GOOGLE EARTH ENGINE AS A REMOTE SENSING TOOL

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Introduction

Increasing availability of publicly accessible remotely sensed data and software via Google Earth has provided a unique tool for the general public, allowing them to discern alterations of the global environment etc. which has historically been limited to industry professionals. Liberalization of this material permits the general public to analyze various global phenomenon that have proven difficult to convey abstractly. Provided pressing issues, ranging from climate change to real time storm tracking, these data sets can be utilized in new ways, from preventive studies to post-analysis. While there has been much movement in ways to acquire data, platforms for processing these data into information has been lacking. Presently, the only publicly available software known to the general public for remote sensing analysis is, by and large, Google Earth.

Despite initial, monumental changes in user access described above we presume that Google is neglecting to achieve the entirety of impact they could, based on deficiencies in further data manipulation. Applications such as ENVI allow users greater manipulation of imagery, yielding exponential benefit to analysis and processes not obtainable with the present functionality of Google Earth.

Background

Presently, Google is making headway with their Google Earth Engine Beta project (hereafter: EE), a software currently available by sign up that allows remote sensing via their hosted cloud computation platform. Similarly, they have begun collecting data that is becoming more publicly available to augment their current remote sensing library, employed on Google Earth, through EE's Data Catalog. They have similarly started projects in the academic space that demonstrates their interest in developing public awareness of remote sensing, for example: Global Forest Change in conjunction with the University of Maryland.

The present paper will attempt to survey Google Earth Engine's current capability, and how we can augment it with remote sensing data and processes used in academia. We hypothesize that some ENVI functions (i.e. spectral band selection, NDVI analysis, etc.), as well as basic algorithms often used in remote sensing, as well as data freely available for the public through USGS, NOAA, and so forth, can be baked into their publicly visible Google Earth Enging software through an intuitive GUI, Thus allowing Google to capitalize on some of the proprietary market share while empowering the public in unprecedented ways by increasing the visibility and viability of remote sensing.

Google is a quintessential player in the information age and if they seek to fulfill their aim "to organize the world's information and make it universally accessible and useful" the aforementioned concepts are imperative in their business model [1].

Methodology

Our first step is to survey the present public and academic usage of Google Earth, since they represent the end user's perspective. Although there were some papers and analysis on Google Earth, studies of the software, particularly for remote sensing, is seldom, which increases the importance of this paper because it suggests that Google Earth is not being used to its full potential in the remote sensing space. To expand our search for literature we also looked for discussion on the use of cloud computation in remote sensing, as well as other remote sensing computation engine.

Once we gain preliminary understanding on the present field, our next step in our project was to acquire access to Google Earth Engine Beta, since this will reveal to us where Google is in their development in this field, and the provider's perspective. We applied too this program, suggesting that we were in the academic remote sensing space, wanting to survey their Data Catalog, and their current techniques for remote sensing analysis.

EE's data catalog was then compared against freely available remote sensing data through governmental databases such as USGS, NOAA and their sundry satellites (e.g. Landsat, GOES, EOG, etc.).

We then surveyed Earth Engine's capability. We looked at its ability to deal with remote sensing from their front end graphical user interface, as well as their programming API. In order to learn more, we also considered the present use of Earth Engine.

Results

At it's core, EE allows user to tap into Google's massive computation capability to apply remote sensing research to general public. Their first massive project, Global Forest Fire, was done in conjunction with the University of Maryland, to demonstrate this capability. "Google Earth Engine is a massively parallel technology for high-performance processing of geospatial data, and houses a copy of the entire Landsat image catalog […] what would have taken a single computer 15 years to perform was completed in a matter of days using Google Earth Engine computing [2]. This project have already been cited in recent papers for its potential in helping developing areas obtain information which may otherwise be unavailable due to resource. In his survey of cloud computation in remote sensing, Kshetri utilizes EE's deforestation data as an example in which cloud computation "can help address environmental issues", thereby offsetting the environmental impact caused by large server farms [3]. In fact, EE was first unveiled during a United Nations climate talk in Mexico, whereby it was positioned as a resource ""for measuring, reporting and verifying anthropogenic forest-related emissions" [4].

EE provides several other processed products available for browsing to the public on its website. They provide specific examples for area study through application of temporal Landsat data such as: "Saudi Arabia Irrigation" "Drying of Lake Urmia, Iran", "Columbia glacier Retreat," "Dubai Coastal Expansion", and "Drying of the Aral Sea," as well as products done through computation such as "Global roadless Areas," "water Mask of central Africa," "NDFI over the Amazon," and "Landsat 7 L1T Coverage" [2].

Another major contribution to the field is Exelis' Service Engine. Service Engine is a buyable product that follows "the concept of master and worker nodes," whereby consumers would load their product on a centralized servers which contains the computation power, as well as the data, which the consumer can then access through thin clients remotely, in other words allows ENVI analytics in the cloud [5]. Examples provided include "environmental responder[s] getting real-time updates on rescue efforts while in the field, a deployed soldier getting updates on enemy troop movements, severe weather warnings going out to disaster response teams, or even an assessment of civil unrest within a region" [5]. On top of existing data on servers, Service Engine enables information uploads through clients on the ground to provide more real-time results. They also tout interoperability, being adherent to Open Geospatial Consortium and the Esri Geo Services REST specification, and accessible via the IDL programming language [5]. Such interoperability is demonstrated with their example of working in conjunction with Milcord on dPlan which optimizes UAV routing and analysis [5]. In fact, Service Engine is largely only a component in Exelis' cloud strategy, since it depends on interfaces for users to use. One such example is Exelis' Jagwire, which is a "web-based software system that is specifically designed for ingest, storage, management, discovery, and delivery of geospatial full motion video (FMV), imagery, and derived products with near real-time access," though they promote "custom web pages designed to enable those capabilities for the end-user. "

A. Applying to Google Earth Engine

Without applying to EE, users can test drive basic features of EE. For example, they may add data from the Data Catalogue and experiment with how the data is viewed (e.g. bands allocation, gain, palette, range, and year). However, more advanced remote sensing analysis is not possible without registration.

