

Monitoring Drought with Climate Engine: From Archives to Answers



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**University
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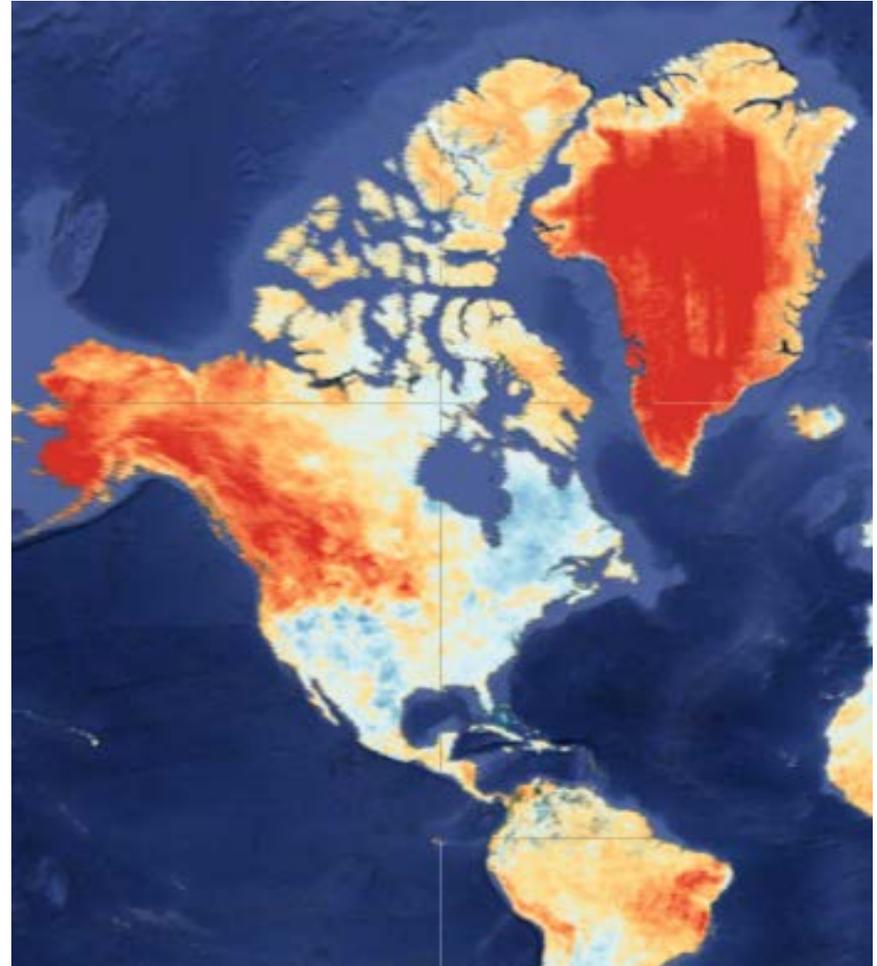


Outline

- The need for place-based information
- Different types of place-based drought impacts
- Cloud computing with climate and remote sensing data for drought/climate/water use monitoring
- Bottle neck – bringing this technology to natural resource management
- Climate Engine web application
- Future directions – water use mapping

Introduction – From Archives to Answers

- In an era of increasing wealth of earth observations and environmental data, approaches for quickly accessing, analyzing and visualizing these data to better inform decision making at relevant and place-based scales is lacking
- Great need to be able to quickly process and visualize data to improve monitoring and early warning of drought, wildfire, and crop-failure risk
- Instead of focusing on processing entire archives, focus on results and answers for efficient decision making



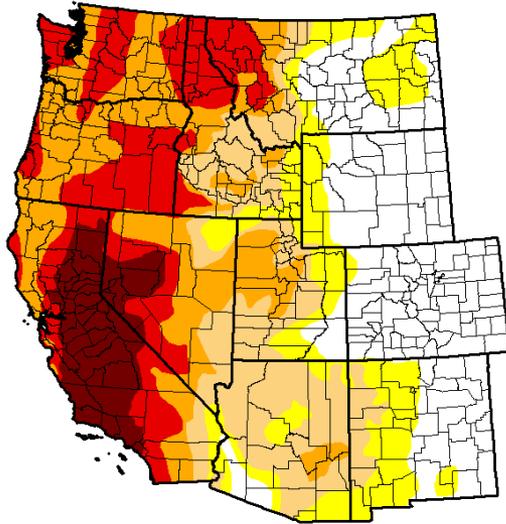
March 15 - May 15, 2016 MODIS Land Surface Temperature Difference from Average (2000-2016) (+/- 6 degC)

Introduction - Drought Information Needs at All Scales

- Drought information is needed at global, regional, and local scales
- Local “place-based” information has traditionally been hard to obtain due to the lack of observations and data access and processing limitations
- With new and easy access to remote sensing, gridded weather data, and cloud computing platforms, place-based, regional, and global drought monitoring needs can be met

Regional & Large Temporal Scale -US Drought Monitor-

U.S. Drought Monitor West



August 18, 2015
(Released Thursday, Aug. 20, 2015)
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	26.53	73.47	58.91	42.01	23.69	7.62
Last Week 8/1/2015	26.53	73.47	58.95	42.43	23.22	7.62
3 Months Ago 5/18/2015	23.49	76.51	60.69	36.57	17.59	7.95
Start of Calendar Year 12/01/2014	34.76	65.24	54.48	33.50	18.68	5.40
Start of Water Year 9/30/2014	31.48	68.52	55.57	35.65	19.95	8.90
One Year Ago 8/18/2014	27.21	72.79	59.27	42.84	20.97	8.90

Intensity

D0 Abnormally Dry	D3 Extreme Drought
D1 Moderate Drought	D4 Exceptional Drought
D2 Severe Drought	

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:

Chris Fenimore
NCEI/NESDIS/NOAA

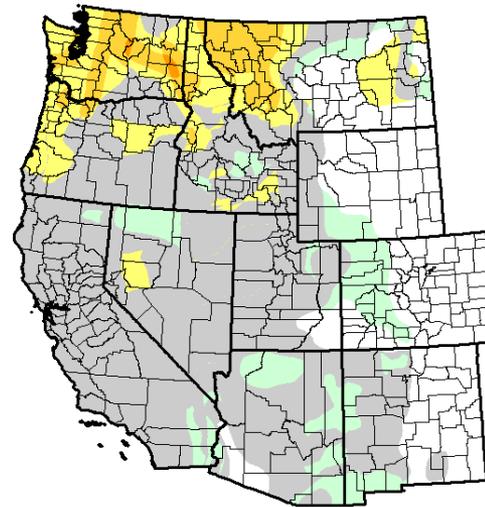


<http://droughtmonitor.unl.edu/>

- Minimal changes in USDM over the summer of 2015

- USDM reflects hydrologic drought more than rangeland drought conditions
- No one map can capture all types of drought

U.S. Drought Monitor Class Change - West 2 Months



August 18, 2015
compared to
June 23, 2015



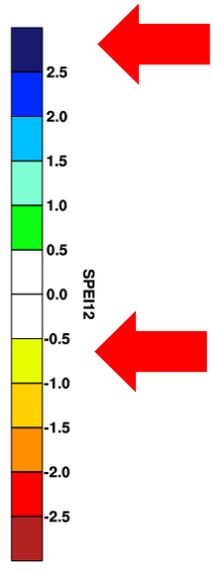
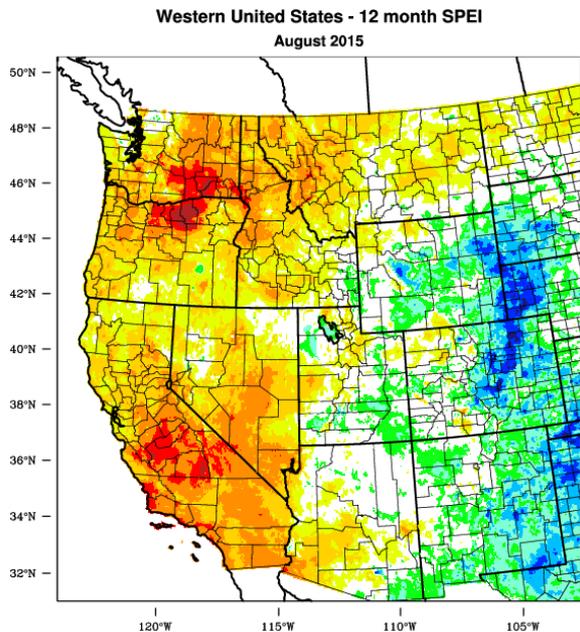
5 Class Degradation
4 Class Degradation
3 Class Degradation
2 Class Degradation
1 Class Degradation
No Change
1 Class Improvement
2 Class Improvement
3 Class Improvement
4 Class Improvement
5 Class Improvement

http://droughtmonitor.unl.edu

Different Types of Drought at the Same Time

Drought is complex: it has multiple drivers and develops and recovers at different time scales

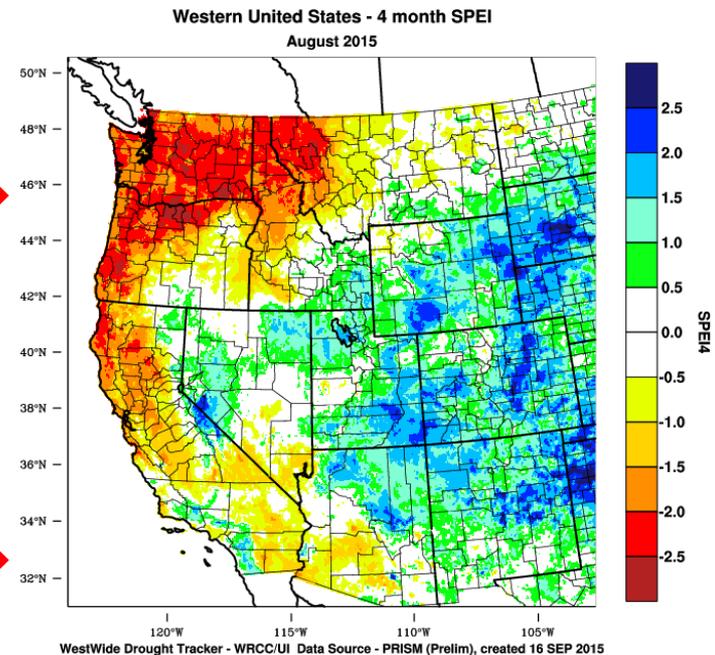
12 Month SPEI Ending in August, 2015



Long Term
vs.
Short Term
Drought

Hydrologic
vs.
Soil Moisture/
Rangeland
Drought

4 Month SPEI Ending in August, 2015

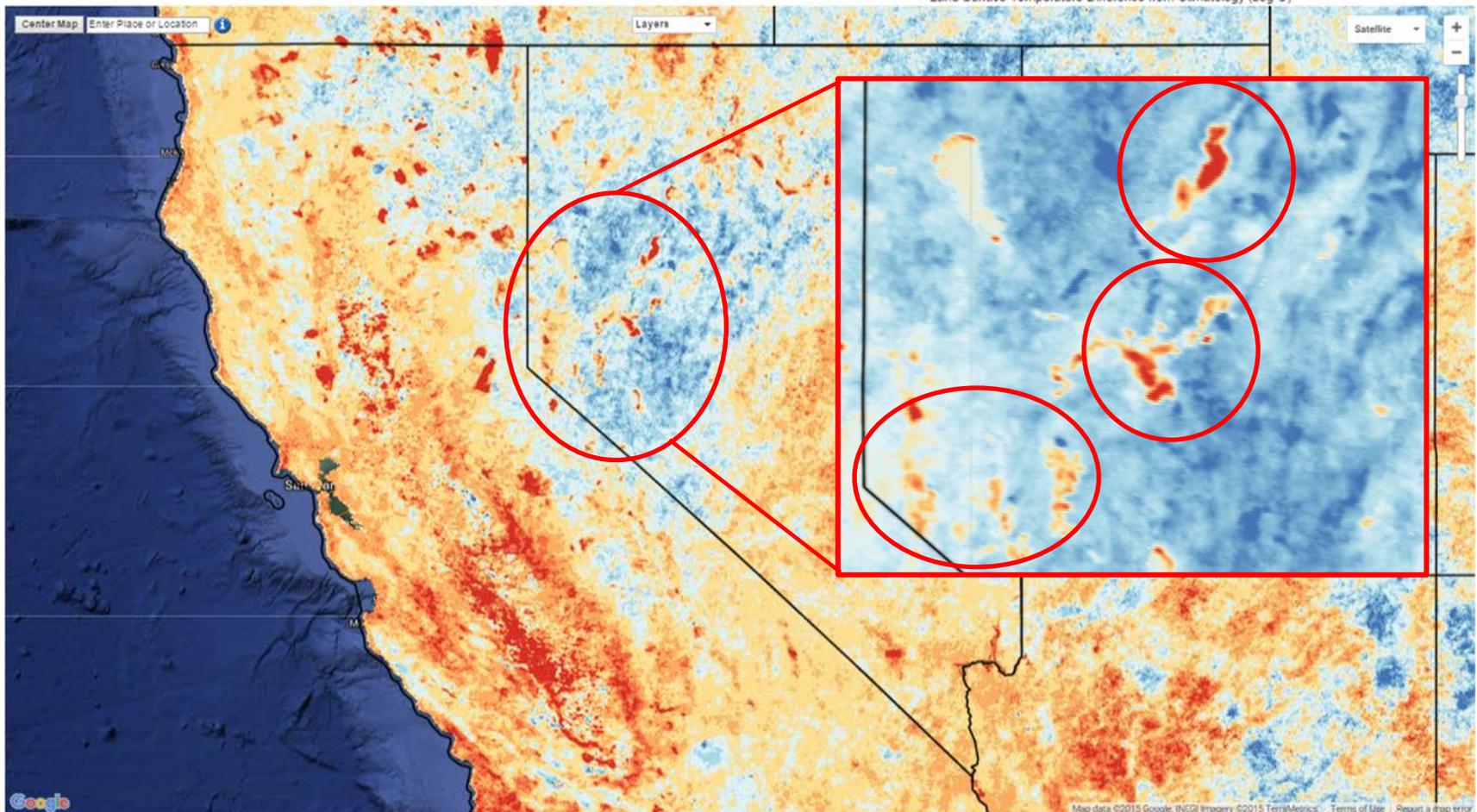
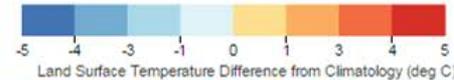


