TOWARDS DETECTING ALGAE USING SATELLITE-BASED REMOTE SENSING AT LAKE MEAD

April, 2001 – Narrows near Callville Bay

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Introduction

- Lake Mead and Mohave provide drinking water for 25 million people and water for 3.2 million acres of agricultural land
- Water quality is becoming more of a concern as water levels fluctuate due to more variable inflows and increased demand
- Lower water levels is that changes in water chemistry appear to increase the potential for algal blooms, including those of toxic microcystis varieties

Introduction

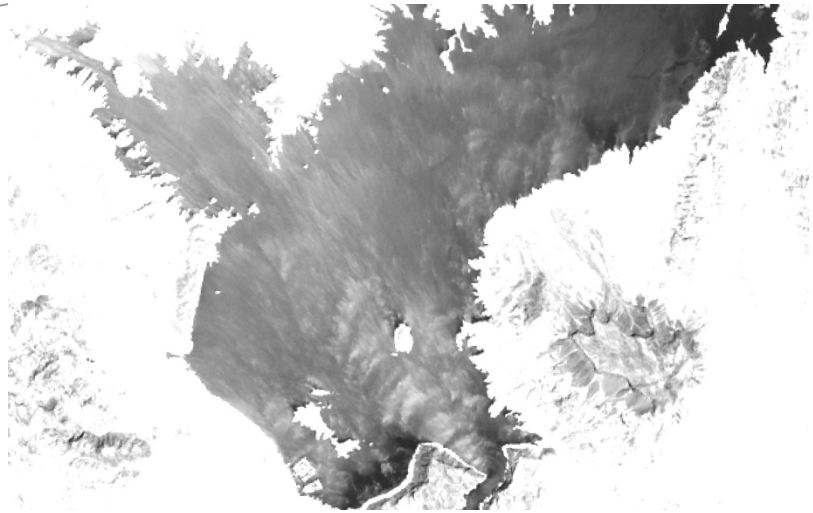
- Currently, algae are monitored with periodic samples taken at specific locations in Lake Mead, and algal biomass is estimated for each sample with laboratory measurements of chlorophyll-a, the photosynthetic pigment in algae
- More frequent and comprehensive sampling is not possible with current funding and staffing
- However, MODIS and Landsat multi-spectral satellite imagery is collected across the park every 1 to 16 days, and available for free
- Previous studies have demonstrated the feasibility of estimating chlorophyll-a concentration in lakes from multi-spectral satellite imagery

Goal – Two Parts

- Develop an empirical approach for estimating chlorophyll-a by relating Landsat and MODIS spectral data to field measurements of chlorophyll-a and other water quality variables (i.e. Total Suspended Sediment and Secchi Disk)

- Develop a monitoring tool that allows stakeholders to rapidly and easily visualize satellite imagery so that water quality variables (chlorophyll-a and others) can be easily monitored in near real-time

Landsat 8 Blue Reflectance - May 5, 2015

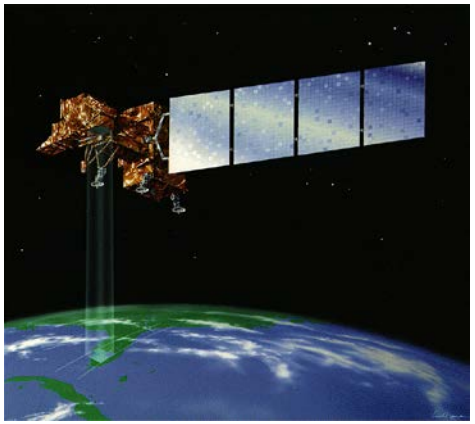


Status and Benefits

- The project started in Fall of 2014
  - We have developed pre-processing algorithms for Landsat and MODIS to estimate at-surface reflectance and extract data at field sampling locations for the entire remote sensing archives
  - We have developed a beta cloud computing tool that access and processes Landsat and MODIS imagery for Lake Mead and Lake Mojave, and is free to the public
  - We are currently analyzing field data and relating the field data to Landsat and MODIS remote sensing products

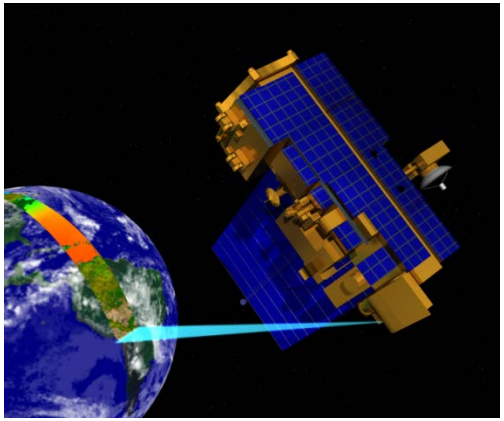
- Products of this study will benefit the National Park Service, other stakeholders, and the public by complementing field sampling and enhancing water quality monitoring in the park, providing more timely information, and allowing managers to better respond to water quality issues

Key Satellite Information



Landsat 5,7,8 – 1985 to pres.

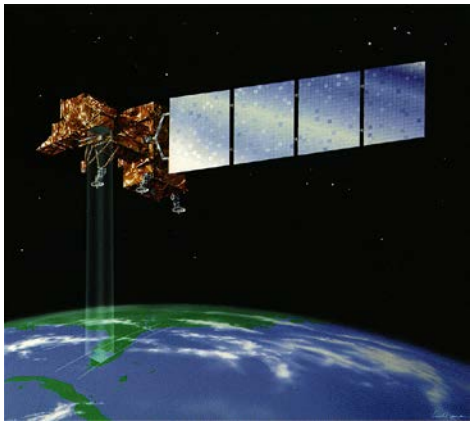
- 30 meter resolution
- Polar Orbiting
- Repeat coverage every 16 days



MODIS Aqua and Terra – 2001 to pres.