We applied to Earth Engine by submitting a request to the Earth Engine Beta Signup, which can be obtain through this form [6]. Earth Engine Beta applicants must have a Gmail account, but other than that there does not seem to be any restrictions. An example of our request looks like, "Some colleagues and I are working on remote sensing application and analysis, at UCLA, were hoping to be permitted access to the Earth Engine Beta. Our work has previously utilized programs such as ENVI and Earth Explorer. In addition we are interested to see how Earth Engine might fit into the academic sphere." Within roughly 24-hours we all go emails outlining how to access the EE workspace. Provided full beta access you are able to do a variety of things, which we will discuss later in in the paper.

B. Data Catalog Availability

Table 1. Earth Explorer sans ASTER, MODIS, LANDSAT

Product Name	Coverage	Availability on EE	Notes
Aerial	Regional	L	NAIP: National Agriculture Imagery Program
Cal/Val-Referece Sites	Regional	N	
Declassified (Old-Military)		N	
Digital Elevation		L	
Digital Line Graphs	Regional	N	
Digital Maps	Regional	N	
USGS	Regional	N	

Group on Earth Observations (GEO) Global Agricultural Monitoring (GLAM)			
Global Fiducials Library (GFL)		N	
Global Forest Observation Initiative		N	
Global Land Survey		Y	
Heat Capacity Mapping Mission	Regional	N	
Lidar	Regional	N	
AVHRR 1km global		L	EE has surface temperature from AVHRR
AVHRR Composites (NDVI)		L	EE has NDVI from other satellites
IKONOS-2	Regional	N	
Declassified Military	Regional	N	USGS has declassified military aerial photos from Corona, Argon, and Lanyard, originally for recon.
EO-1		N	
JECAMM	Regional	L	Joint Experiment of Crop Assessment and Monitoring. data may intersect with NAIP, although it seems its for Canada only
Orbview		L	Orbview itself is not listed, but maybe it is a part of EE's base map
National Land Cover Data	Regional	Y	
NASA LPDACC		Y	
GEO-Eye		N	

Table 2. Landsat Data

Satellites	Availability on EE
Landsat 1	Available as part of Land Survey 1975
Landsat 2	Available as part of Land Survey 1975
Landsat 3	Available as part of Land Survey 1975
Landsat 4	Yes
Landsat 5	Yes
Landsat 7	Yes
Landsat 8	Yes

Table 3. NOAA Data

Name of Data	Availability
VIIRS (Night fire / infrared spectral)	No
DMSP (Night time lights)	Yes
Nightsat (Moderate resolution human settlements sprawl)	No
GOES (Continuous atmosphere monitoring)	No

Table 4. MEaSUREs Data Products Availability in Google Earth Explorer

Short Name	Collection	MEaSUREs Data Product	Spatial Resolution	Available in EE
SRTM GL1	SRTM	SRTM Global 1 arc second	1 arc-second	No
SRTM GL1N	SRTM	SRTM Global 1 arc second number	1 arc-second	No
SRTM GL3	SRTM	SRTM Global 3 arc second	3 arc-second	No
SRTM GL30	SRTM	SRTM Global 30 arc second	30 arc-second	No
SRTM GL3N	SRTM	SRTM Global 3 arc second number	3 arc-second	No
SRTM GL3S	SRTM	SRTM Global 3 arc second sub-sampled	3 arc-second	No
SRTMS WBD	SRTM	SRTM Water Body Data Shapefiles & Raster Files	1 arc-second	No
SRTMUS1	SRTM	SRTM US 1 arc second	1 arc-second	No
SRTMUS1N	SRTM	SRTM US 1 arc second number	1 arc-second	No
WELD AKLL	WELD	WELD Alaska Lat/Longs	30 m	No
WELD AKMO	WELD	WELD Alaska Monthly	30 m	No
WELD AKSE	WELD	WELD Alaska Seasonal	30 m	No
WELD AKWK	WELD	WELD Alaska Weekly	30 m	No
WELD AKYR	WELD	WELD Alaska Annual	30 m	No
WELDUSLL	WELD	WELD CONUS Lat/Long	30 m	No
WELDUSMO	WELD	WELD CONUS Monthly	30 m	No
WELDUSSE	WELD	WELD CONUS Seasonal	30 m	No
WELDUSWK	WELD	WELD CONUS Weekly	30 m	No
WELDUSYR	WELD	WELD CONUS Annual	30 m	No