Blue = Wet, Cool : Red = Dry, Hot

Different Types of Drought at the Same Time - Summer 2015

Median Land Surface Temperature during Day Difference from Average

Data Source: MODIS 8-day LST_Day_1km from 2015-07-01 to 2015-09-30
Average calculated from 2000-2015



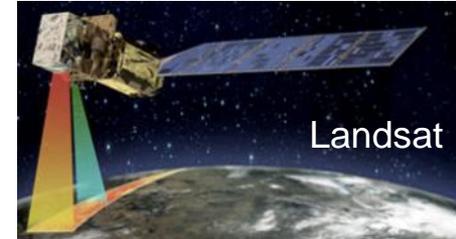
MODIS Surface Temperature Anomaly for July – Sept, 2015

Place-Based Hydrologic and Rangeland Drought Assessments

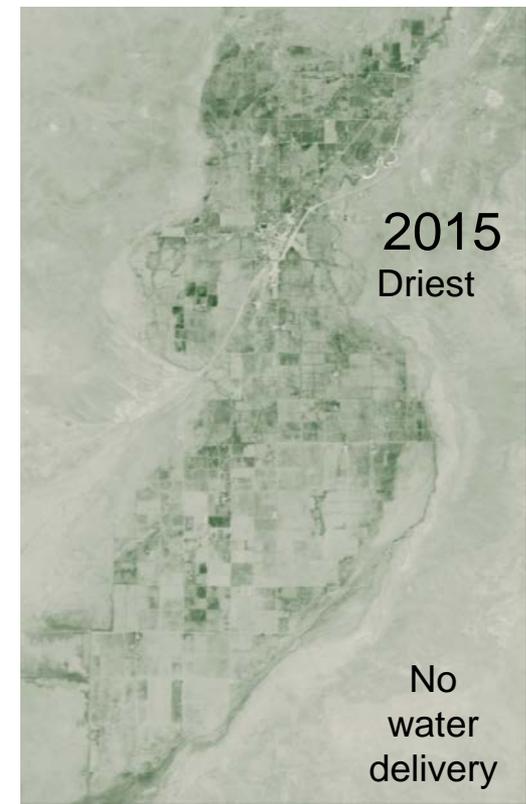
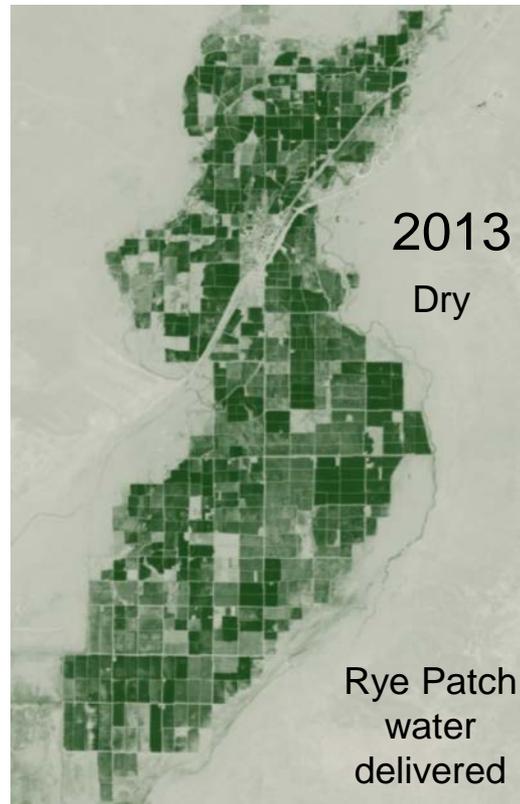
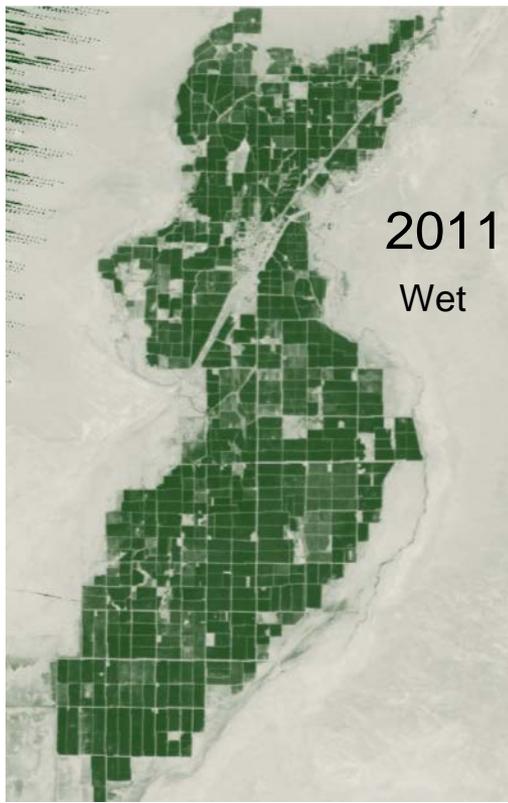


Lovelock, Nevada – Humboldt River Basin

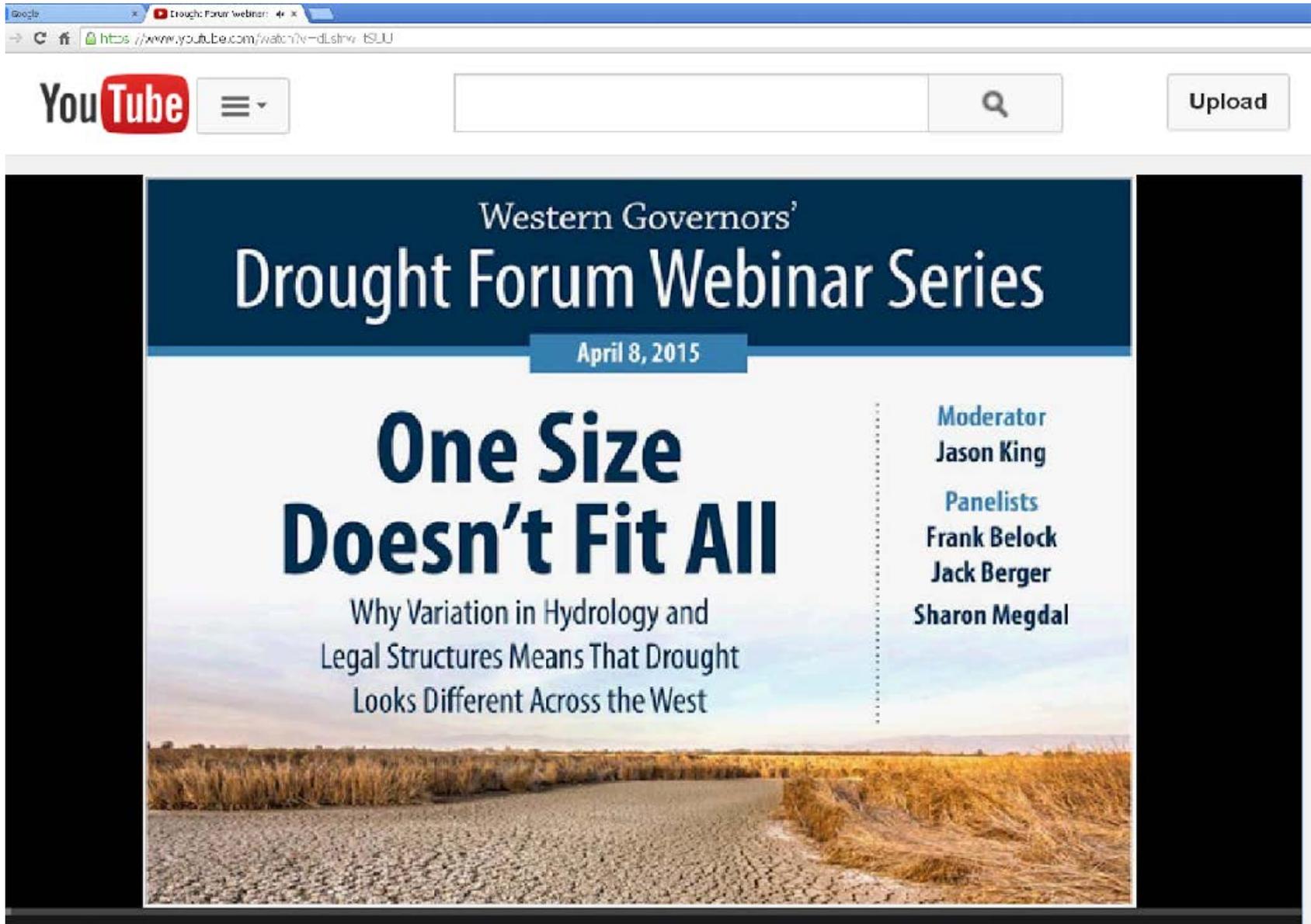
- No groundwater pumping for irrigation (too salty)
- Very little storage upstream
- Extremely sensitive to persistent hydrologic drought



-Growing Season Max NDVI (30m Pixels)



Western Governors' Drought Forum



The image is a screenshot of a YouTube video player. The browser's address bar shows the URL: <https://www.youtube.com/watch?v=dLstnvtSUU>. The YouTube logo is visible in the top left corner, along with a search bar and an 'Upload' button. The video content is a title card for a webinar series. The background of the title card is a photograph of a dry, cracked riverbed in a field of dry, yellowed grass under a cloudy sky.

Western Governors'
Drought Forum Webinar Series

April 8, 2015

**One Size
Doesn't Fit All**

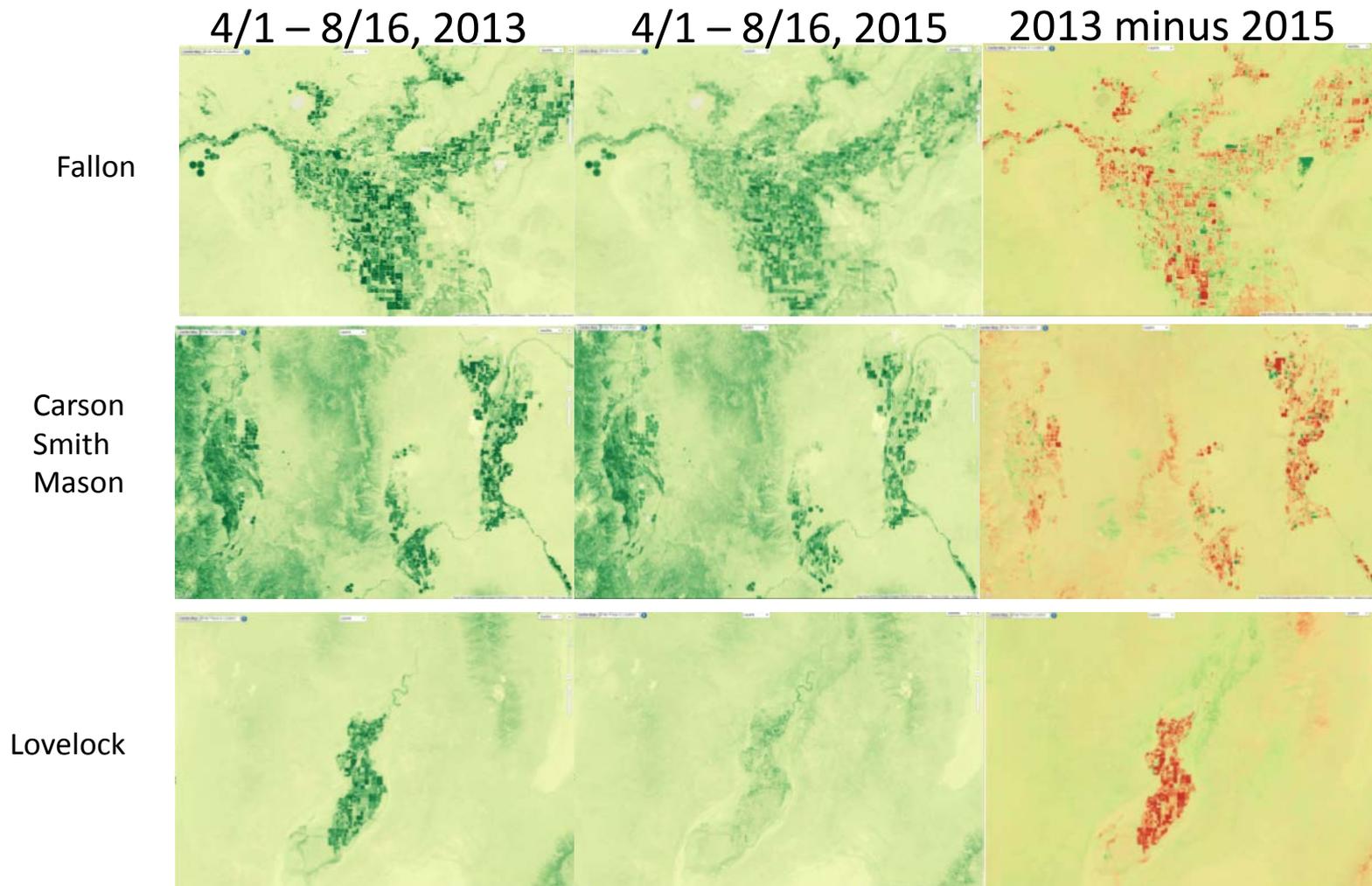
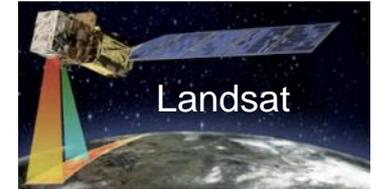
Why Variation in Hydrology and
Legal Structures Means That Drought
Looks Different Across the West