- 500 meter resolution
- Polar Orbiting
- Repeat coverage every day – but at high view angle – every 4 days near nadir

Landsat and MODIS



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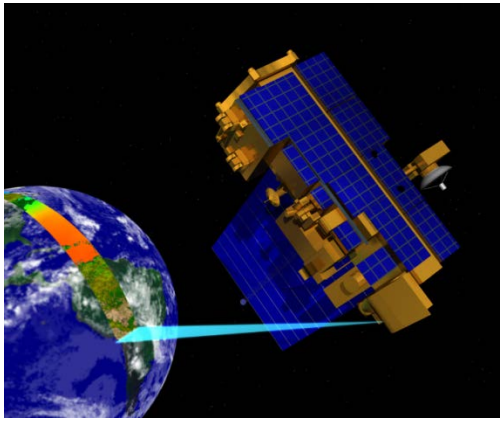
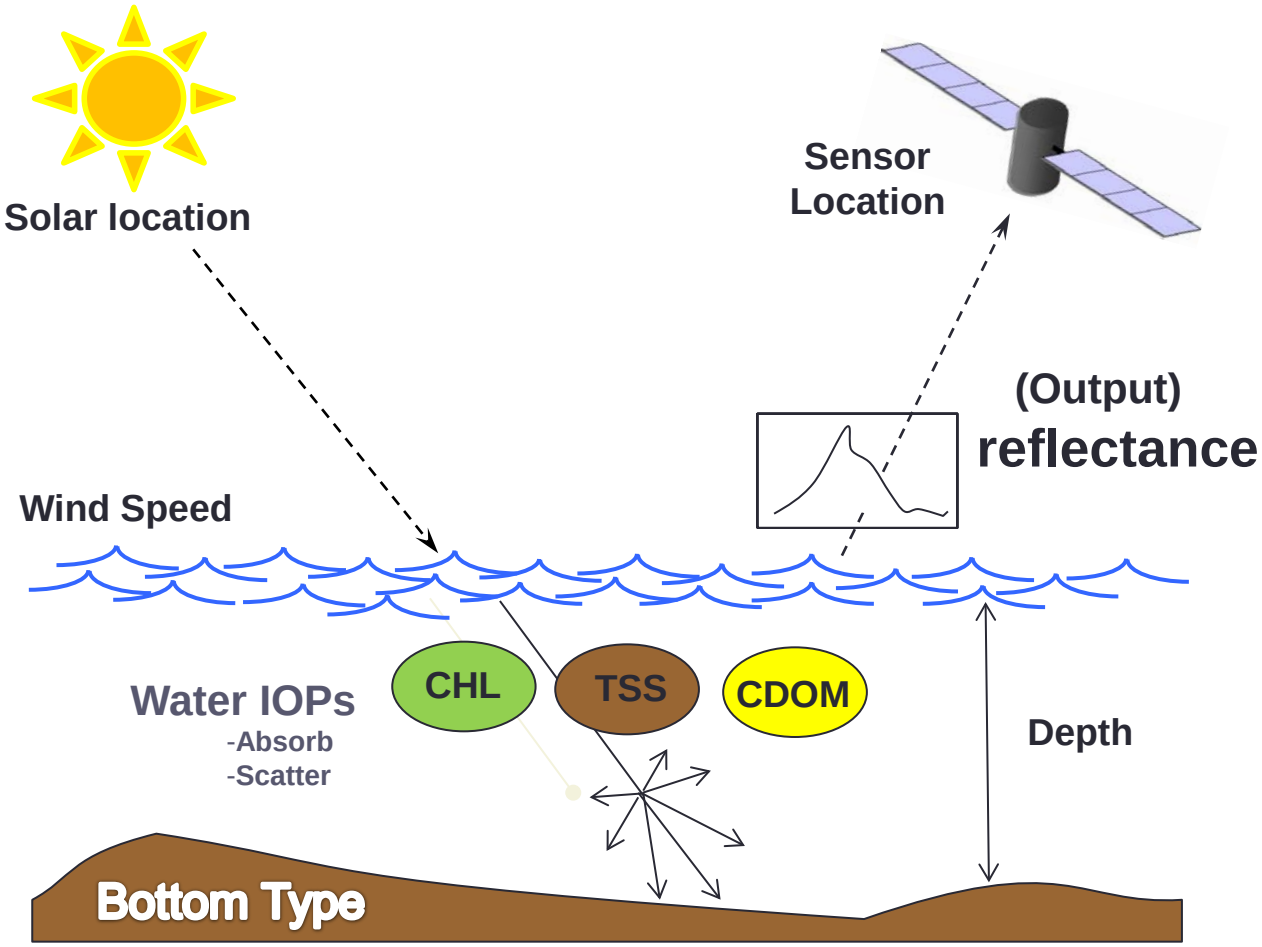


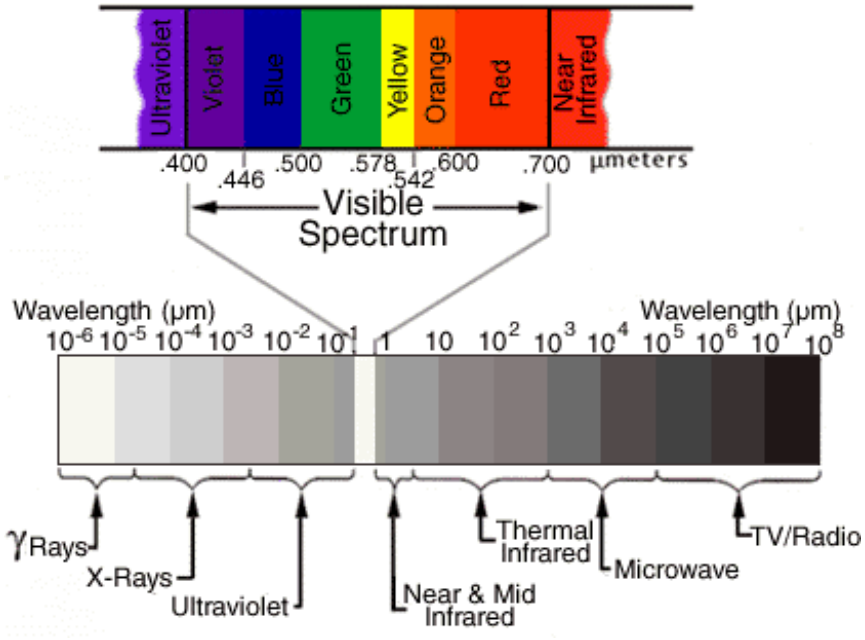
MODIS Aqua and Terra – 2001 to pres.