Table 5. ASTER Data Products Availability in Google Earth Explorer

Short name	Level	Aster Data Product	Resolution	Available in EE	Alternative in EE
AST_L1BE	1B	Registered Radiance at the Sensor – Expedited	15, 30, 90	No	
AST_L1AE	1A	Reconstructed Unprocessed Instrument Data – Expedited	15, 30, 90	No	
AST_07	2	Surface Reflectance – VNIR & SWIR	15, 30	No	Landsat 5 Surface Reflectance
AST_07XT	2	Surface Reflectance – VNIR & Crosstalk Corrected SWIR	15, 30	No	Landsat 5 Surface Reflectance
AST_09	2	Surface Radiance – VNIR & SWIR	15, 30	No	

AST_09XT	2	Surface Radiance – VNIR & Crosstalk Corrected SWIR	15, 30	No	
AST_09T	2	Surface Radiance TIR	90	No	
AST_08	2	Surface Kinetic Temperature	90	No	MOD11A1 Land Surface Temperature and Emissivity Daily Global 1 km Grid SIN
AST_05	2	Surface Emissivity	90	No	MOD11A1 Land Surface Temperature and Emissivity Daily Global 1 km Grid SIN
AST14OTH	3	Registered Radiance at the Sensor – Orthorectified	15, 30, 90	No	
AST_L1B	1B	Registered Radiance at the Sensor	15, 30, 90	No	
AST14DMO	3	Digital Elevation Model & Registered Radiance at the Sensor – Orthorectified	15, 30, 90	No	SRTM Digital Elevation Data Version 4
AST_L1A	1A	Reconstructed Unprocessed Instrument Data	15, 30, 90	No	
AST14DEM	3	Digital Elevation Model	30	No	SRTM Digital Elevation Data Version 4
AST GTM	3	ASTER Global Digital Elevation Model	30	No	SRTM Digital Elevation Data Version 4

Table 6. MODIS Data Products Availability in Google Earth Explorer. See Appendix.

C. GUI & Programming

Both EE and alternative software, such as ENVI have their benefits and drawbacks when it comes to UI . However, the breadth of manipulation in EE is highly dependent on the users programming capabilities (either java or python).

Generally speaking microscale analysis is much more difficult in EE than alternative, proprietary platforms. It should be mentioned that this is largely with regard to non-classified data. Imagery and analysis that has been published in EE allows quite intuitive manipulation. Furthermore, not having to download imagery via platforms such as Earth Explorer and then upload it into the desired program can be very efficient.

Macro or global scale analysis of precomputed data sets including NDWI, NDVI, etc. facilitate tremendously powerful computation processed with Google’s serves. If one wanted to do the similar scale analysis on their own machine, not only would it take a tremendous amount of time but would surely strain your computer (if even possible). Additional benefits of EE’s platform and data repository include pre-written java templates for image classification. Again the downside of this is needing Java programming experience and the disorganization of resource material.

To the same end, working with imagery that is not included in the EE catalog requires laborious processes. Simple functions that can be completed in ENVI such as color mapping, are much more complex to mimic using EE palette classification (Figure 4). The ability to obtain a cursor location/value in ENVI is something that does not seem possible in EE, with or without programming abilities (Figure 3). It would be nice to have some basic tools, and UI function in EE similar to those offered in the standalone platforms. Below are some screenshots demonstrating or displaying the comments mentioned above.