Moderator
Jason King

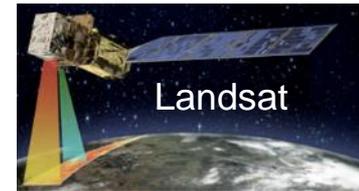
Panelists
Frank Belock
Jack Berger
Sharon Megdal

Place-Based Hydrologic and Rangeland Drought Assessments

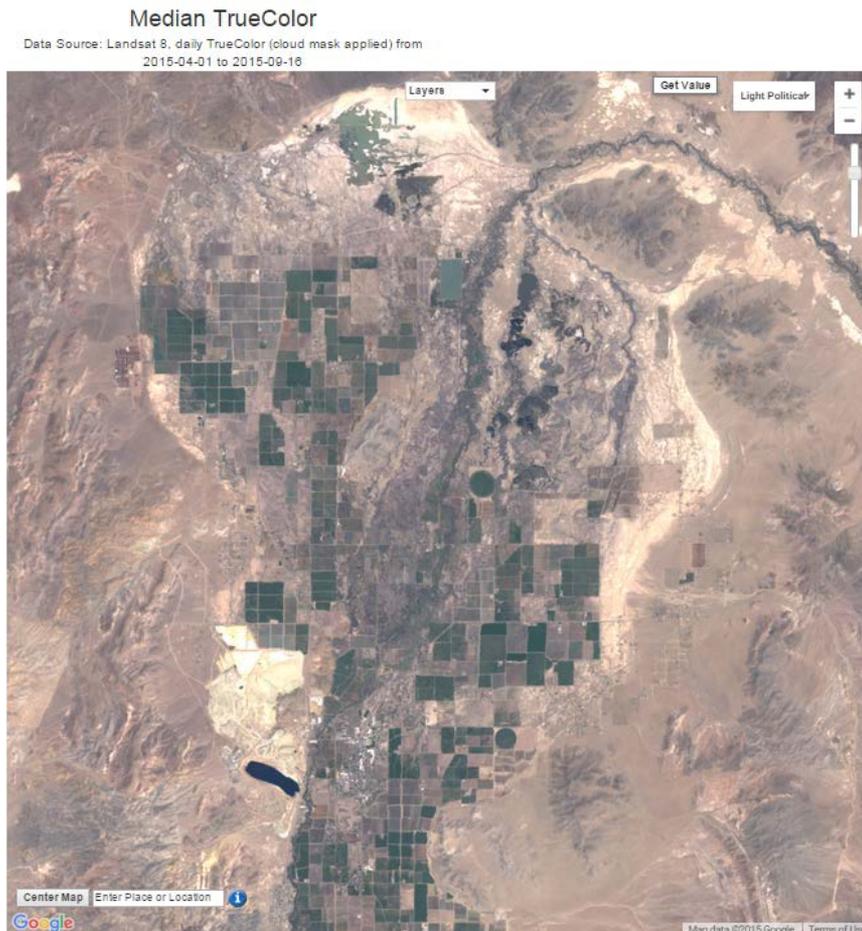
- Landsat Median Vegetation Greenness (NDVI)



Place-Based Hydrologic and Rangeland Drought Assessments

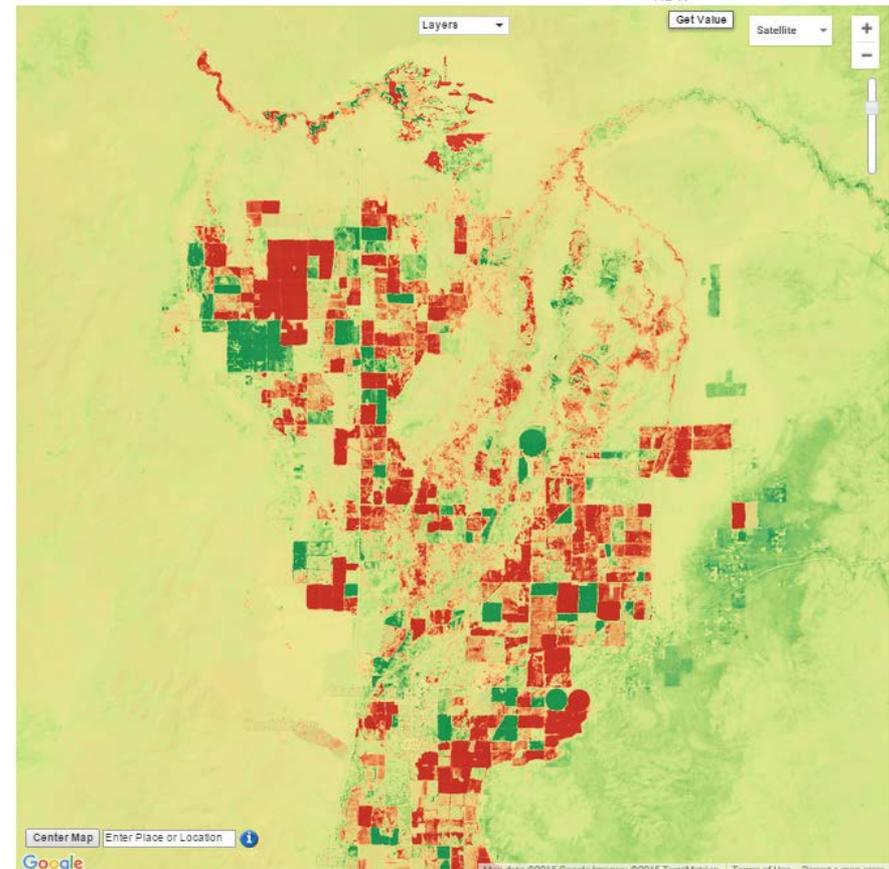
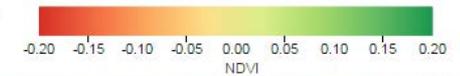


- Mason Valley 2015 difference from 2013 Greenness (April – Sept of 2015)

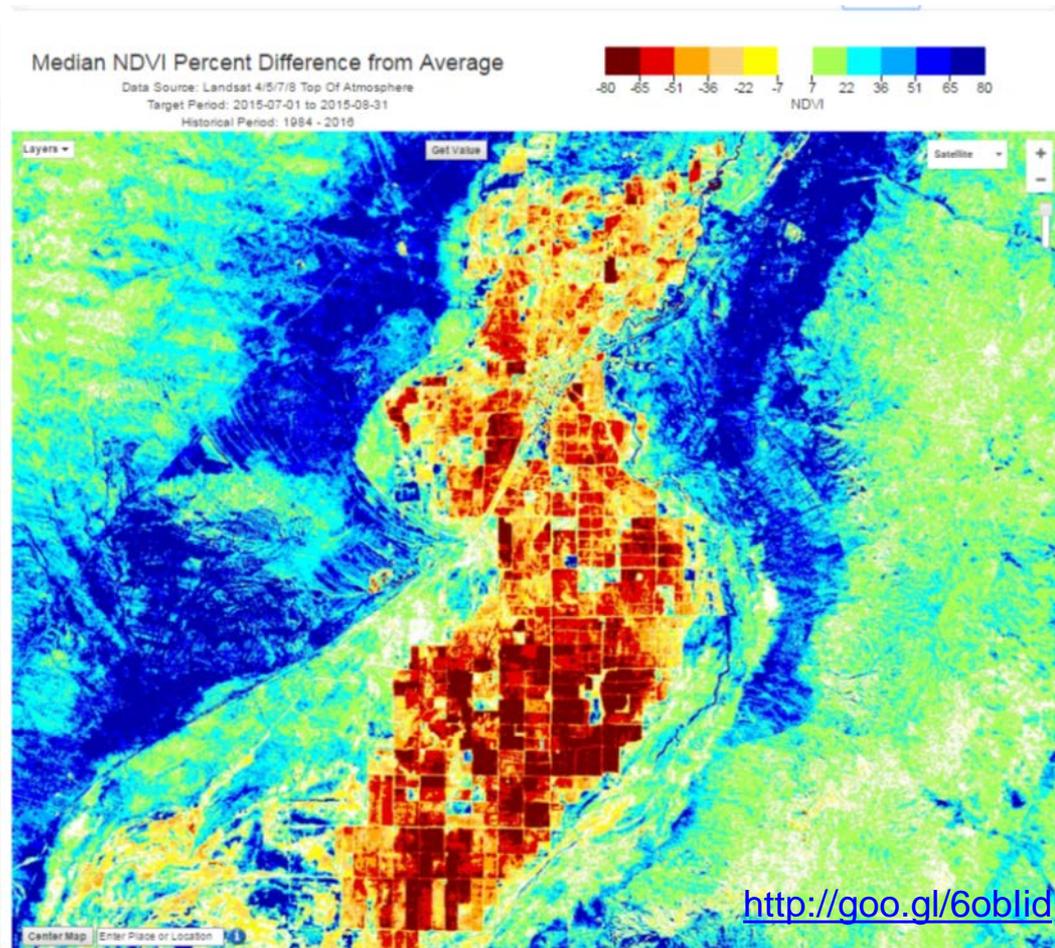


Median NDVI Difference from Average

Data Source: Landsat 8, daily NDVI (cloud mask applied) from 2015-04-01 to 2015-09-16
Average calculated from 2013-2013



Place-Based Hydrologic and Rangeland Drought Assessments



Landsat Percent Difference from Average (30yr) for July – August, 2015

Place-Based Hydrologic and Rangeland Drought Assessments

- Smith Creek Ranch (Desatoyas) 2015 difference from 2013 Greenness (April – Sept of 2015)



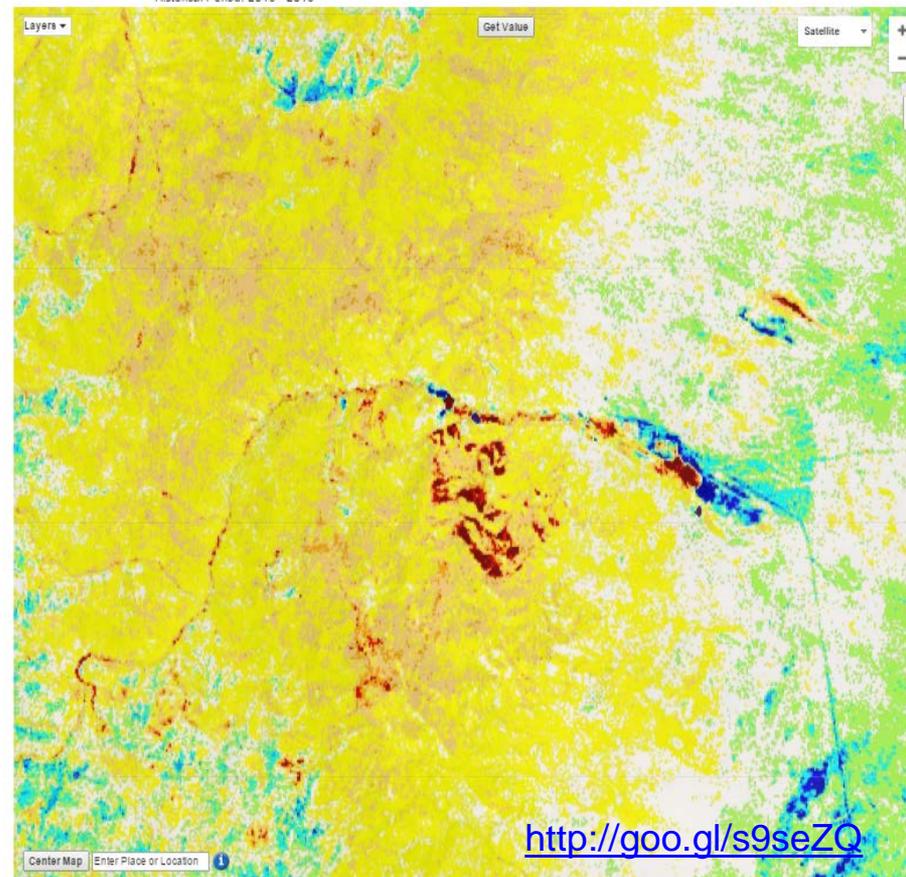
Median TrueColor

Data Source: Landsat 8, daily TrueColor (cloud mask applied) from 2015-04-01 to 2015-09-16