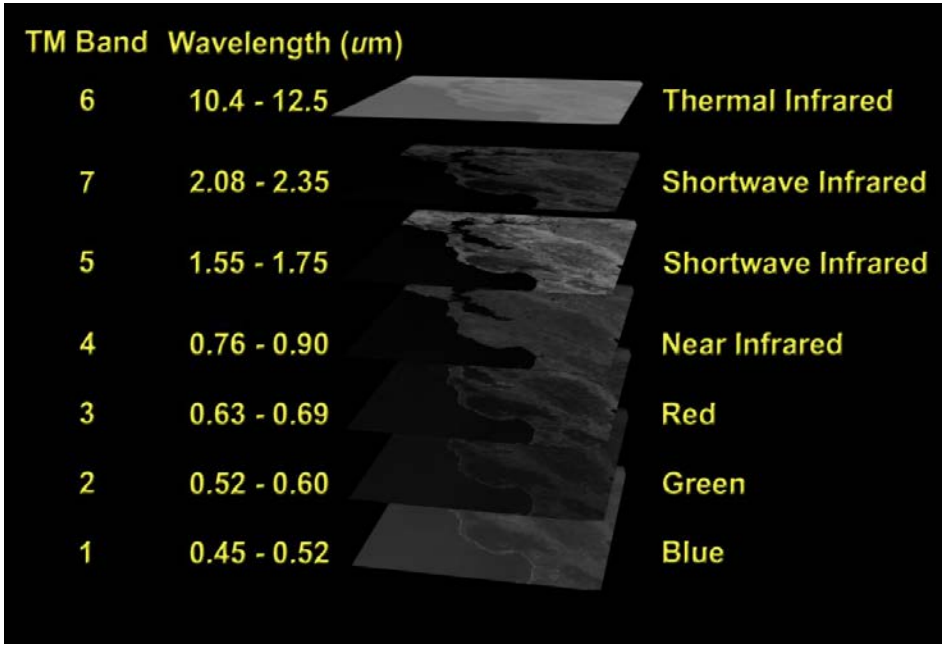
- Landsat and MODIS data are mostly used for vegetation and water resource monitoring, but many groups use these data for ocean water quality monitoring. Few groups use these data for in-land lake monitoring due to the many challenges.. (will discuss later..)

Conceptual Diagram

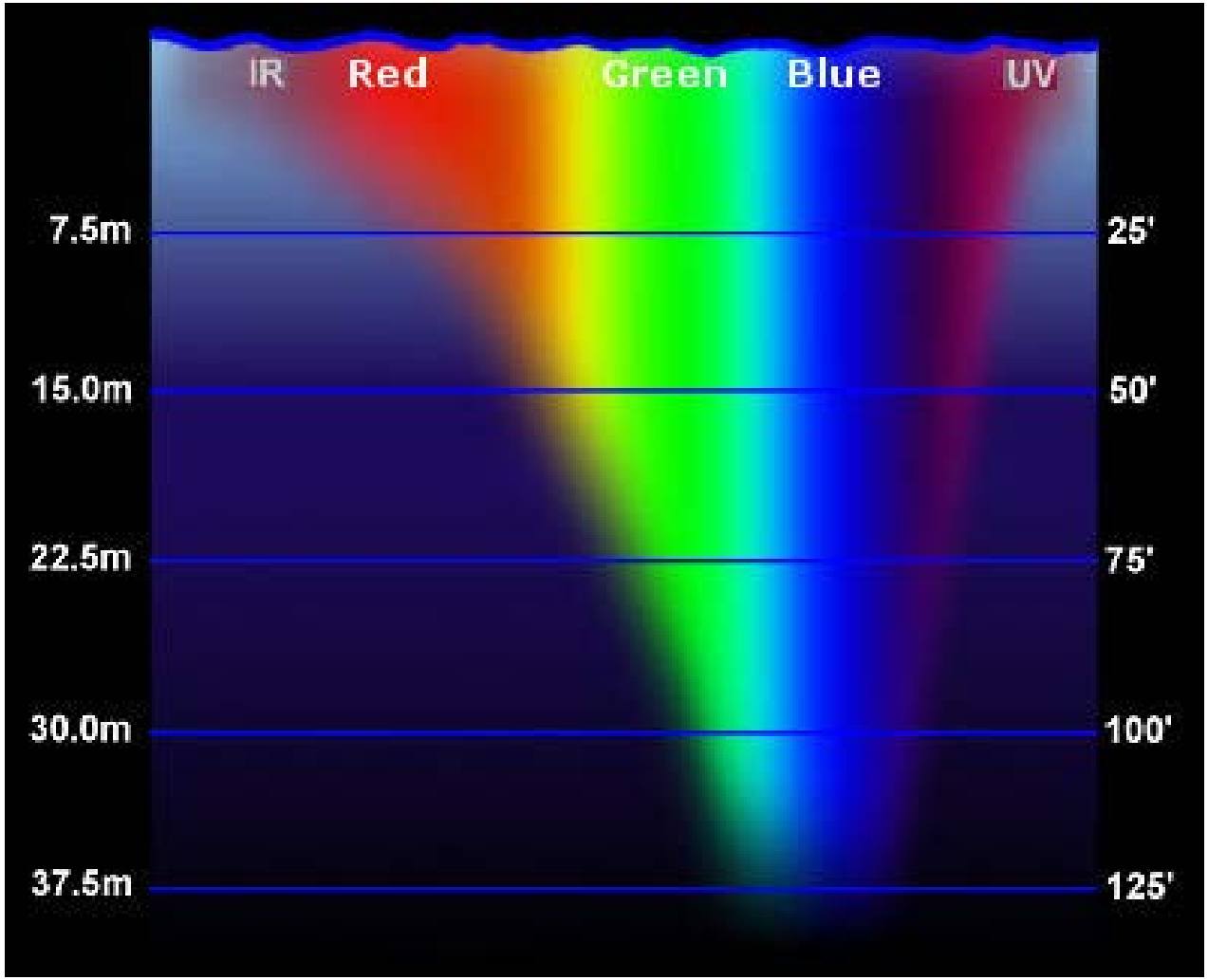


Landsat Bands (MODIS is similar)