D. ENVI vs EE

ENVI

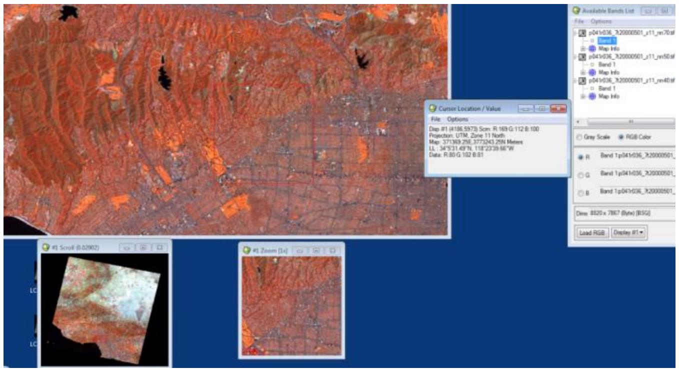


Figure 1. Thermal (4,5,7) Band Selection-ENVI

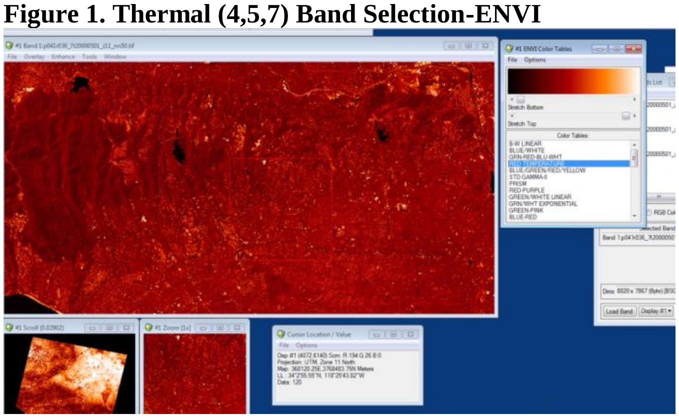


Figure 2. Color Mapping with Color Tables ENVI

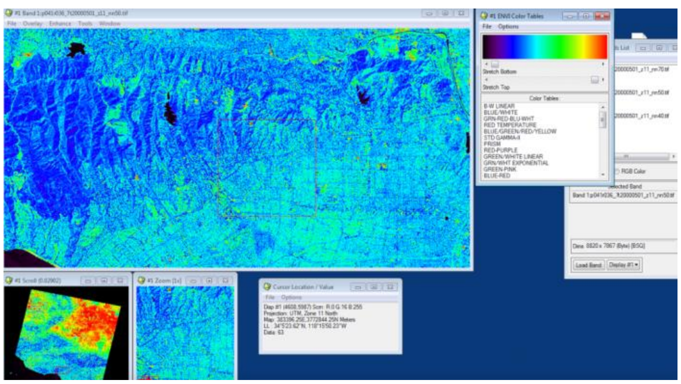


Figure 3. Cursor Location/Value- ENVI

EE

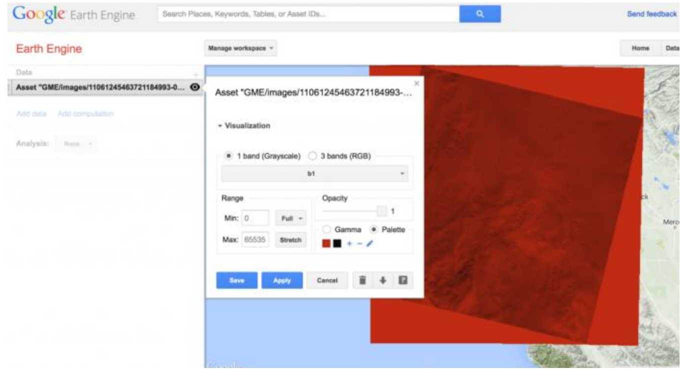


Figure 4. Color Palette (without programming & Clouds)

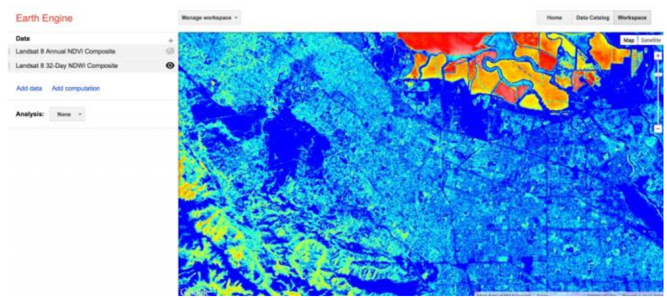


Figure 5. Landsat 8 32-Day NDWI- Precomputed (EE)

Figure 6. Landsat 8-Annual NDVI- Precomputed (EE)

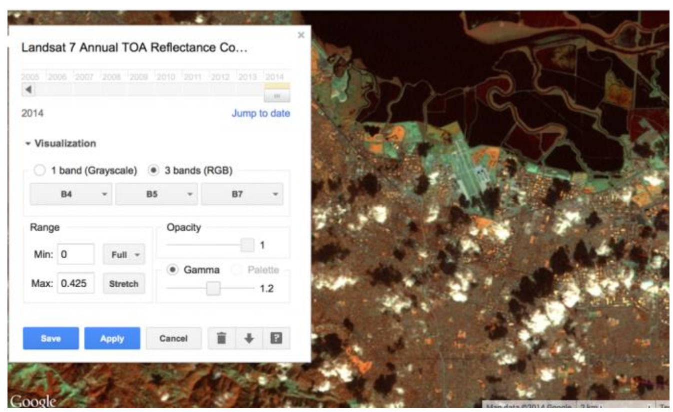


Figure 7. Thermal Band Selection(4,5,7)- EE

Discussion

A. Data Catalog & Data Usage

One of the benefits in using EE is the marriage between the data source and the analysis software. Unlike the traditional desktop software model, EE allows the user to focus on the analysis and not on acquiring data since the data has been precomputed by Google for use on EE platform. A quick search of "Night lights" will immediately show data from NOAA's DMSP. Moreover, some data have been further computed for basic information. For example, a quick search on "Landsat" will provide composites (8 days, 32 days, etc.), indices (NDVI, NDSI, EVI, etc.). It is additionally useful that EE combines several temporal data into one set–that is, a search for "Landsat 8 NDWI" will allow the user to scrub through all available years that data is available for.

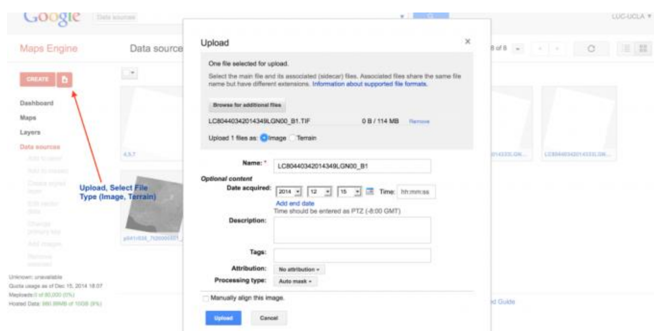
However, although EE makes a venerable attempt to simplify the process of acquiring data, there are quirks that make the process limiting. For example, some data sets are searchable through the data catalog, but at the same time cannot be added to the workspace (e.g. Landsat Global Land Survey 1975). It is unclear why this is, and there is no way to filter results. Moreover, while it's good that EE combines temporal data together, its lack of filtering makes finding the right set difficult. For example: there is no way to only look for data between a date range, which must be possible since EE does know which years as available.