Median NDVI Percent Difference from Average

Data Source: Landsat 4/5/7/8 Top Of Atmosphere
Target Period: 2015-04-01 to 2015-09-30
Historical Period: 2013 - 2013



Place-Based Ecological Drought Assessments



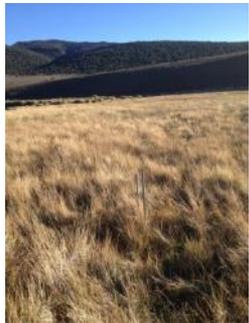
2013 July-Aug
Max NDVI



2014 July-Aug
Max NDVI



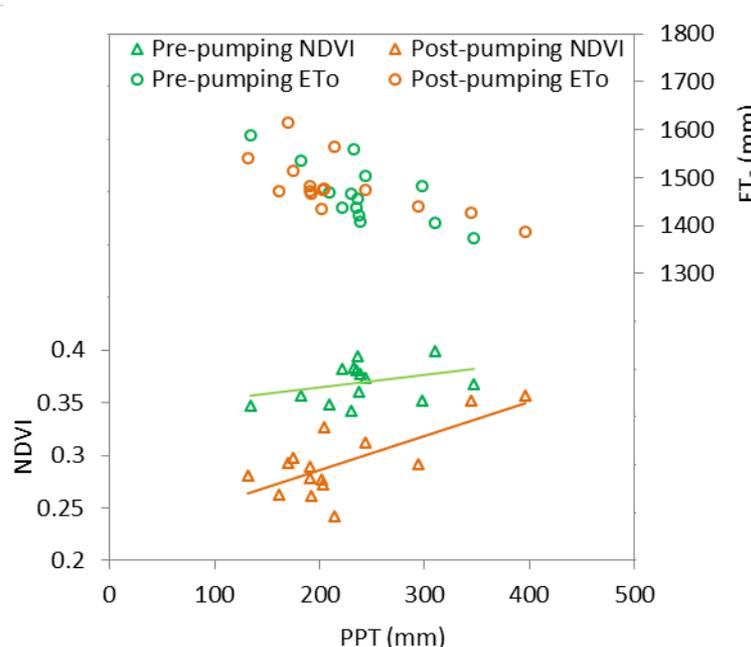
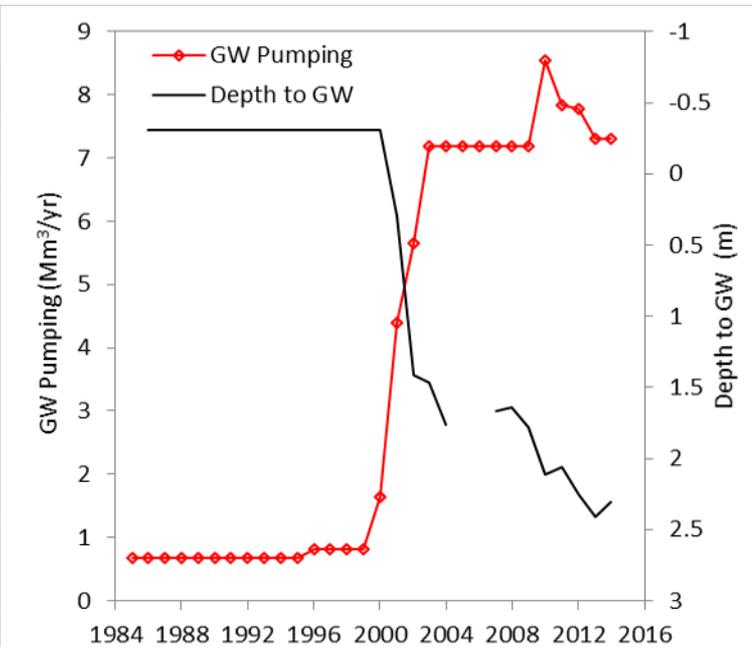
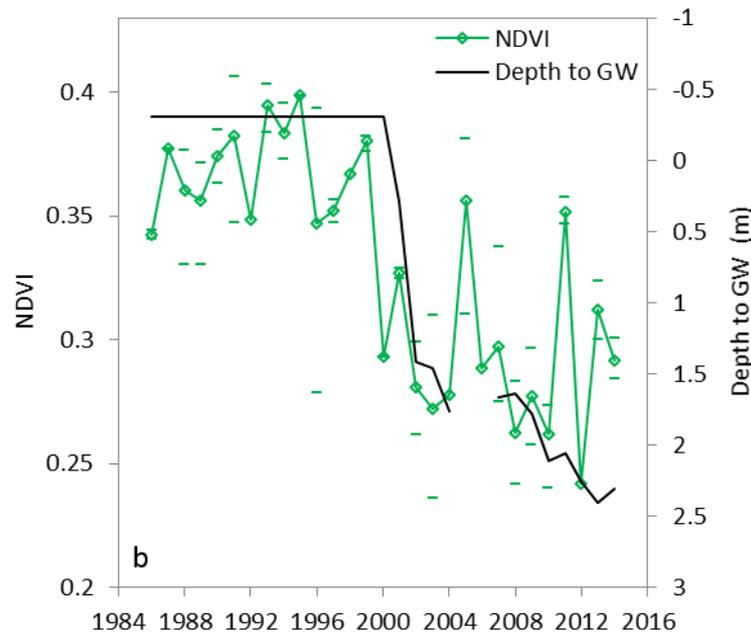
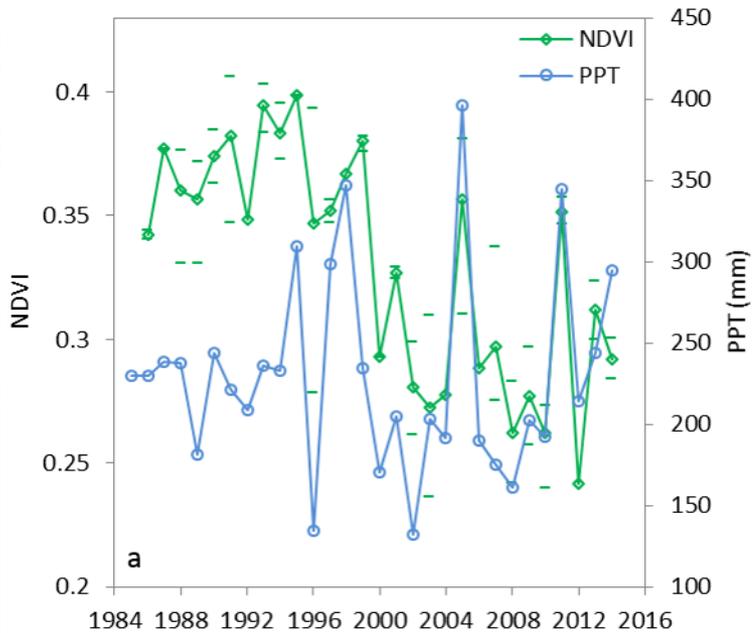
2015 July-Aug
Max NDVI



Indian Valley, NV (Upper Reese River) supports the largest sage-grouse lek counts (i.e. dance floors) in NV

Which areas are resilient to extended droughts?

Plac Assess



S



bed

cts?

dsat

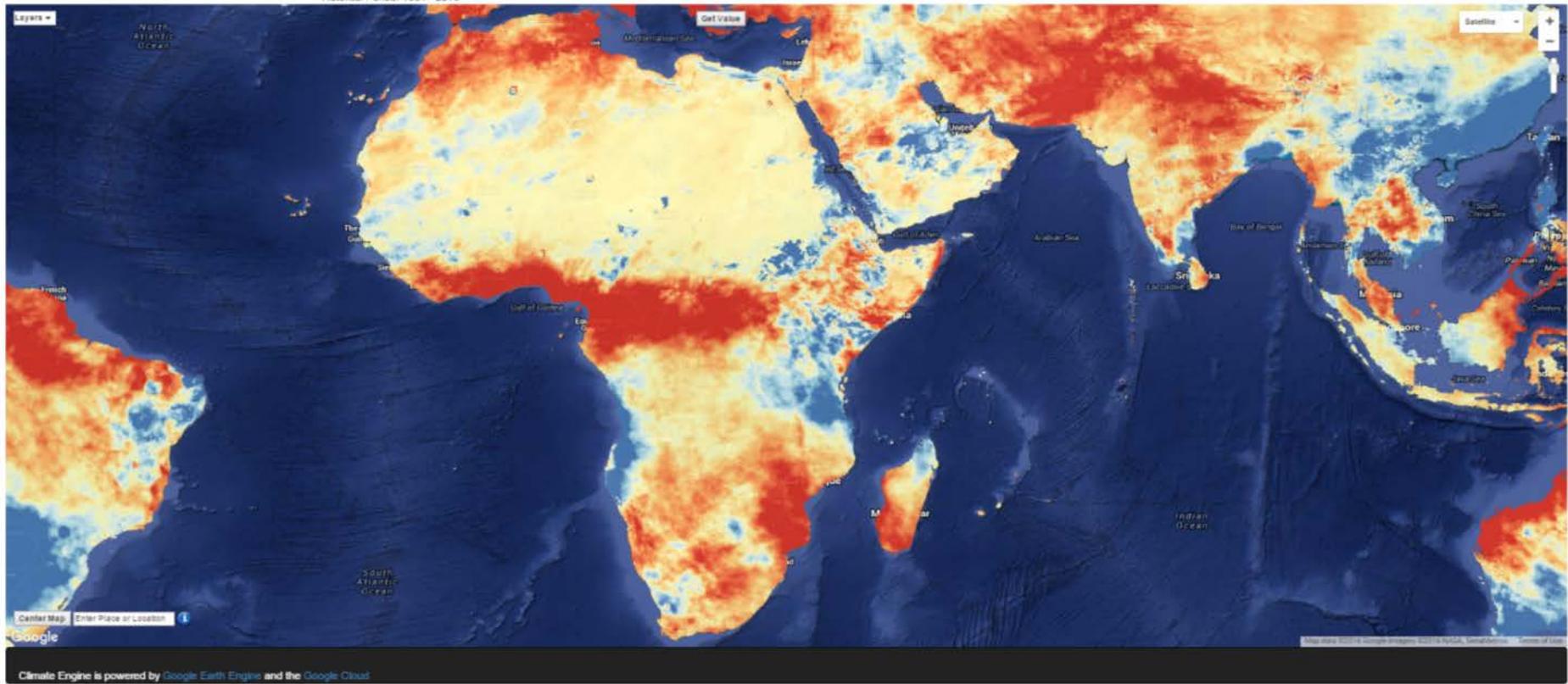
!!

Global Scale – Drought and Famine Watch

CHIRPS December-February 2015/2016 percent difference from average precipitation

Total Precipitation Percent Difference from Average

Data Source: CHIRPS 4.8-km (1/20-deg) precipitation dataset (UCSB/CHG)
Target Period: 2015-12-01 to 2016-02-28
Historical Period: 1981 - 2015



Example shows the impact of El Nino on Africa and Asia where crop failure was extreme due to low PPT