Light attenuation with water depth

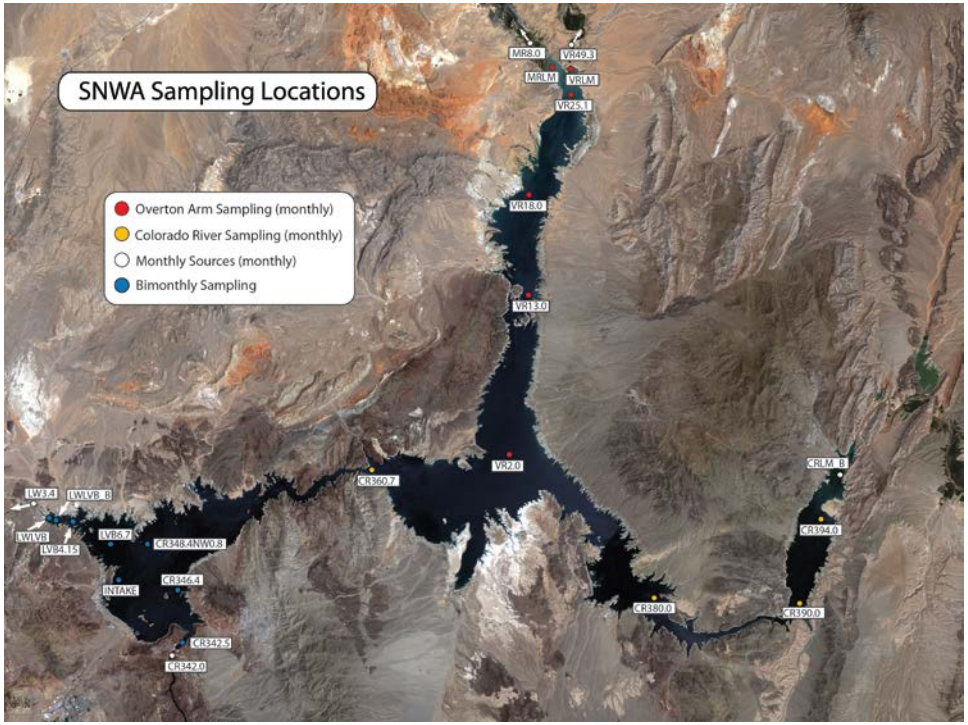


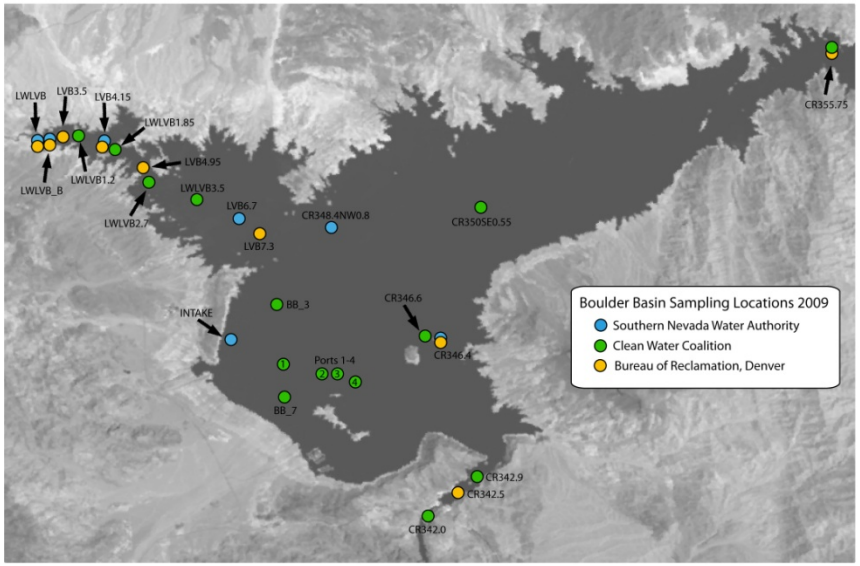
Landsat Data Processing

- Landsat bands are grids of digital numbers from 1 – 255
- Need to convert digital numbers into Top-Of-Atmosphere and At-Surface Reflectance
- For each image the following must be considered
  - Solar elevation
  - Earth-Sun distance
  - Compute the radiance measured at the satellite
  - Compute TOA reflectance
  - Compute at-Surface reflectance through *ATM corrections*

Landsat Data Analyses So Far

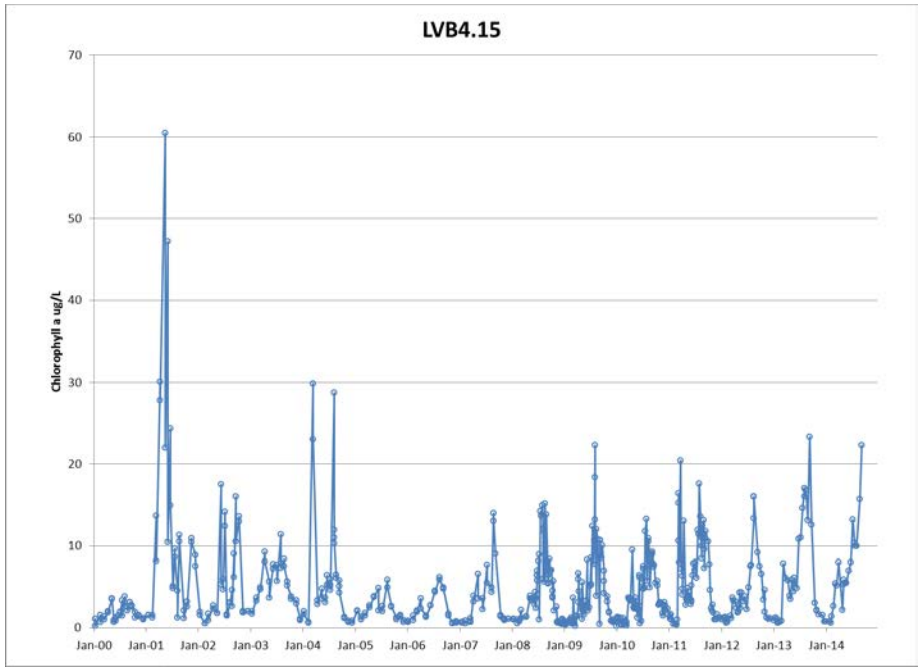
- ~90 m radius buffer at each WQ site – ***93*** in total
- Eliminated dates with cloud cover
- Determined mean TOA and At-Surface reflectance for Bands 1 – 8 and computed many different WQ indices using band ratios
- Filtered Landsat 5,7,8 and MODIS images for least amount of time between WQ data and image acquisition
  - Limited lag times range from 0 to 5 days