B. Uploading Imagery

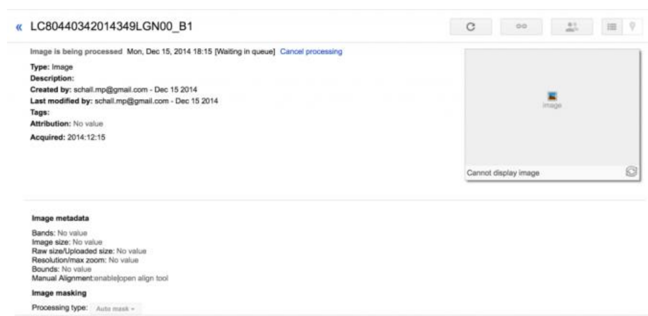
One of biggest problems encountered while using EE was attempting to upload our own imagery. In contrast to other platforms EE is largely designed to be stand alone. Adding an image is extremely cumbersome, and the current documentation can be misleading. For instance you might find contradictory information in the google tutorials about uploading images, as stated, "You may wonder about uploading your own imagery to Google Earth Engine for analysis. This feature is not yet completed, but we plan to offer the ability to upload and analyze your own imagery in the future [2]." However, if one takes a deeper look they will find that you can infact upload external imagery, with a few caveats.

Primarily, you are required to upload the imagery into Google Maps Engine, another google platform, not into EE directly (Step 1). Second, you can only upload one image at time, resulting in a very tedious process if you want to examine multiple bands in a given satellite. Once the image has uploaded into Maps Engine you have to process the image, which can take quite some time (Step 1.5). After the image is processed you can can obtain an access link, where you copy the the EE ID (Step 2), and paste it into the search bar of your EE workspace (Step 3). In theory this should prompt the "Custom Assets" option as captured in step 3. In our experience this has only worked intermittently. Assuming it has worked, you may then manipulate the image you have uploaded.

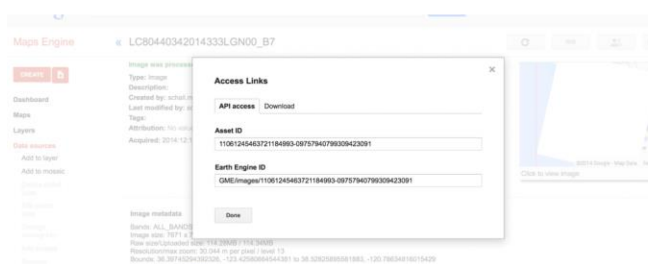
The pictures below below demonstrates the process of uploading a satellite image into Maps Engine, where it is processed and then available to search In EE.



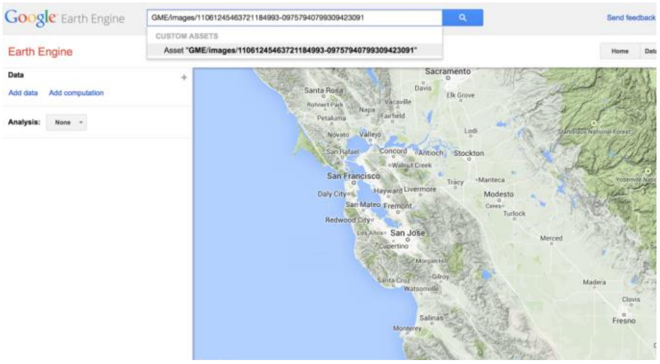
Step 1



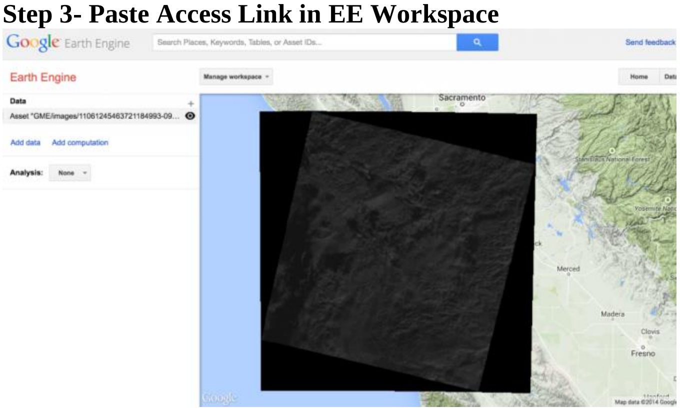
Step 1.5 (Wait for Processing)



Step 2- Copy Access Link



Step 3- Paste Access Link in EE Workspace



Step 4- Finally the image in EE!

Beyond the issues encountered with uploading imagery, were classification discrepancies. This becomes problematic since, as shown previously in the results, some data sources are not available. Somehow google has managed to thwart their search functionality within the EE workspace either intentionally or unintentionally. Moreover, real time/continuous data, such as NOAA's GOES, is unavailable for quick retrieval. Thus EE is largely limited by what the team deems to be important; although they provide a ton of data already, and is often convenient, processing is ultimately limited due to the inextensibility of the platform.

Additionally, unlike most data repository for remote sensing, it is not possible to search availability by region of interest. It is to note, that the availability of data may be a result of the platform's centralized computation paradigm–that is, since EE stores all its data on Google's servers than the individual users, it may be prohibitive to have a copy of all possible data.

Another data source that we wished EE would have employed is NASA and USGS' Web-enabled landsat Data projects (WELD), which provides preprocessed Landsat data which has spectral calibration coefficients, solar information, reflectance, brightness and temperature, as well as temporal alignment is another example of data we wished. [7] Such data set would fit perfectly into EE since EE deals with similar data. Utilization of this resource may provide boonful to researchers, having access to quicker data updates, as well as EE developers themselves since they no longer need to do the processing.