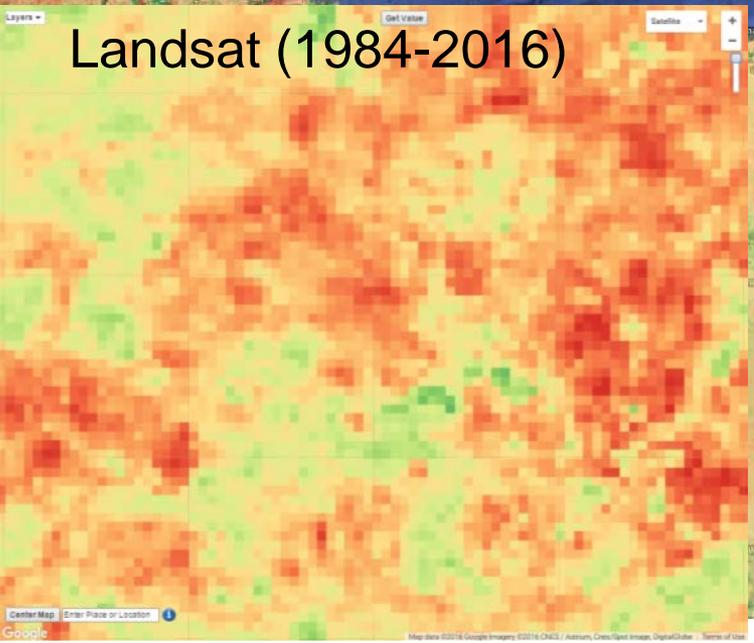
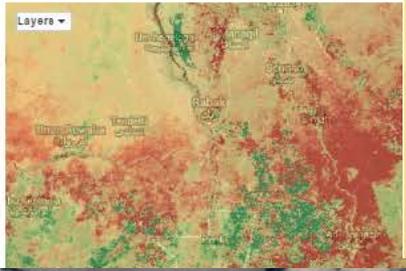
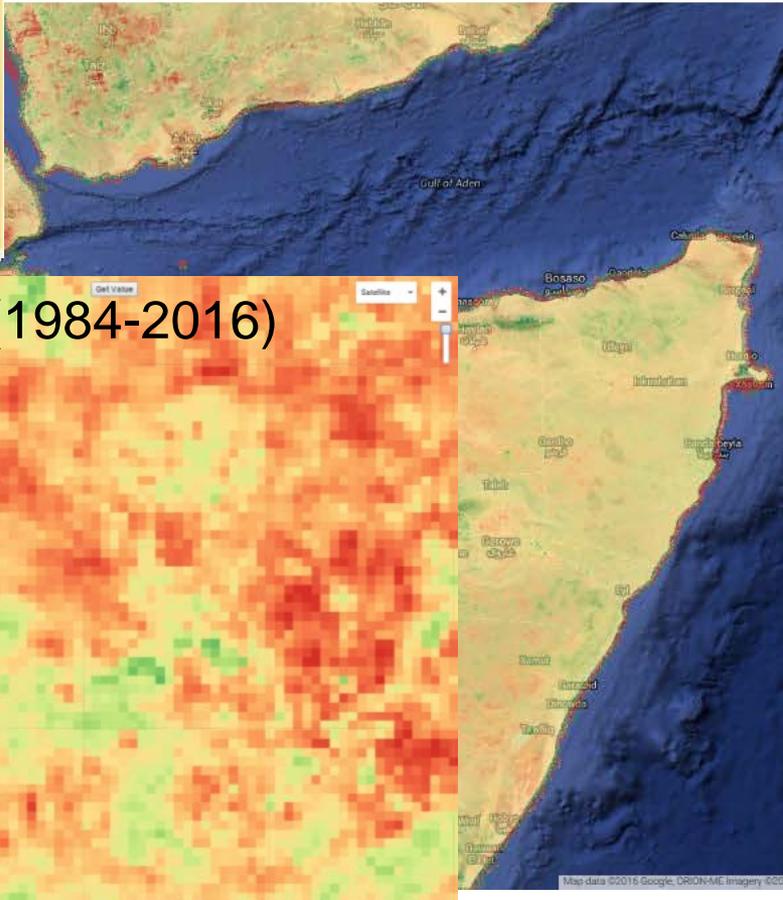
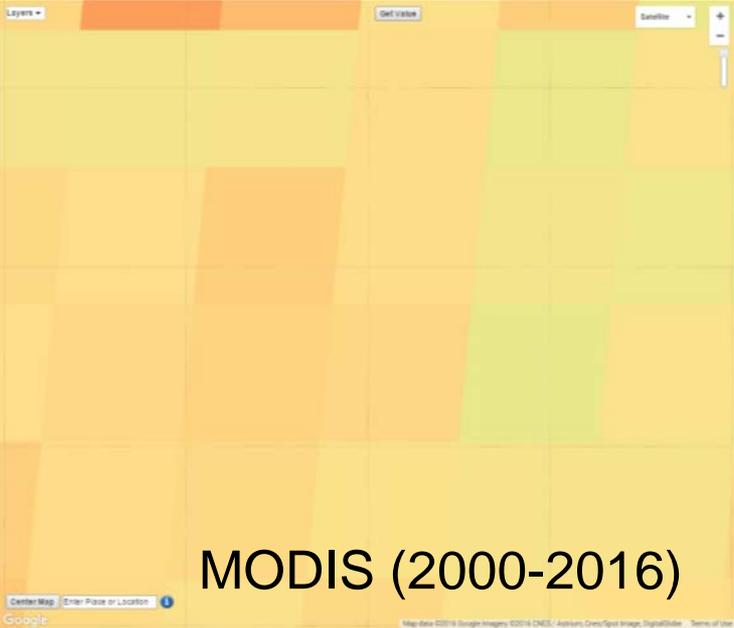
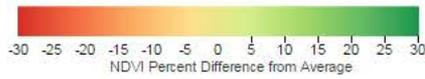
Global Scale

Light and Famine Watch

MODIS NDVI

from May – October, 2015

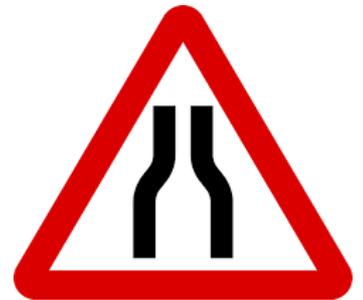
Median NDV



Example shows the impact of El Nino on Ethiopia crop failure

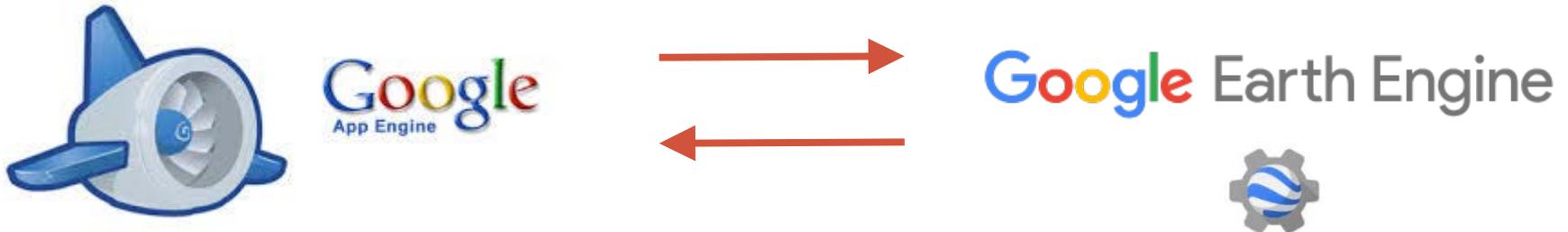
From Archives to Answers that Programmers and Non-programmers can obtain...

- Having Landsat, MODIS, and gridded climate and weather archives combined with cloud computing is super!!
- But the bottleneck is providing the ability for anyone to perform data analysis on their own
 - BLM staff, State water agencies, African field scientists, etc..
- Solution? – Link Google Earth Engine to a web-based frontend where coding by users is not needed to provide commonly needed drought/climate/water maps, metrics, and time series



Earth Engine Based Web Application for Drought Monitoring - ClimateEngine.org

- Everything shown so far was created with Earth Engine
- ClimateEngine.org relies on Google App Engine and Google Maps linked and Google Earth Engine through the Python API
- Users input collection and time parameters -> Google App Engine passes these parameters to Google Earth Engine -> results return to Google App Engine



How We Started, Motivation, Our Team

How We Started

- Our project was funded through a **Google** Earth Engine Faculty Research Award in Summer of 2014

Motivation

- Develop a web application that allows the public to visualize global and place based maps and time series of climate and remote sensing archives together and in near real-time, for drought, climate, and vegetation monitoring and post processing and, **data discovery**



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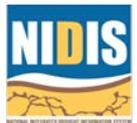
Donovan VanSant

Graduate Student
University of Idaho, Moscow
vans1746 [at] vandals.uidaho.edu

Now collaborating with:

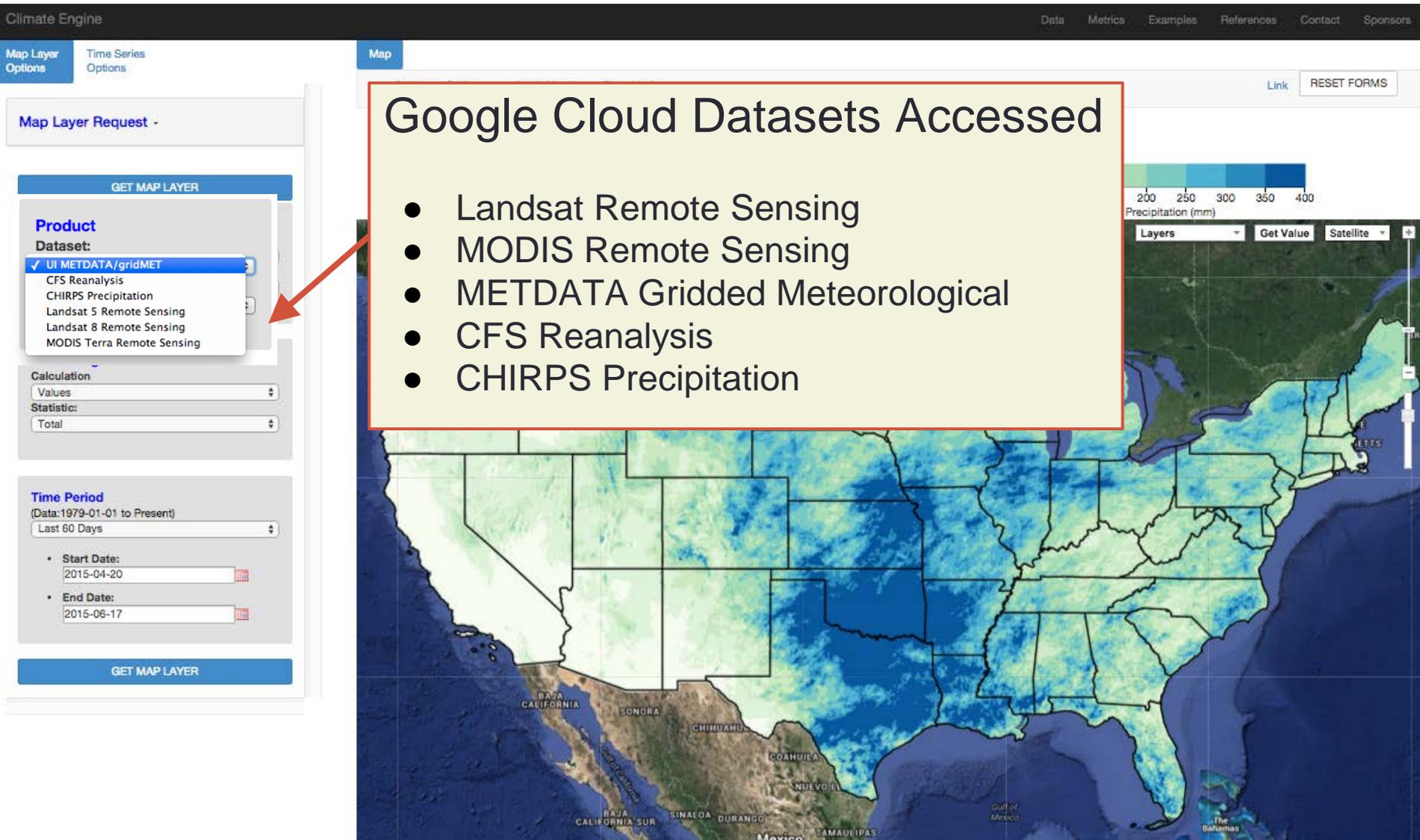


UC Santa Barbara

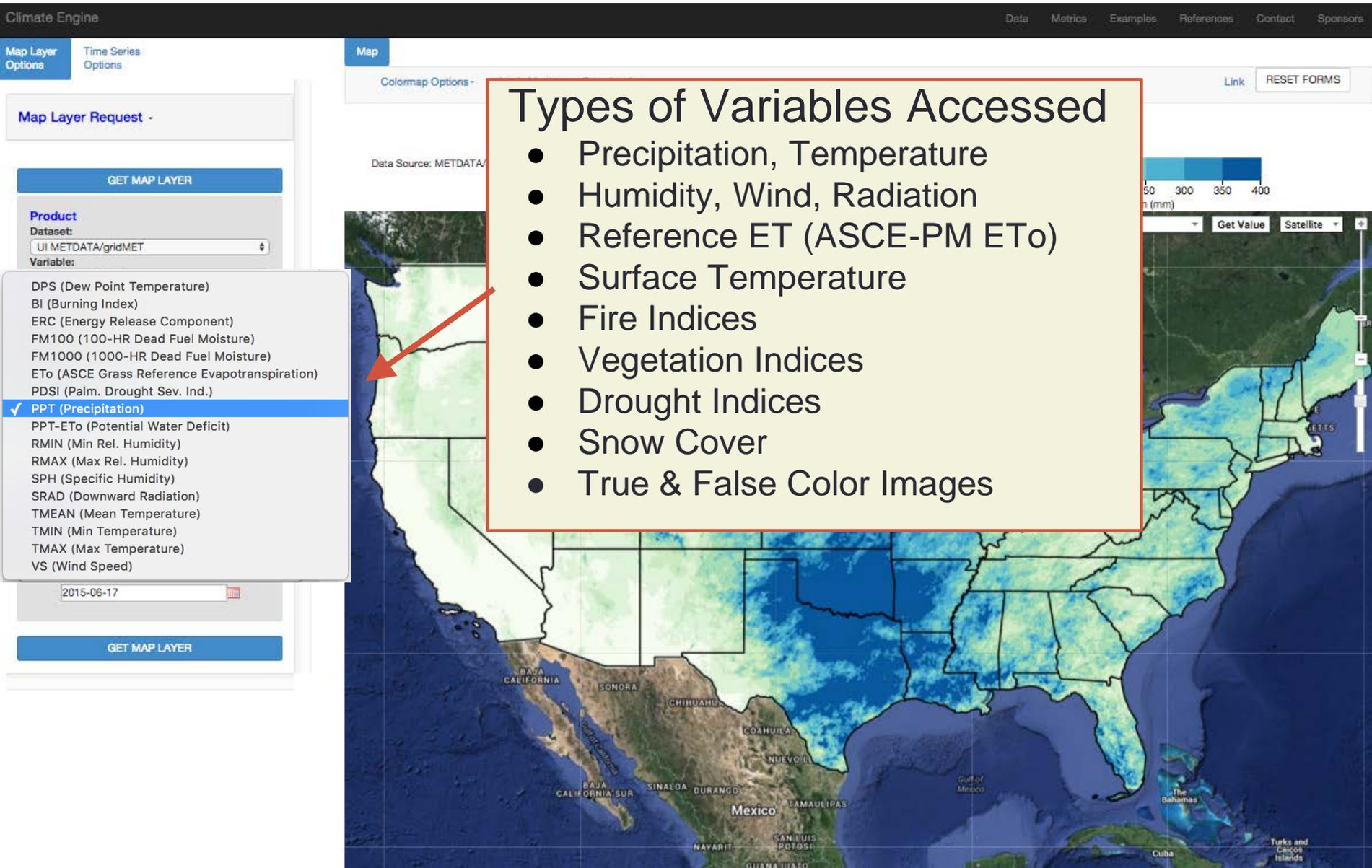


Recently Unveiled at the White House Water Summit

Google Cloud Assets



Variables Computed or Accessed



Time Series at Point Locations

Climate Engine

Data Metrics Ex

Map Layer
Options

Time Series
Options

Map

Colormap Options - Apply Mask - Download -

Time Series Request -

GET TIME SERIES

Time Series Calculation:

Daily Data over Time Period

One Variable Analysis

Region:

Points

Point(s):

Marker	Zoom	Location	Name
<input checked="" type="checkbox"/>			<input type="text"/>
<input checked="" type="checkbox"/>		-121.8328,37.32	<input type="text"/>
<input checked="" type="checkbox"/>		-120.6352,35.46	<input type="text"/>
<input checked="" type="checkbox"/>		-119.0971,35.34	<input type="text"/>
<input checked="" type="checkbox"/>		-119.7673,36.70	<input type="text"/>
<input checked="" type="checkbox"/>		-120.4484,37.32	<input type="text"/>

Product 1

Product 1

Dataset:

UI METDATA/gridMET

Variable:

PPT (Precipitation)

Time Period 1

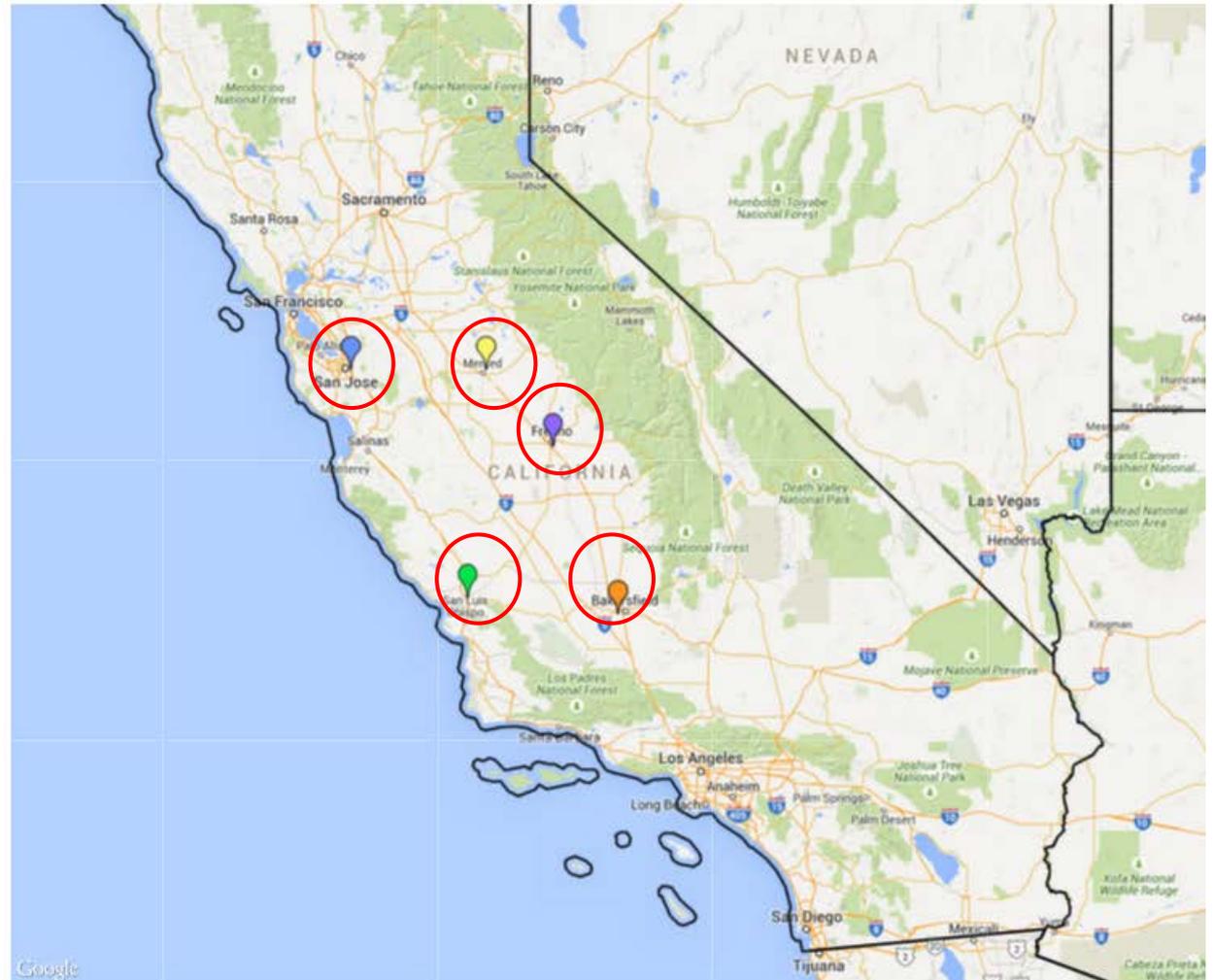
(Data:1979-01-01 to Present)

Last 60 Days

Start Date:

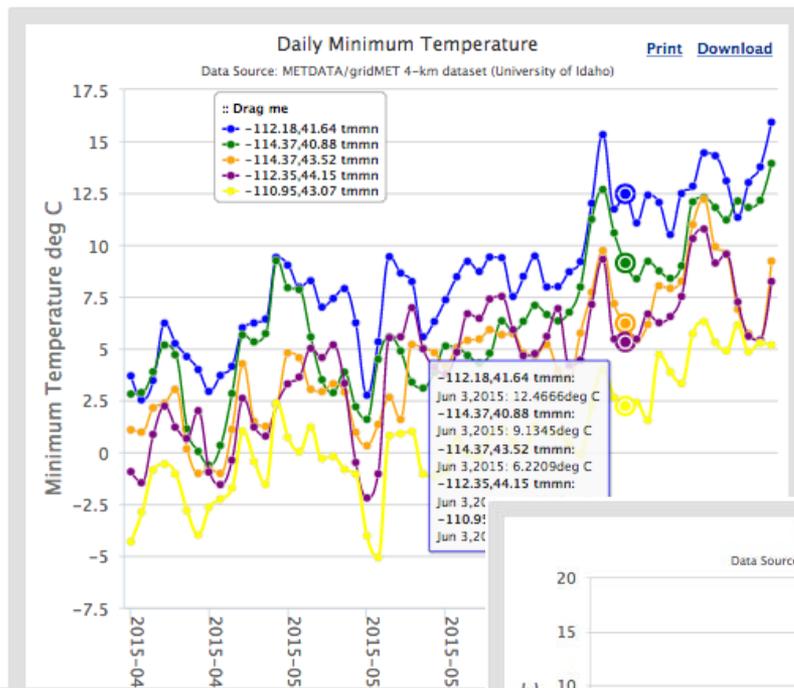
2015-04-21

End Date:

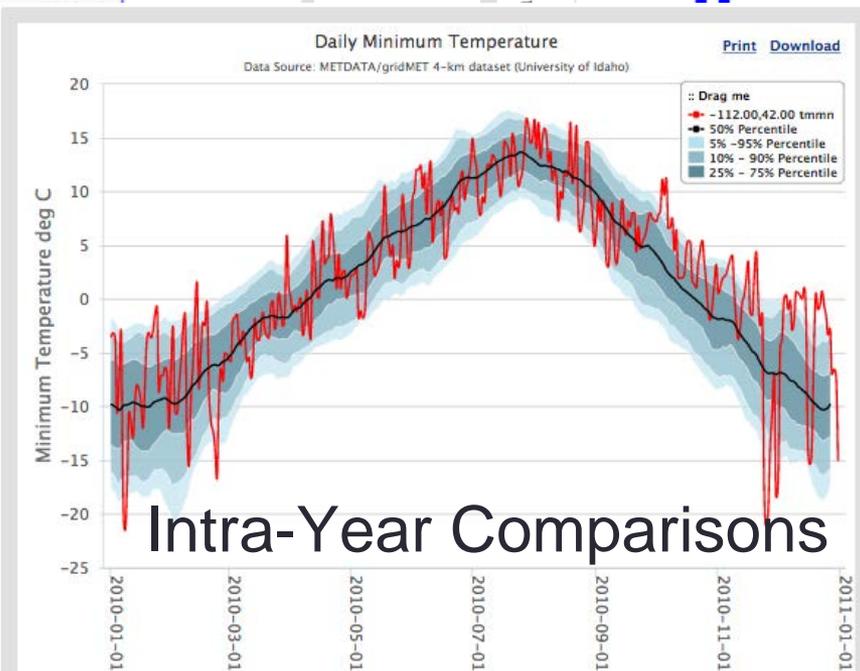
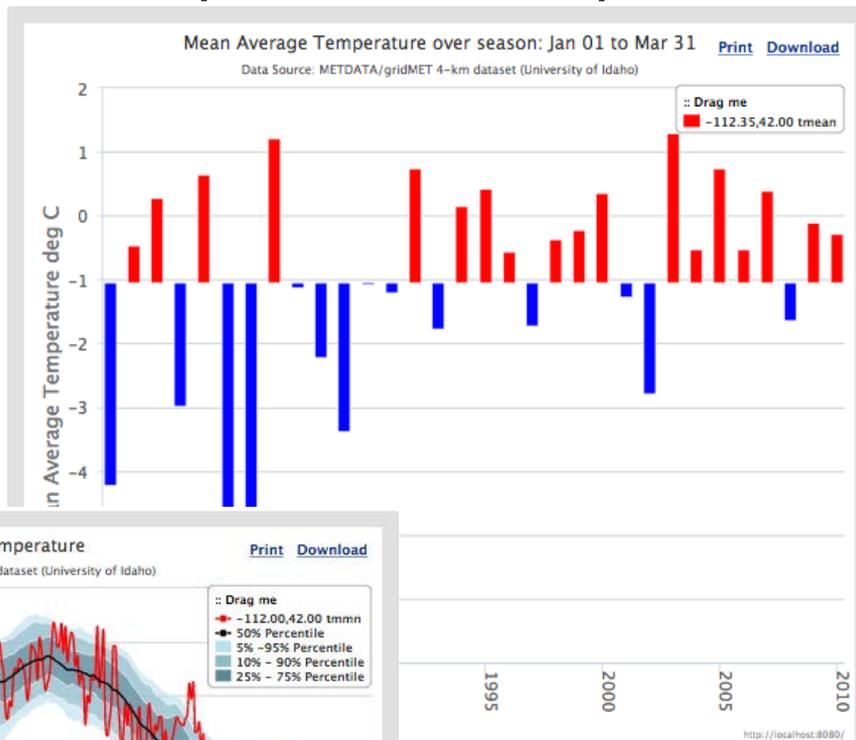