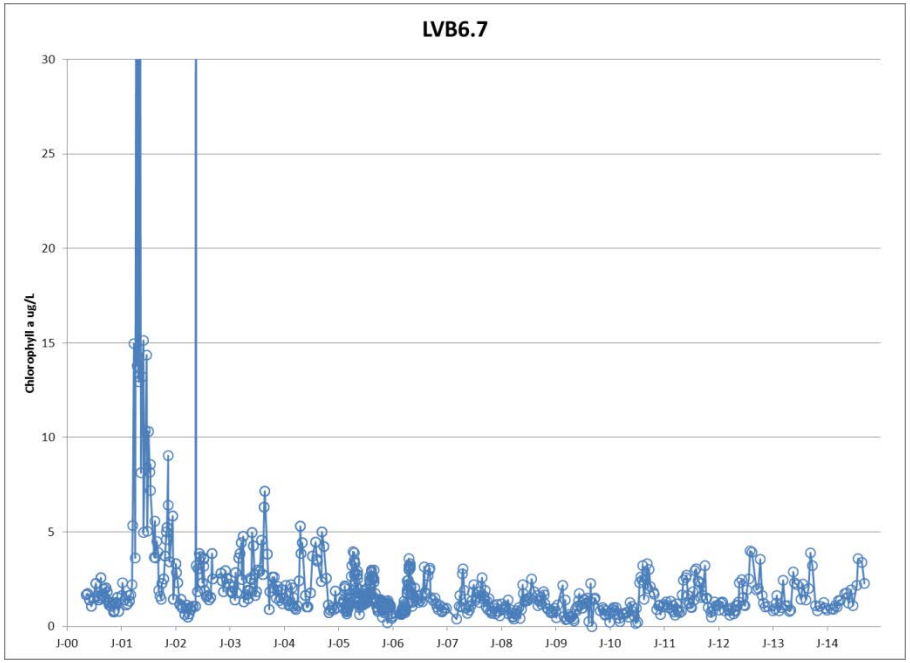




Time Series Data Examples

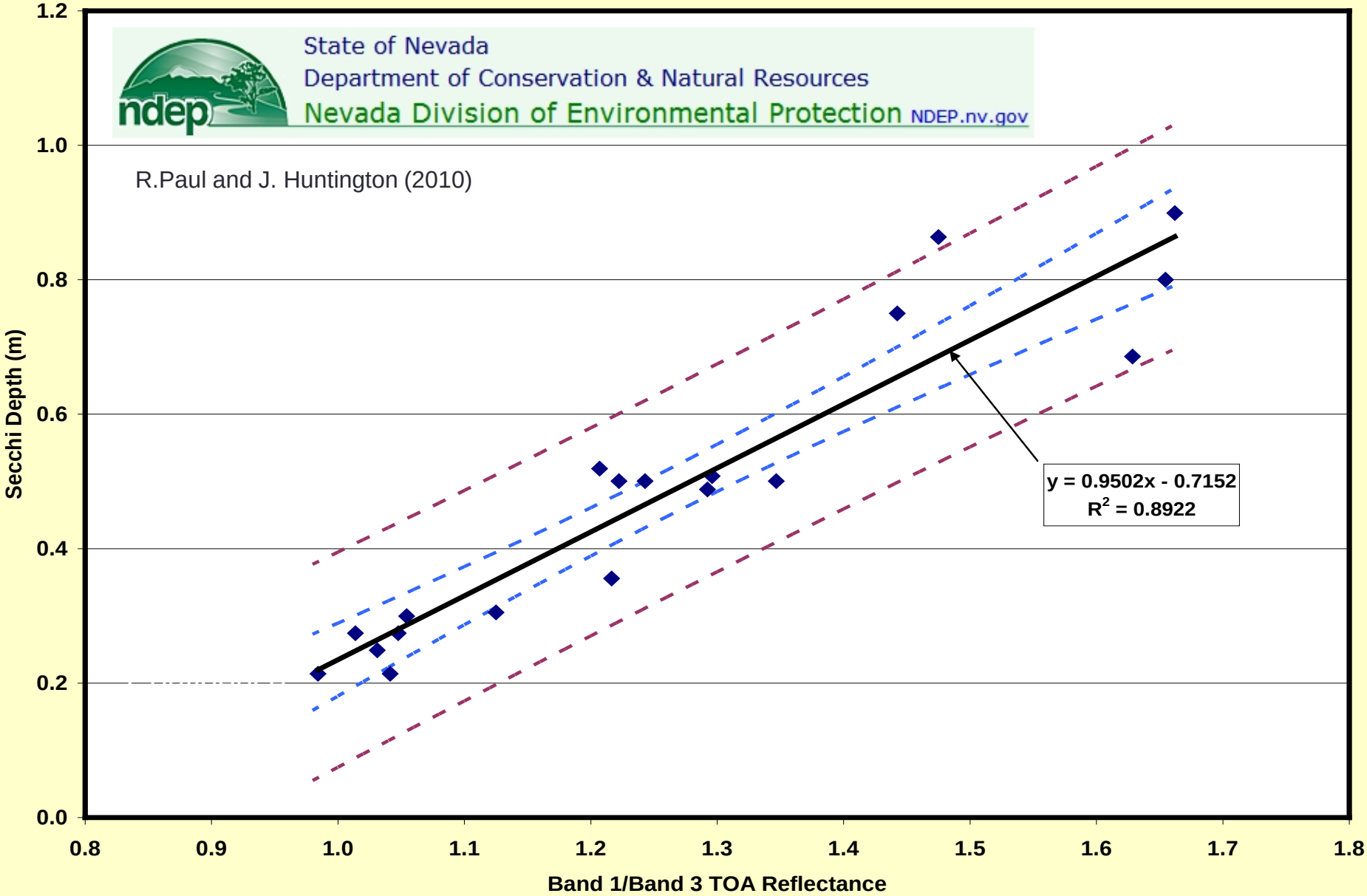
- Most Chl data are well below 20 μg/l, which makes it difficult to correlate with Landsat and MODIS reflectance..





- We are in the process of making correlations now that we have all the Landsat and MODIS data processed.. stay tuned..

