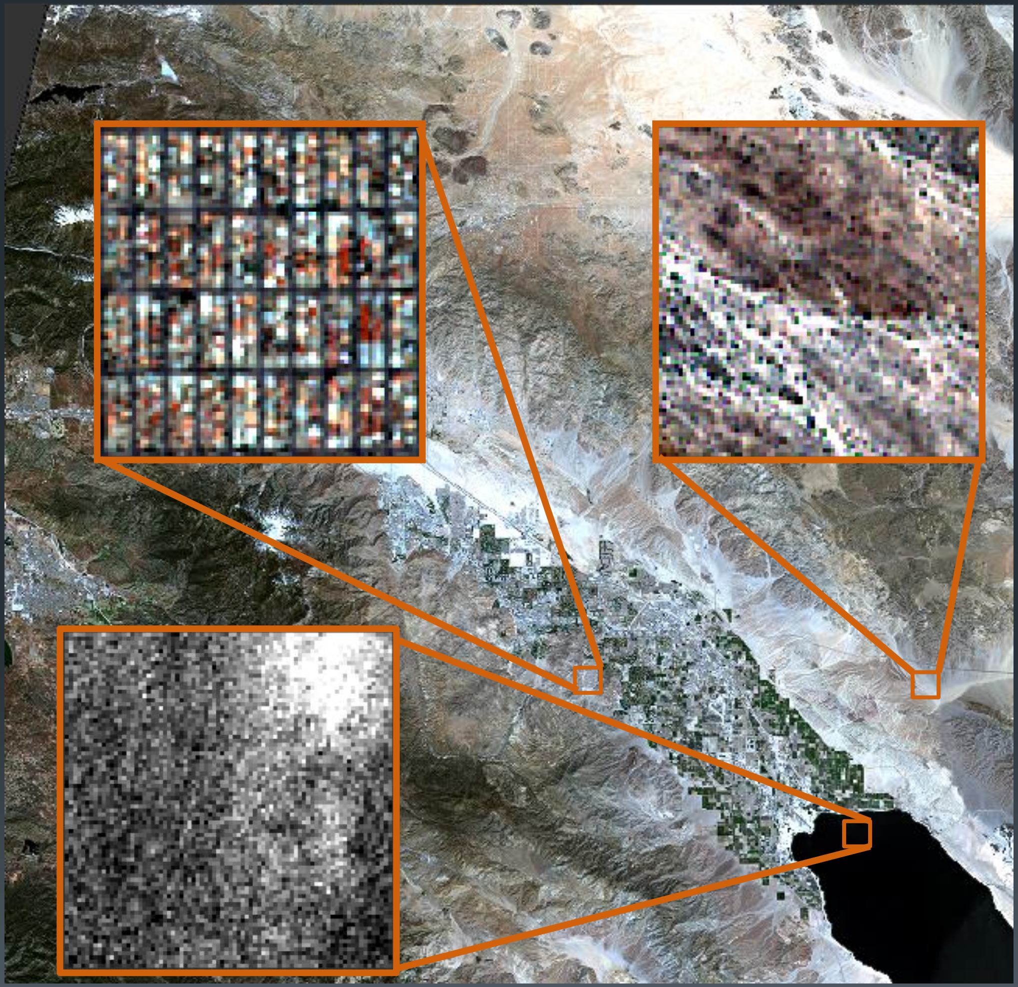
- Derive 2A BOA imagery products – Sen2Cor
- Use band ratios on 1C, 2A images

$$\frac{Near\ Infrared\ (B8)}{Blue\ (B2)}$$

- Resulting product pixels show the rate of atmospheric attenuation – specifically how much energy is being imaged to that which is being scattered by the atmosphere.
- Chip 3 sections for land covers
  - Desert
  - Urban
  - Water
- Gather statistics for each image chip – focusing on mean
- Plot in a time-series analysis
- Interpret the results