Time Series Summaries

Multiple-Region Comparisons



Multiple-Year Comparisons

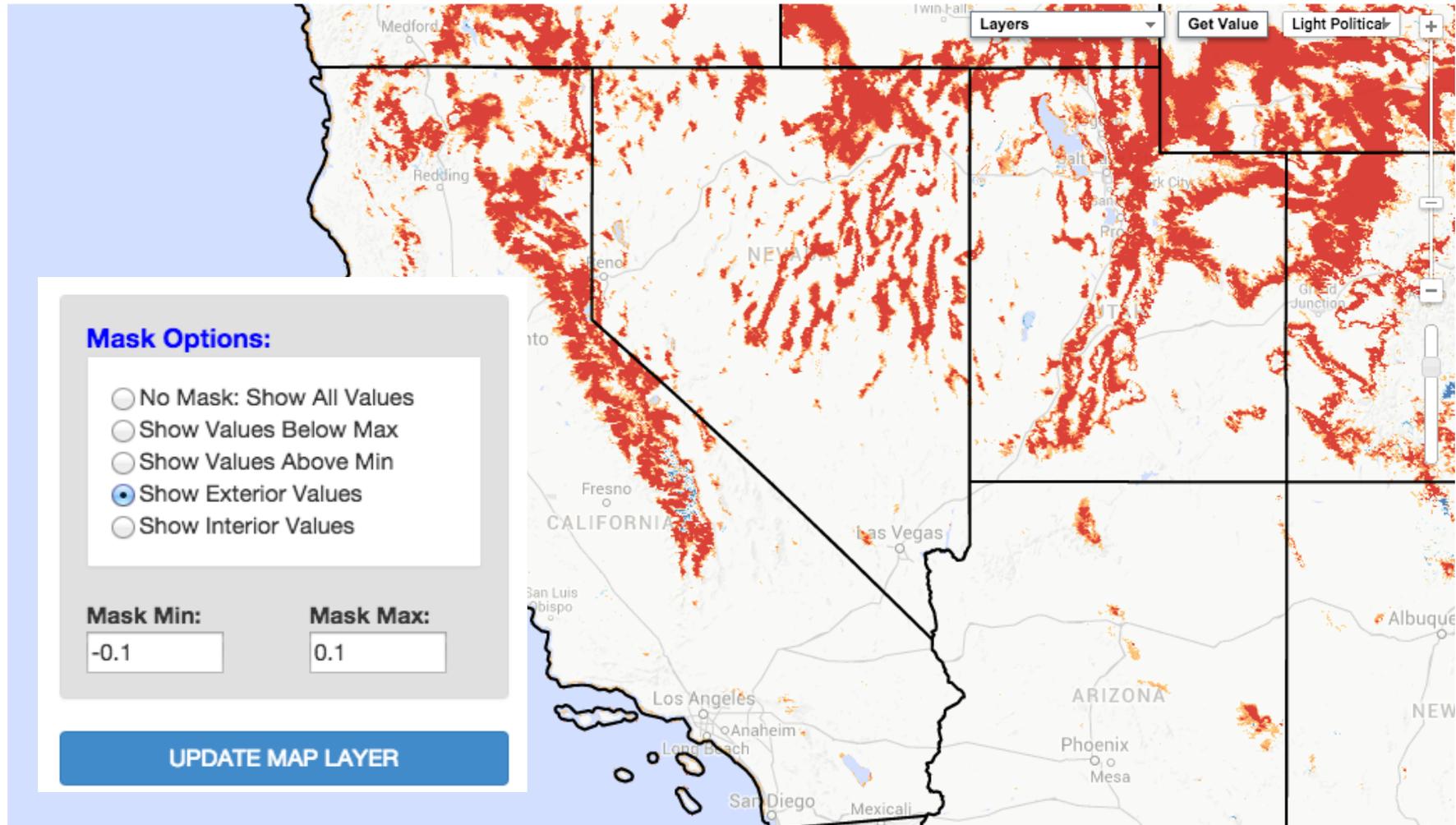
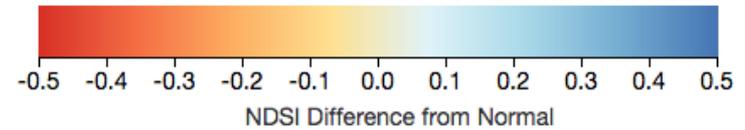


Intra-Year Comparisons

Custom Masking

Median NDSI Difference from Average

Data Source: MODIS 16-day average NDSI from 2014-10-01 to 2015-04-01
Average calculated from 2000-2010



Spatial Averaging in Time

Landsat 7 and 8 NDVI Time Series for 2014 – Alfalfa Field

Map Layer Options | Time Series Options | INFO | HIDE MENU

GET TIME SERIES

Time Series Calculation: ?
Raw Data over Time Period
One Variable Analysis

Region: ?
Area Averages

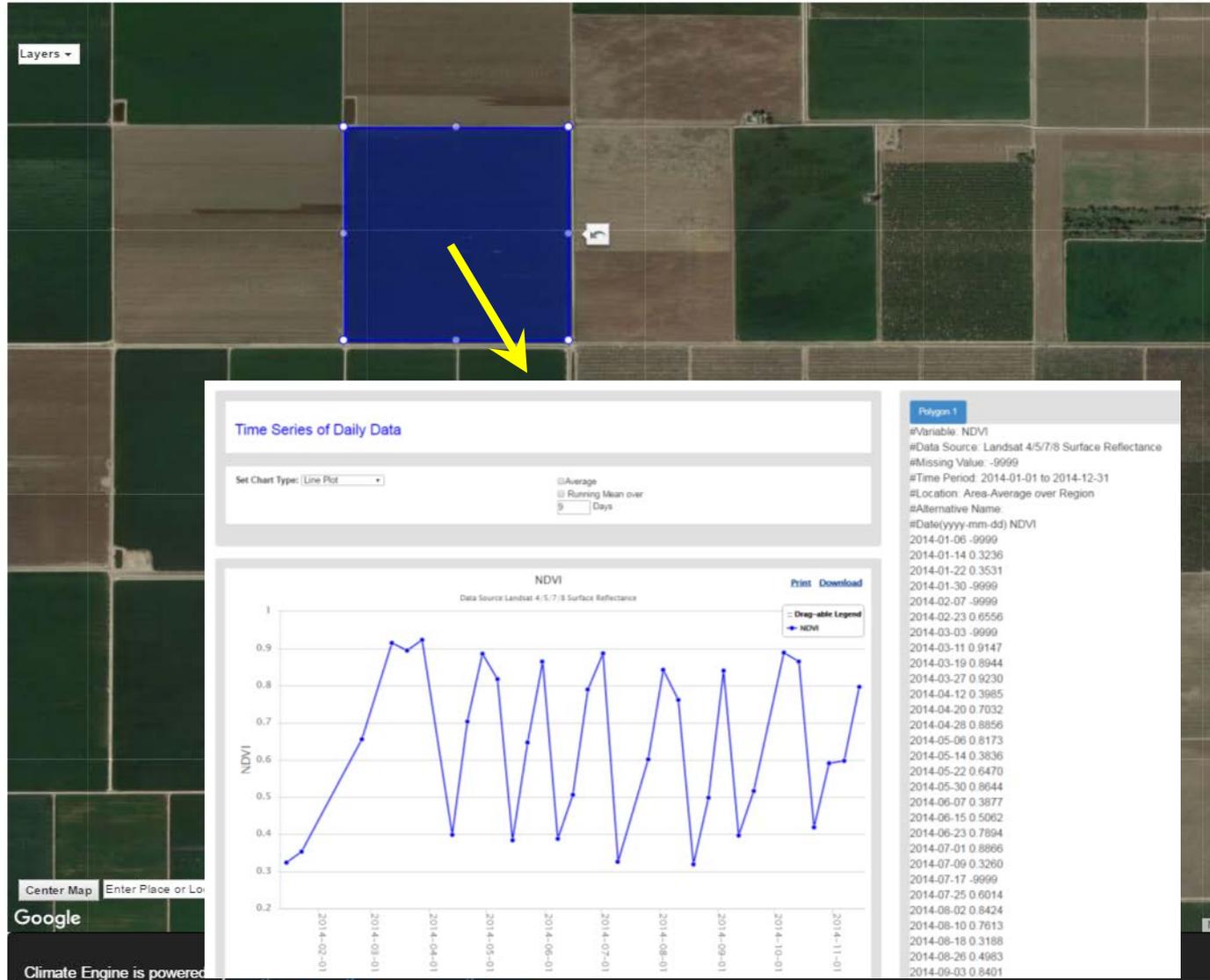
Area of Interest: ?
 Polygon

Variable 1

Variable 1 ?
Type: Remote Sensing
Dataset: Landsat 4/5/7/8 Surface Reflectance
Variable: NDVI (Vegetation Index)
Time Period: (Data: 1982-01-01 to 2016-06-07)
Custom
Start Date: 2014-01-01
End Date: 2014-12-31

GET TIME SERIES

Plot Options



Download Maps

The screenshot displays the Climate Engine web application interface. The browser tabs include "Inbox - Outlook Web App", "Pandora One - Listen", "USGS WebEx Enterprise", "Figures - Climate Engine", and "Climate Engine". The address bar shows the URL: `clim-engine.appspot.com/climateEngineExpert?toolAction=downloadRectangleSubset&productType=RS&product=M&variable=NDSI&statistic=Median&calculation=anom&units=metric&varUnits=&dateStart=21`.

The page header features the "Climate Engine Beta" logo and navigation links: "Guided Tours", "Video Tutorials", "Examples", "Manual", "Contact", "ClimateEngine", "Data", "Metrics", "References", and "Sponsors".

The interface is divided into several sections:

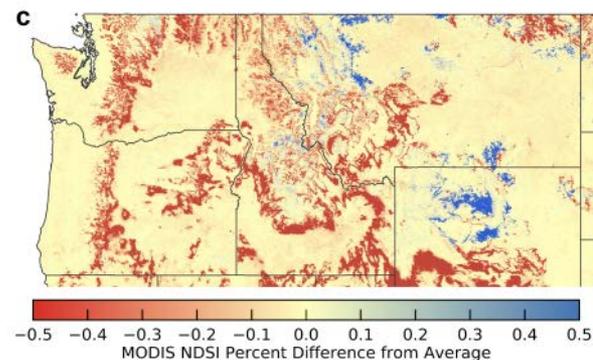
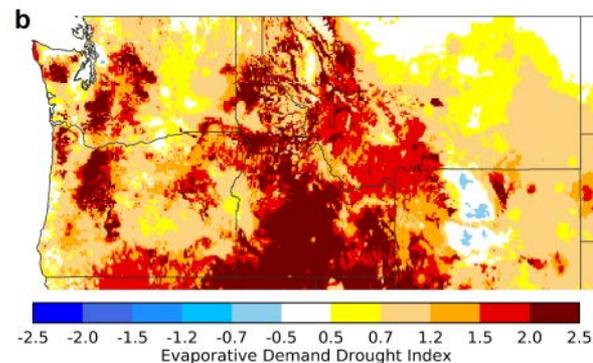
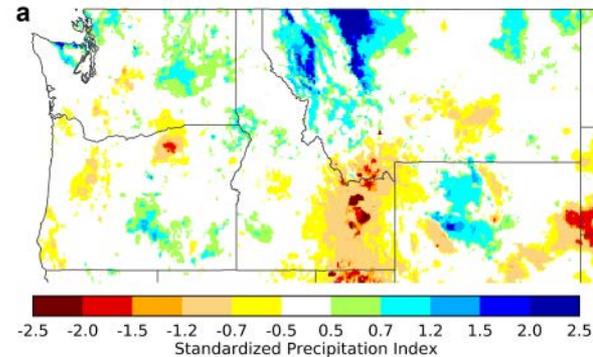
- Map Layer Options:** Includes "GET MAP LAYER" buttons and dropdown menus for "Product" (Remote Sensing), "Dataset" (MODIS Terra), "Variable" (NDSI (Snow Index)), "Processing" (Difference From Average Conditions, Median), and "Time Period" (2014-10-01 to 2015-03-31).
- TOGGLE MENU:** Contains "Map" and "Annotations" tabs.
- Download Panel:** A modal window titled "Download Map Layer" with the following settings:
 - Download Resolution: 0.5 km
 - Download Projection: WGS84 for Google Earth
 - Download Format: GEO TIFF
 - Download Filename: Auto-Fill (ndsi)
 - Select a Region: No Region Selected
 - Rectangle Information:
 - NE corner: 50.0000 N, -107.8359 E
 - SW corner: 41.0741 N, -126.0000 E

- Map:** A satellite map of the United States with a color scale for "NDSI Difference from Average" ranging from -0.5 (red) to 0.5 (blue). A black rectangle highlights a region in the western US. A "Get value" button is visible on the map.