Rye Patch - Band 1/Band 3 v. Secchi Depth



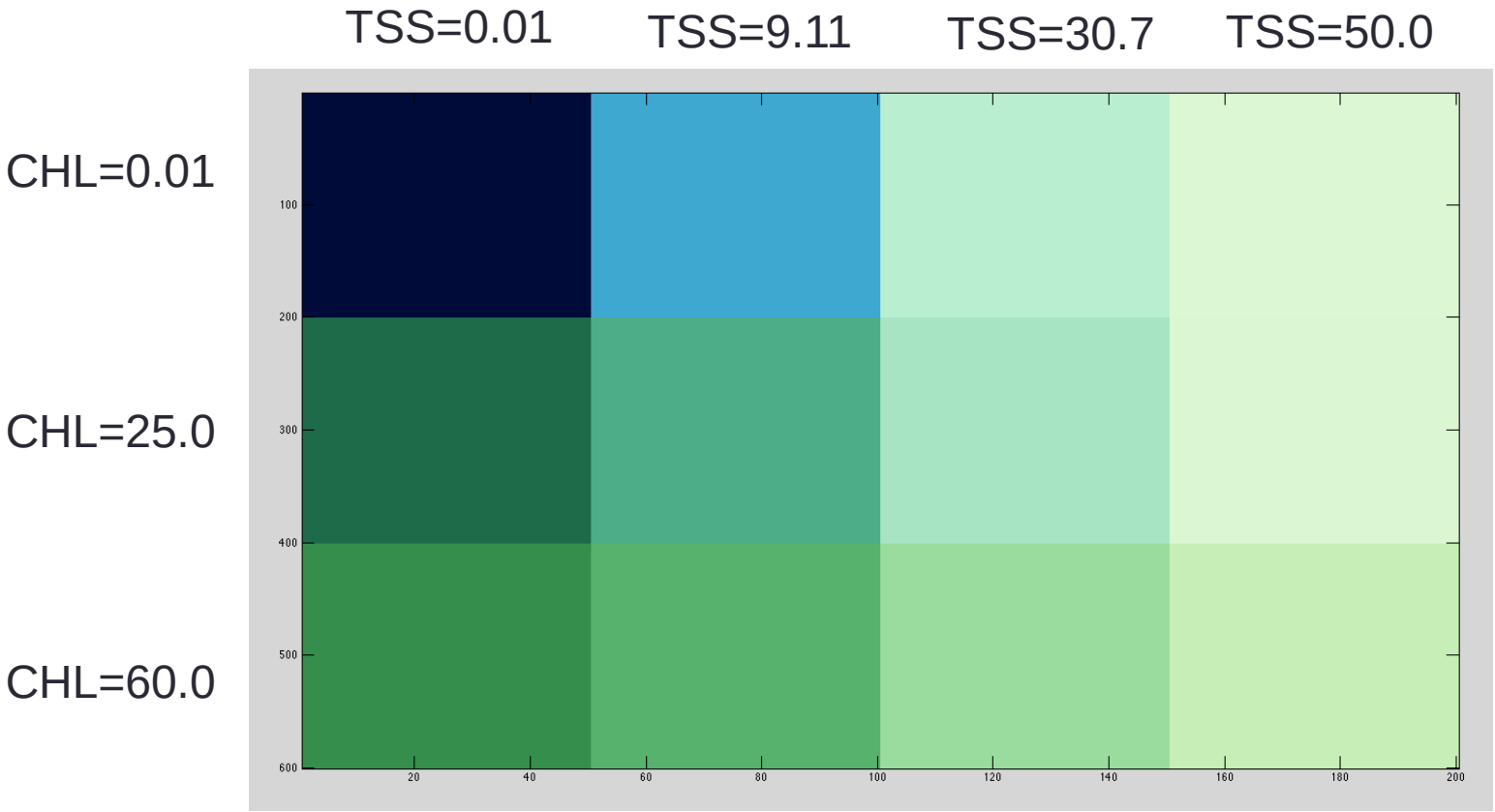
Challenges

- Remote sensing of water quality in relatively clear water is extremely difficult due to
  - Very low reflectance in all bands (this is why water is dark looking)
  - Atmospheric correction can be greater than the signal (i.e. noise greater than signal)
  - Sun glint impacts reflectance from water
  - Depth of sampling vs. light attenuation with depth
  - A non-unique problem (i.e. combination of different constituents can give the same result / colors)

- Evaluating relative spatial and temporal differences in a qualitative way, is still very useful..