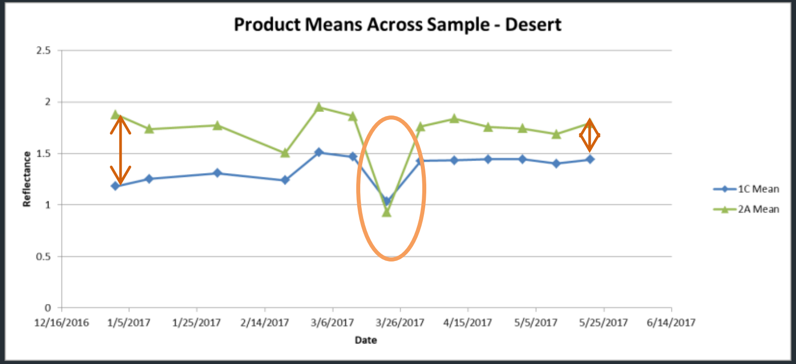
Controls

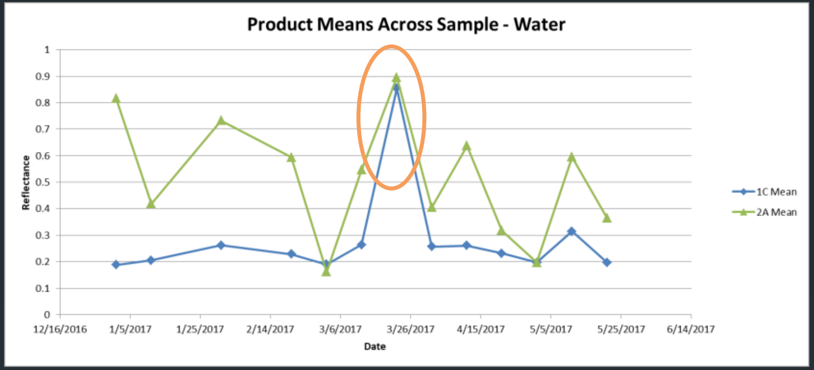
- Three different land covers show how the Sen2Cor algorithm handles different reflectances
  - Desert
  - Urban
  - Water
- Consistent sample sizes – each chip was 79x81 pixels
- Limited to bands of same resolution – 10 meters
- Use only of Sentinel 2A

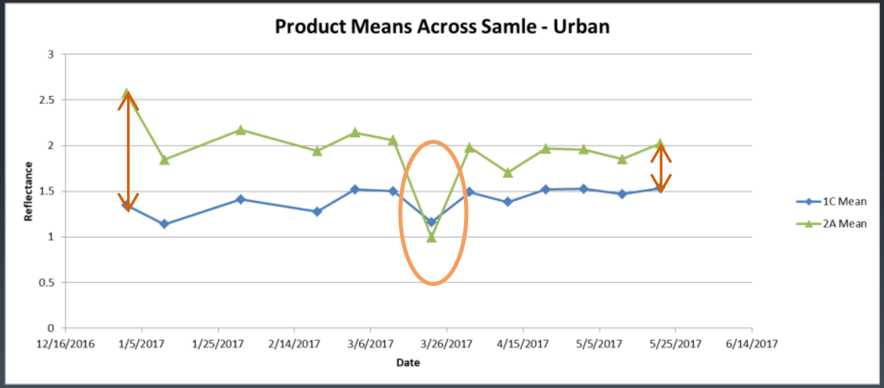


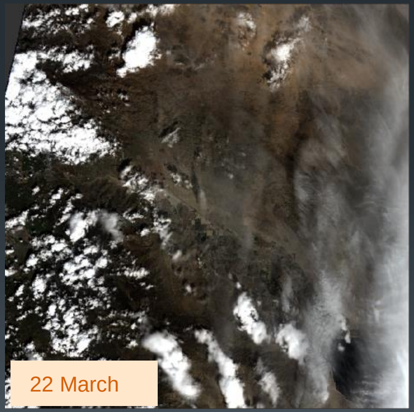
21 April 2017

Preliminary Results









Only 50% of the images have been processed and examined. The rest will be processed over the next month.

Implications for Interpretation

- Sen2Cor algorithm – overall good model
  - Clouds and heavy aerosols cause problems
- BOA Water is most difficult to model
  - Waves/Wind on moving surface
  - Salt/Dirt/etc. content within the water
- Urban second most difficult to model
  - Some seasonality
    - 1C and 2A grow together during summer – less correction needed
  - Pollutants are probably heavier
  - Cars may be moving in-scene, contributing to reflectance changes
- Desert is most consistent and easiest to model
  - Less water vapor
  - Less pollutants

Implications for Algorithms

- Images are typically a means of answering a question
  - How healthy are crops?
  - What areas have resources to sustain development?
  - How did an area change over time?
- Research is being done to automate signature interpretation

- My preliminary research indicates that algorithms may be developed to discover several things about imagery based on atmospheric attenuation
  - Where there is water in-scene – instability of signatures
  - Cloudy imagery
    - 1C and 2A products have equivalent values
  - Stable periods with consistent differences between 1C and 2A will reveal images which are suitable for signature analysis, within images and across multiple images

Conference Venue

- Committee for Space and Atmospheric Research (COSPAR) July 2018 – Pasadena, California
- Scientific Event A: *Space Studies of the Earth's Surface, Meteorology and Climate*
- Specific Sub – Event: A1.1 *Space-based and Sub-orbital Observations of Atmospheric Physics and Chemistry*

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Backup

- Other Correction Tools/Options (not included in this study)
  - FLAASH – Fast Line of Sight Atmospheric Analysis of Spectral Hypercubes
    - Physics based model – requires manual inputs
  - QUAC – QUick Atmospheric Correction
    - Empirically derived atmospheric correction