It is interesting to compare EE with other remote sensing analysis solution which encourages integration of other platforms. As mentioned before, Exelis' Service Engine prides itself in its ability to integrate different platforms. In fact, it provides no data of its own and depends on the user contributing the data into its repository. Even better, with Jagwire, users are able to upload data live, on site. Moreover, Service Engine's capability to connect via OGC and ESRI rest specifications, allows Service Engine to be used as part of a greater workflow.

It is possible, however, that such capability highlights the fundamental difference between EE and other remote sensing softwares. Whereas Service Engine seems to be focused on on-demand analysis, e.g. UAV and military application, EE is aimed for large data crunching for research, which precludes time insensitivity, e.g. Forest deforestation, Global roadless Areas, etc.

It behooves the writer to note some issues that may have compromise the data catalog summary and capability. Although we did our best to find data, EE's search platform is limited to some degree. Although VIIRS data may not seem to be available if we search "VIIRS," it may be possible that it has been combined with another data set. We hope that the EE team provides a solution and a more robust search solution that searches more than the title, but includes the metadata. To note: EE demonstrates how to calculate Tree Height via LIDAR data. Despite this, searching for "LIDAR" in the data catalog will provide nothing. Looking at the programming layer for this demonstration, we noticed a data set named "Simard_Pinto_3DGlobalVeg_JGR". Searching for this,results in nothing as well [8].

B. EE Workspace and Remote Sensing Analysis

Presets

Currently EE provides several preprocessing of images such as simple indices (see results). Given that EE seems to attempt to provide public access to remote sensing analysis (e.g. the examples), it may be beneficial to provide additional algorithms to demonstrate the power of the platform to those new to the field or EE. We propose some general algorithm that has been demonstrated in the field as starting points. Since EE already has the ability to change band combination, it may be useful to create presets that can highlight different water bodies, soil, vegetation, man-made materials, and snow and ice as per common band combinations such as the one given by Portland State University. In addition, other classification system can be integrated beside band combination, such as the Maximum Likelihood classification [9]. Another great example of analysis that Google can develop based on existing academic research is Whale Counting [9] [10] and building types [11]. Additionally, it may be interesting to compare Service Engine's default preprocessing: find white planes, find red roofs, line of sight, and relative water depth, and look for avenues of possible improvements.

Blab la

One of the benefits in using EE is the marriage between the data source and the analysis software. Unlike the traditional desktop software model, EE allows the user to focus on the analysis and not on acquiring data since the data has been precomputed by Google for use on EE platform. A quick search of "Night lights" will immediately show data from NOAA's DMSP. Moreover, some data have been further computed for basic information. For example, a quick search on "Landsat" will provide composites (8 days, 32 days, etc.), indices (NDVI, NDSI, EVI, etc.). It is additionally useful that EE combines several temporal data into one set–that is, a search for "Landsat 8 NDWI" will allow the user to scrub through all available years that data is available for.

Continual computation

One of the biggest selling point for EE is its computation capability. Recent advancement in remote sensing has allowed near real time imagery of the earth through different sensors. "Today, commercial Earth observation satellites collect more than 4 million square kilometers of imagery daily, totaling petabytes every year " [12]. Given that these data are public, EE should allow for utilization of these continuous data feed, allowing near real time algorithmic analysis at the global level. Example data feed could be NOAA satellites: Suomi NPP (VIIRS) for weather, climate, ocean dynamic, volcanic eruption, forest fire, and global vegetation analysis, GOES for severe weather, storm and hurricane warning, DMSP for snow and ice cover, climate change and sea-level rise, cloud type, ocean surface temperatures and currents, Jason-2 for oceanic depth and temperature, and DSCOVR for sun-lit face of the earth (not yet launched) (NOAA). Such capability will be novel and could be groundbreaking for the industry at large.

Change detection

EE currently has some advanced methods dealing with time series data such as trend analysis (using covariate), and cross correlation analysis (resulting in delta x, y and euclidean distance difference [8]. We suggest that a basic change detection tool in the GUI can improve user experience. Their documentation currently suggests that change detection can be done by toggling layer visibility. Although layer capabilities is novel and other remote sensing application should look to this feature, such feature is not a replacement for change detection in comparing raster values. A simple implementation of a tool that takes in two maps from the data catalog and outputs a new map that calculate the difference in each pixel value may prove to be boonful to newcomers and the general public not used to remote sensing analysis. Such tool would take advantage of the fact that EE already groups common data sets as well as aligning them together.

Statistics

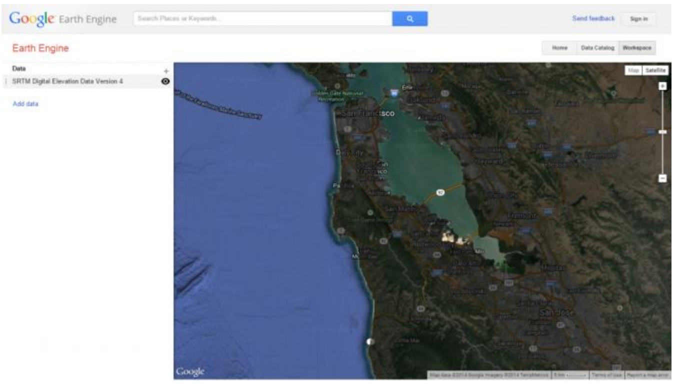
Currently EE allows user to perform statistical analysis through their programming layer, such as covariance, standard deviation, min, max and so forth. However, such a tool is absent from the GUI layer, limiting its capability. It may be important to view data generated from EE in another format, such as a graph. For example, in Exelis' ENVI, users may use a tool called "cursor location/values" which provide a graph of how values change within a map [9]. such graphical tool may provide information to the user.