Non-uniqueness challenges

CDOM fixed = 0.0954 1/m



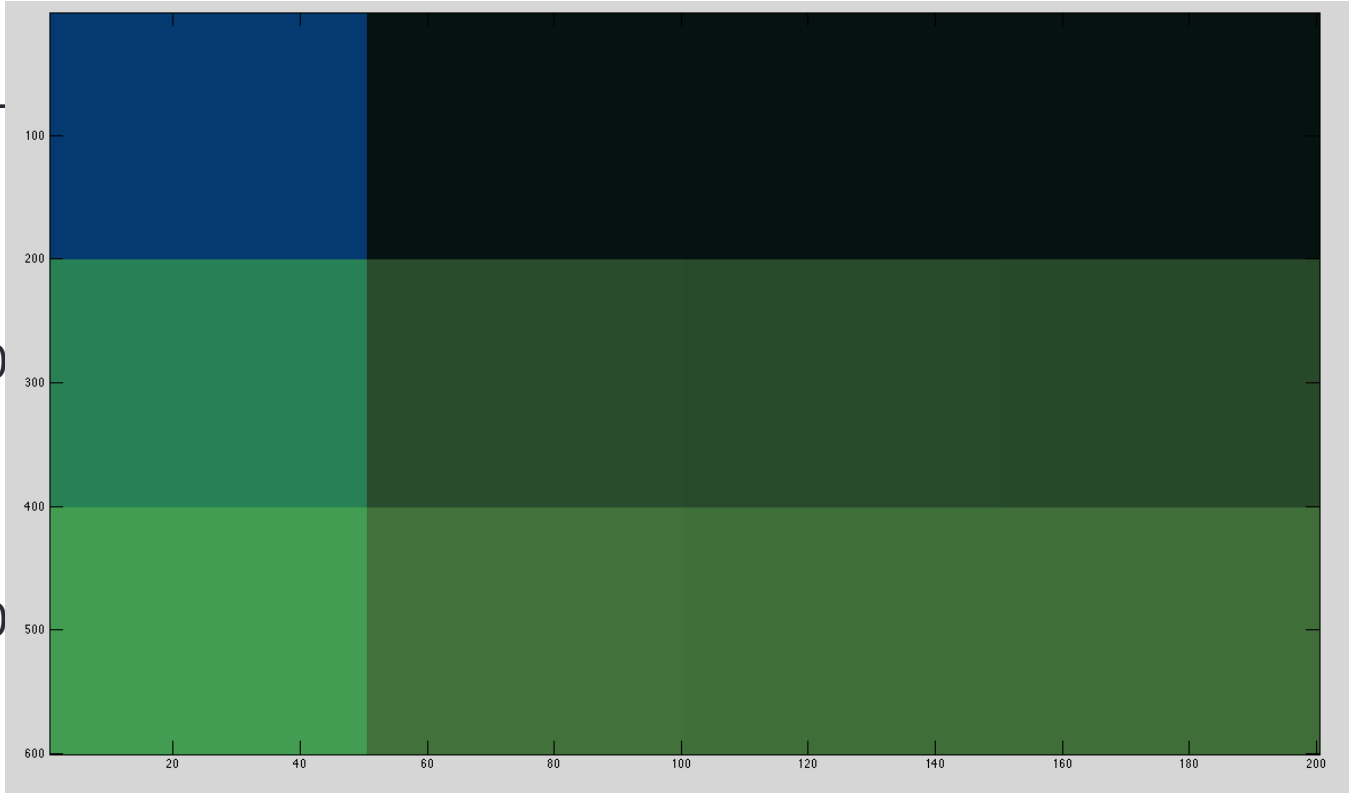
TSS fixed = 1.4 g/m^3

CDOM=0.0954 CDOM=0.9297 CDOM=1.0025 CDOM=1.0194

CHL=0.01

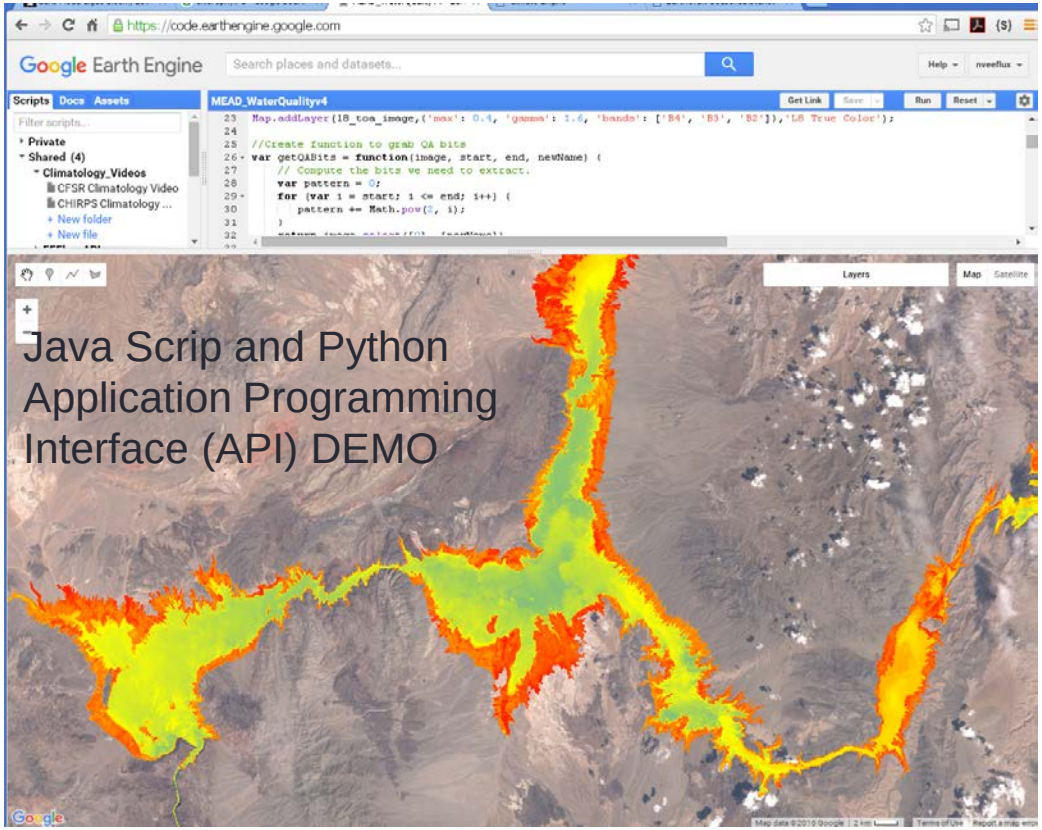
CHL=25.0

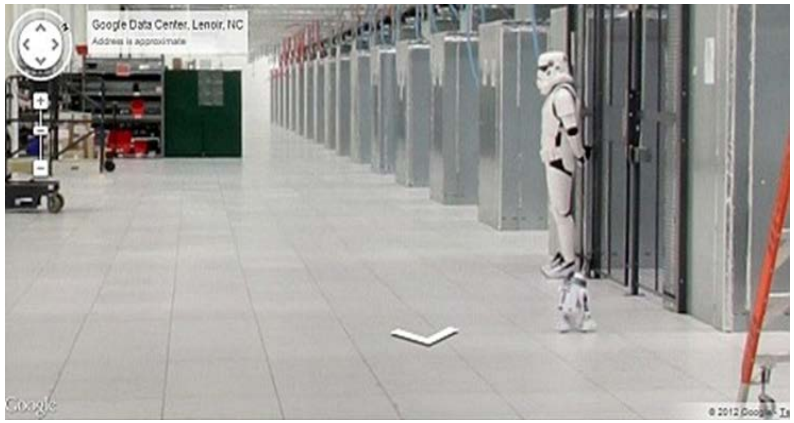
CHL=60.0



Google Cloud Computing

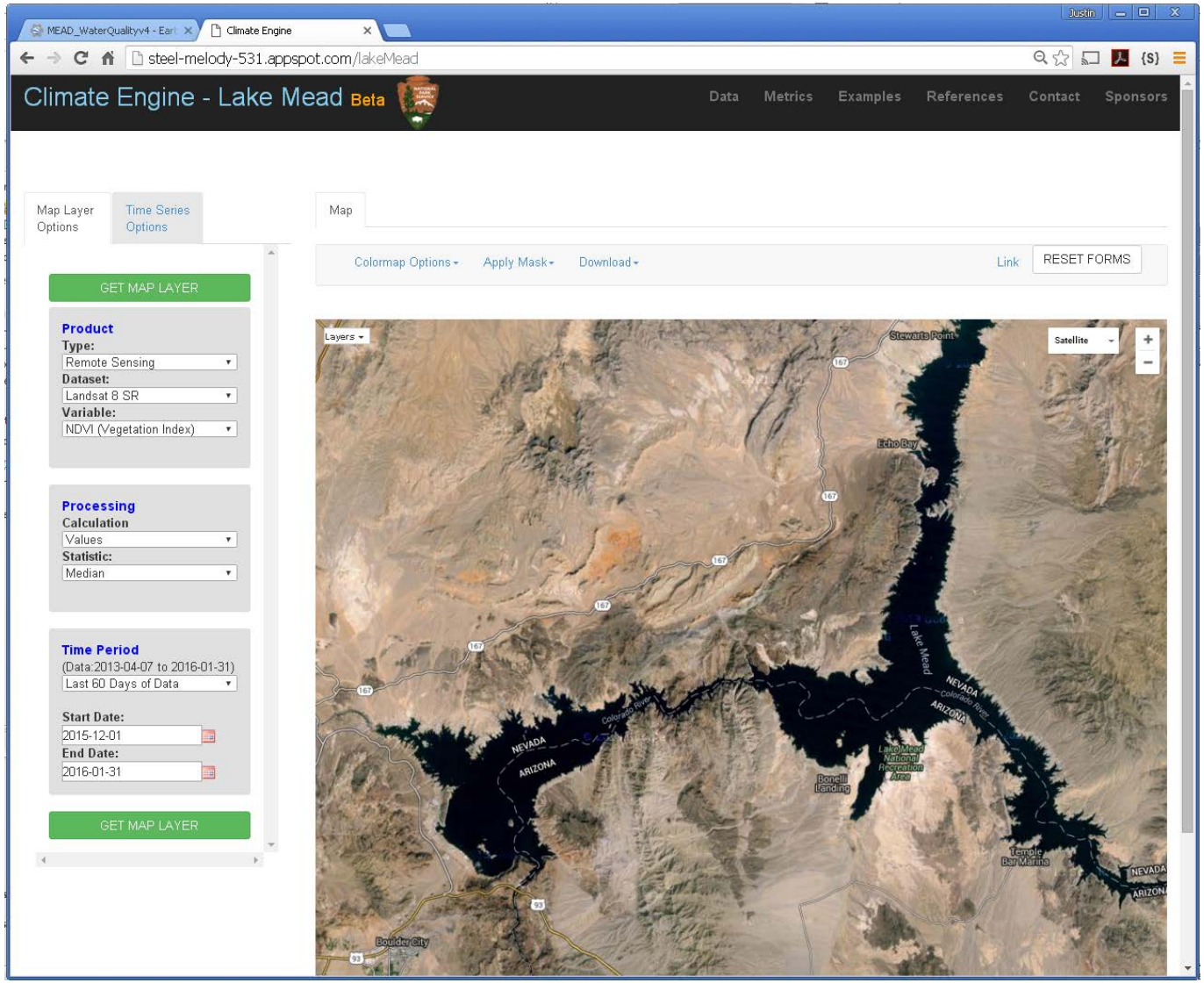
- Rely on Google Earth Engine cloud computing and environmental monitoring platform
- Google has the entire archive of Landsat and MODIS archives and downscaled Land Data Assimilation System (NLDAS) gridded weather data available for massive parallel processing in the cloud
- This technology has changed the paradigm of how we process and analyze Landsat and MODIS imagery





DEMO of Custom NPS App

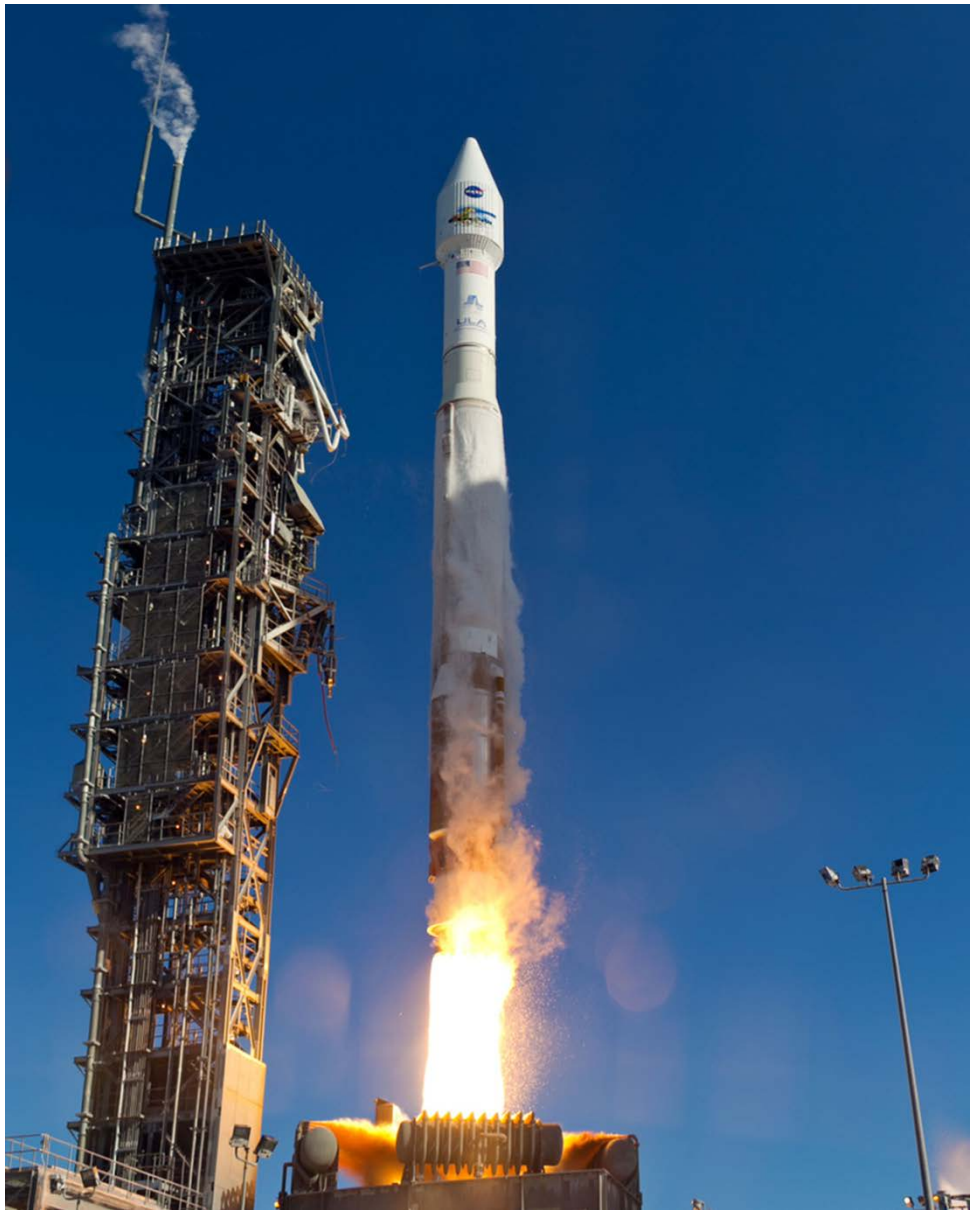
- We created a custom NPS Landsat, MODIS, and climate data application using Google Earth Engine
- Water quality, vegetation, and climate monitoring



Conclusions

- Landsat probably has potential for monitoring water quality (WQ) and clarity
- Pairing Landsat and MODIS images close to the sample dates, and atmospheric corrections to tease out more signal will be challenging, but a quick survey of images available, and initial results looks somewhat promising..
- Empirical relationships with WQ variables will likely have low correlation coefficients due to non-uniqueness of water color
- However, we believe imagery will still be useful for looking at spatial and temporal distributions for near real-time monitoring
- Cloud computing through Google Earth Engine allows for rapid and efficient near real-time monitoring of environmental variables using satellite and climate data

Landsat 8, Launched Feb 11, 2013



Many thanks to:

You
National Park Service
SNWA
Landsat Science Team
Google
USGS/NASA
NV Division of Environmental Protection

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Thanks – Questions?