Mobile

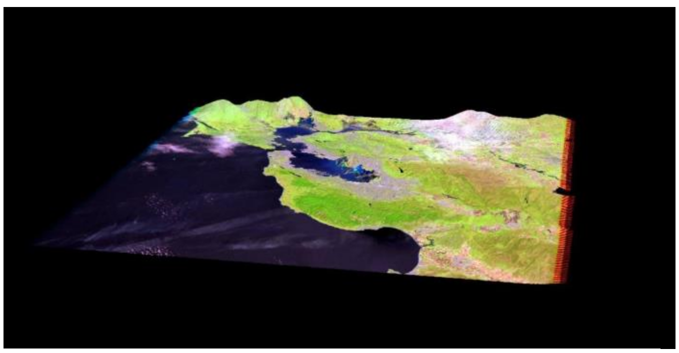
One of the primary benefit of cloud computing is that computation is offloaded from the user's device and thus a thin client can be used for access. EE should exploit this capability, allowing users to remote analysis in rural areas via mobile devices. Service Engine's main feature points to its ability to be accessible on the ground to provide real time information [5]. Since EE runs on the expansive Google network, EE should have no problem in creating a thin client version of EE. In doing so, EE will once again push the field by giving information to those traditionally without access to remote sensing, a goal which they seem to aim for and people applaud for in Global Forest Fire.

3D capability and Topography

Although EE can calculate elevation related operations, such as hillshadow and hillshade, it currently only has one way to view the data–top down. The capability of viewing data within the three-dimensional scope is absent from the current EE GUI. For example: this function is referred to as "3D SurfaceView function" within the Exelis ENVI Classic software user interface. Furthermore, although EE has the ability to employ layers, because there is no 3D function within it, it is impossible to view two layers simultaneously beside color layering. For example, when using the DEM, the user can not overlay data on top of it without obscuring DEM.



ASTER DEM (ASTGDEMV2_0N37W123) + Landsat 5



(LT50440342011117PAC01) using ENVI's 3D surface view.

Appendix

Table 6. MODIS Data Products Availability in Google Earth Explorer

Short Name	MODIS Data Product	Res (m)	Temporal Granularity	Available in EE	Alternative in EE
MCD 12C1	Land Cover Type	5600m	Yearly	No	MCD12Q1 Land Cover Type Yearly Global 500m
MCD 12Q1	Land Cover Type	500m	Yearly	Yes	
MCD 12Q2	Land Cover Dynamics	500m	Yearly	No	
MCD 15A2	Leaf Area Index – FPAR	1000m	8 day	No	MCD12Q1-3 LAI/fPAR
MCD 15A3	Leaf Area Index – FPAR	1000m	4 day	No	MCD12Q1-3 LAI/fPAR
MCD 43A1	BRDF-Albedo Model Parameters	500m	16 day	Yes	
MCD 43A2	BRDF-Albedo Quality	500m	16 day	Yes	BRDF-Albedo Model Parameters 16-Day L3 Global 500m
MCD 43A3	Albedo	500m	16 day	No	
MCD 43A4	Nadir BRDF-Adjusted Reflectance	500m	16 day	Yes	
MCD 43B1	BRDF-Albedo Model Parameters	1000m	16 day	No	BRDF-Albedo Model Parameters 16-Day L3 Global 500m
MCD 43B2	BRDF-Albedo Quality	1000m	16 day	No	MCD43A2 BRDF-Albedo Quality 16-Day Global 500m
MCD 43B3	Albedo	1000m	16 day	Yes	

MCD 43B4	Nadir BRDF-Adjusted Reflectance	1000m	16 day	No	MCD43A4 BRDF-Adjusted Reflectance 16-Day Global 500m
MCD 43C1	BRDF-Albedo Model Parameters	5600m	16 day	No	BRDF-Albedo Model Parameters 16-Day L3 Global 500m
MCD 43C2	BRDF-Albedo Snow-free Quality	5600m	16 day	No	
MCD 43C3	Albedo	5600m	16 day	No	
MCD 43C4	Nadir BRDF-Adjusted Reflectance	5600m	16 day	No	MCD43A4 BRDF-Adjusted Reflectance 16-Day Global 500m
MCD 45A1	Thermal Anomalies & Fire	500m	Monthly	No	N/A
MOD 09A1	Surface Reflectance Bands 1–7	500m	8 day	Yes	
MOD 09CMG	Surface Reflectance Bands 1–7	5600m	Daily	No	
MOD 09GA	Surface Reflectance Bands 1–7	500/1000m	Daily	Yes	
MOD 09GQ	Surface Reflectance Bands 1–2	250m	Daily	Yes	
MOD 09Q1	Surface Reflectance Bands 1–2	250m	8 day	No	MOD09GQ Surface Reflectance Daily L2G Global 250m
MOD 11A1	Land Surface Temperature & Emissivity	1000m	Daily	Yes	
MOD 11A2	Land Surface Temperature & Emissivity	1000m	8 day	Yes	
MOD 11B1	Land Surface Temperature & Emissivity	5600m	Daily	No	MOD11A2 Land Surface Temperature and Emissivity 8-Day Global 1km
MOD 11C1	Land Surface Temperature & Emissivity	5600m	Daily	No	MOD11A2 Land Surface Temperature and Emissivity 8-Day Global 1km
MOD 11C2	Land Surface Temperature & Emissivity	5600m	8 day	No	MOD11A2 Land Surface Temperature and Emissivity 8-Day Global 1km

MOD 11C3	Land Surface Temperature & Emissivity	5600m	Monthly	No	MOD11A2 Land Surface Temperature and Emissivity 8-Day Global 1km
MOD 11_L 2	Land Surface Temperature & Emissivity	1000m	5 min	No	MOD11A2 Land Surface Temperature and Emissivity 8-Day Global 1km
MOD 13A1	Vegetation Indices	500m	16 day	Yes	
MOD 13A2	Vegetation Indices	1000m	16 day	No	MOD13A1 Vegetation Indices 16-Day L3 Global 500m
MOD 13A3	Vegetation Indices	1000m	Monthly	No	MOD13A1 Vegetation Indices 16-Day L3 Global 500m
MOD 13C1	Vegetation Indices	5600m	16 day	No	MOD13A1 Vegetation Indices 16-Day L3 Global 500m
MOD 13C2	Vegetation Indices	5600m	Monthly	No	MOD13A1 Vegetation Indices 16-Day L3 Global 500m
MOD 13Q1	Vegetation Indices	250m	16 day	Yes	
MOD 14	Thermal Anomalies & Fire	1000m	5 min	No	N/A
MOD 14A1	Thermal Anomalies & Fire	1000m	Daily	No	N/A
MOD 14A2	Thermal Anomalies & Fire	1000m	8 day	No	N/A
MOD 15A2	Leaf Area Index – FPAR	1000m	8 day	No	N/A
MOD 17A2	Gross Primary Productivity	1000m	8 day	No	N/A
MOD 17A3	Net Primary Productivity	1000m	Yearly	No	MCD12Q1-4 NPP
MOD 44A	Vegetation Continuous Cover	250m	96 day	No	N/A
MOD 44B	Vegetation Continuous Fields	250m	Yearly	Yes	
MOD 44W	Land Water Mask Derived	250m	None	Yes	
MYD 09A1	Surface Reflectance Bands 1–7	500m	8 day	Yes	
MYD 09CMG	Surface Reflectance Bands 1–7	5600m	Daily	No	MYD09GA Surface Reflectance Daily L2G Global 1km and 500m
MYD	Sur-	500/10	Daily	Yes	

09GA	face Reflectance Bands 1–7	00m			
MYD 09GQ	Surface Reflectance Bands 1–2	250m	Daily	Yes	
MYD 09Q1	Surface Reflectance Bands 1–2	250m	8 day	No	MYD09GQ Surface Reflectance Daily L2G Global 250m
MYD 11A1	Land Surface Temperature & Emissivity	1000m	Daily	Yes	
MYD 11A2	Land Surface Temperature & Emissivity	1000m	8 day	Yes	
MYD 11B1	Land Surface Temperature & Emissivity	5600m	Daily	No	MYD11A1 Land Surface Temperature and Emissivity Daily Global 1 km Grid SIN
MYD 11C1	Land Surface Temperature & Emissivity	5600m	Daily	No	MYD11A1 Land Surface Temperature and Emissivity Daily Global 1 km Grid SIN
MYD 11C2	Land Surface Temperature & Emissivity	5600m	8 day	No	MYD11A1 Land Surface Temperature and Emissivity Daily Global 1 km Grid SIN
MYD 11C3	Land Surface Temperature & Emissivity	5600m	Monthly	No	MYD11A1 Land Surface Temperature and Emissivity Daily Global 1 km Grid SIN
MYD 11_L 2	Land Surface Temperature & Emissivity	1000m	5 min	No	MYD11A1 Land Surface Temperature and Emissivity Daily Global 1 km Grid SIN
MYD 13A1	Vegetation Indices	500m	16 day	Yes	
MYD 13A2	Vegetation Indices	1000m	16 day	No	MYD13A1 Vegetation Indices 16-Day L3 Global 500m
MYD 13A3	Vegetation Indices	1000m	Monthly	No	MYD13A1 Vegetation Indices 16-Day L3 Global 500m
MYD 13C1	Vegetation Indices	5600m	16 day	No	MYD13A1 Vegetation Indices 16-Day L3 Global 500m
MYD 13C2	Vegetation Indices	5600m	Monthly	No	MYD13A1 Vegetation Indices 16-Day L3 Global 500m
MYD 13Q1	Vegetation Indices	250m	16 day	Yes	
MYD	Ther-	1000m	5 min	No	N/A

14	mal Anomalies & Fire				
MYD 14A1	Thermal Anomalies & Fire	1000m	Daily	No	N/A
MYD 14A2	Thermal Anomalies & Fire	1000m	8 day	No	N/A
MYD 15A2	Leaf Area Index – FPAR	1000m	8 day	No	MCD12Q1-3 LAI/fPAR
MYD 17A2	Gross Primary Productivity	1000m	8 day	No	N/A

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