Bring Maps into GIS for Publication

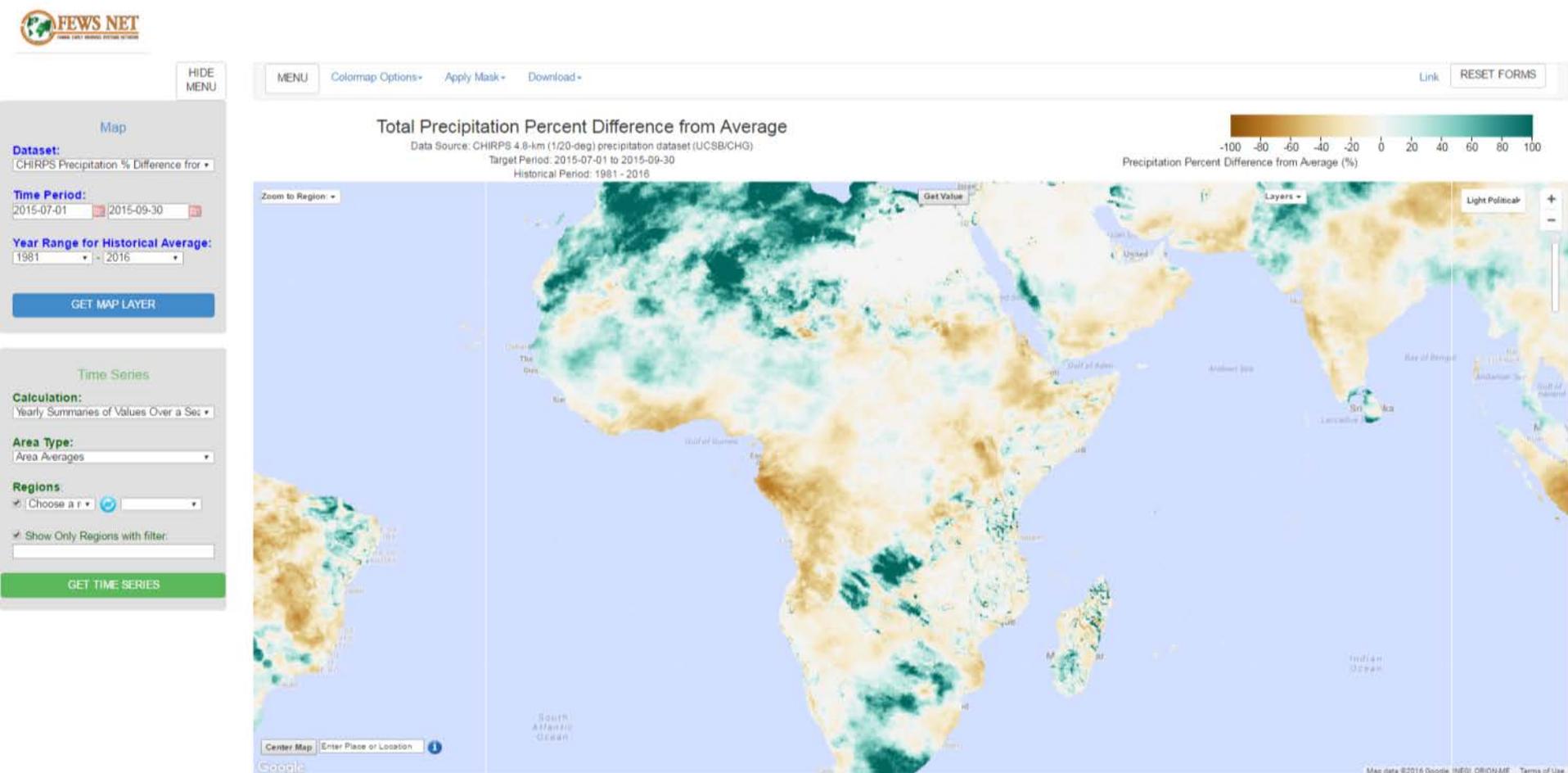
Pacific Northwest Snow Drought

- SPI from Oct. 2014 to March 2015 is largely normal in Cascades N. Rockies
- Evaporative Demand High (high temp and solar radiation)
- Let to high snow line, high snow melt, and “snow drought”
- Download answers instead of archives!!



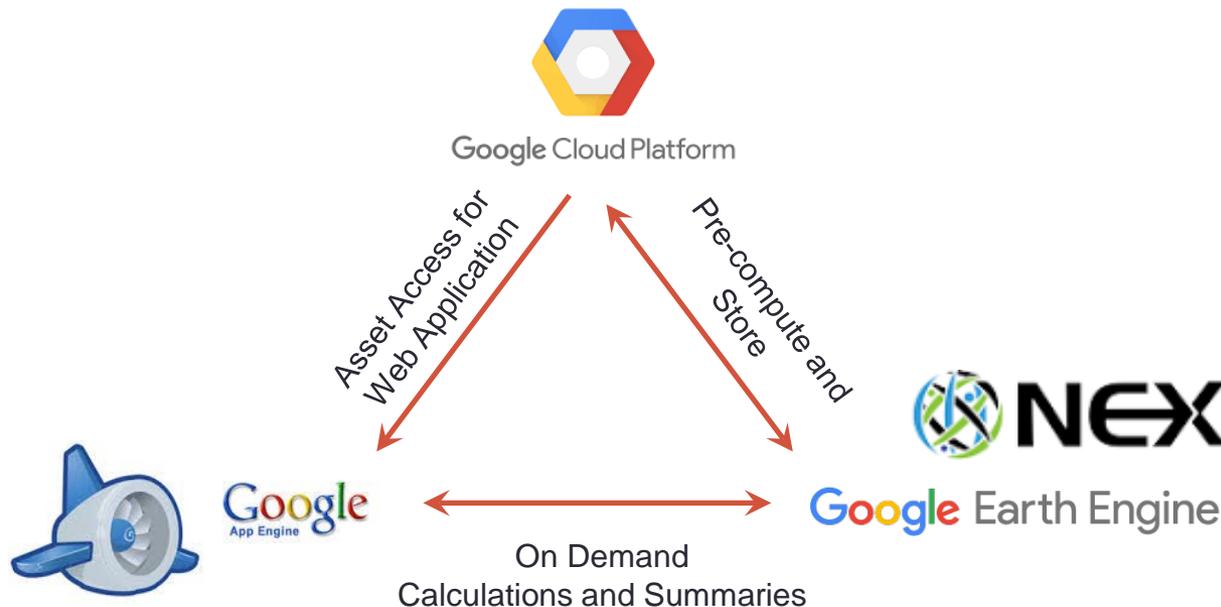
Created Spin-off App. For Famine Early Warning System

- Took all the core assets and functions of ClimateEngine.org and made it FEWS NET focused
- Collaboration with UC Santa Barbara, USGS, and USAID



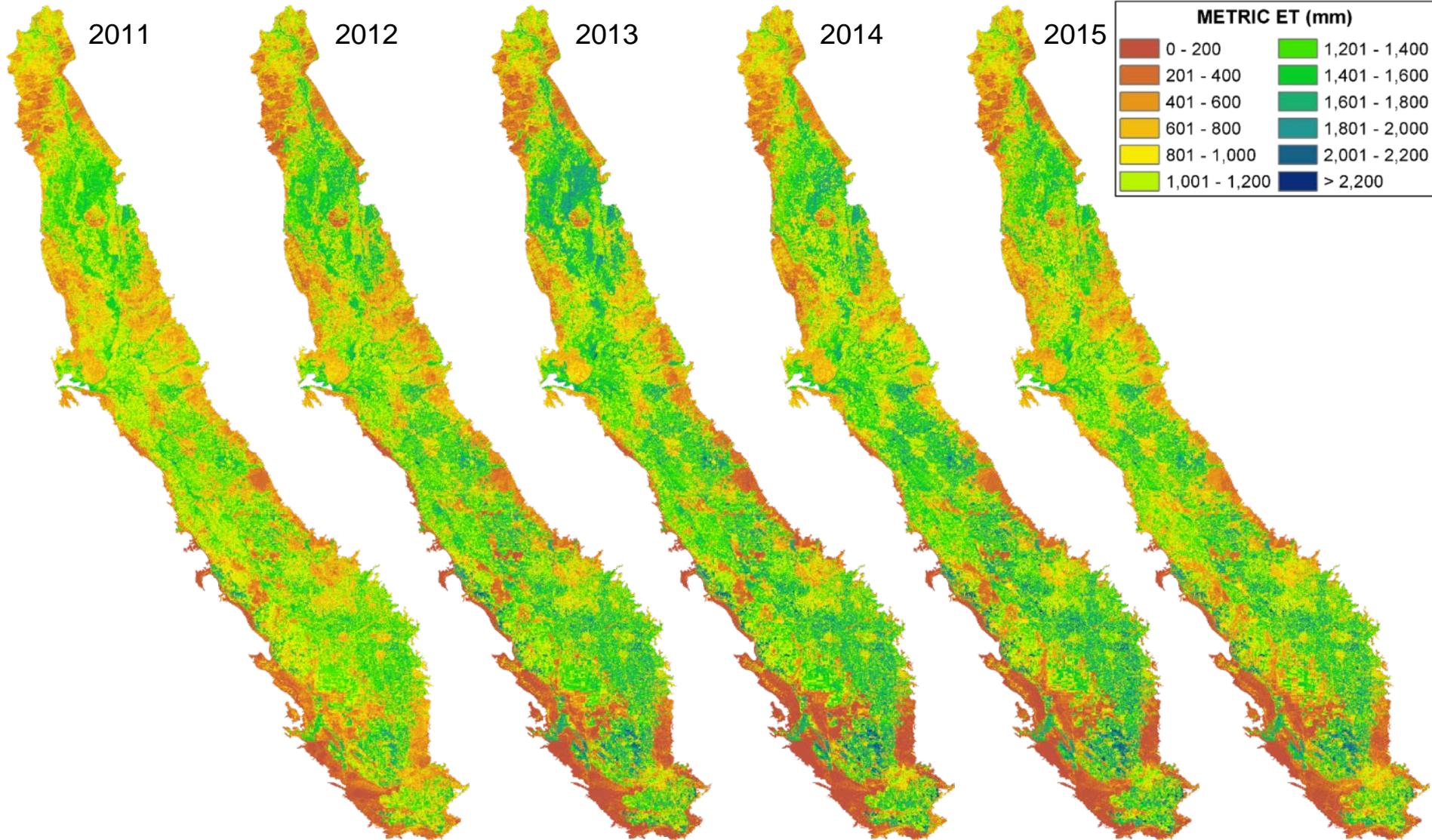
Future Directions – Export.image.toAsset

- New Earth Engine asset manager allows users to create data and export “assets” to the cloud
- Assets can then be accessed through a web application like ClimateEngine.org
 - New ability to programmatically and operationally compute, store, and access data in the cloud is really powerful and exciting..game changer!!



ET for the last 5 years generated on

- Lower ET during drought in water limited areas
- Higher ET during drought in well-watered areas



Our First Test

Uploaded NEX pre-computed Landsat monthly METRIC ET (2011-2015) to asset manager, and accessed in the Earth Engine Playground and ClimateEngine.org

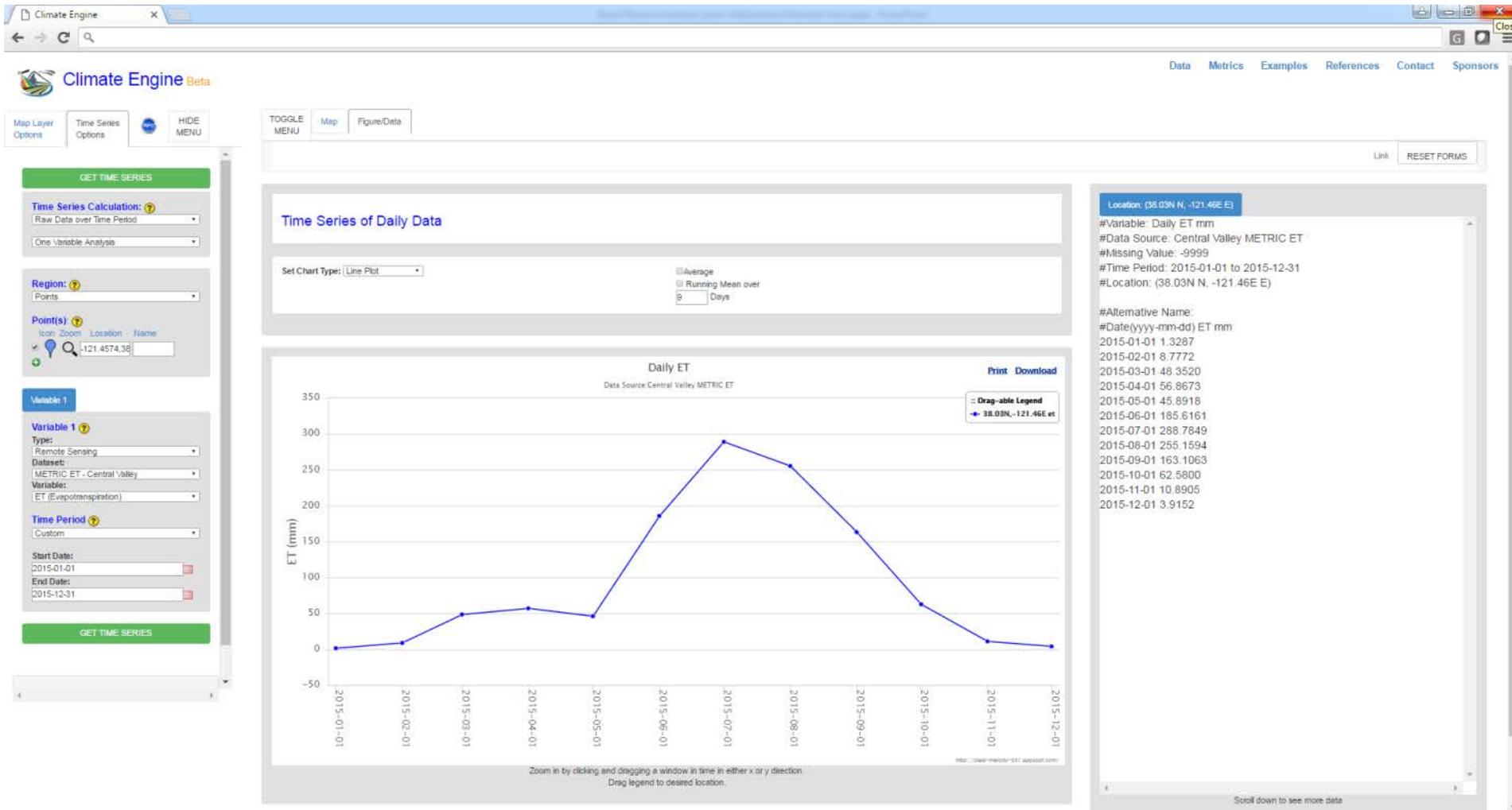
The screenshot displays the Google Earth Engine Playground interface. At the top, the search bar contains "Search places and datasets...". Below it, the code editor shows the following JavaScript code:

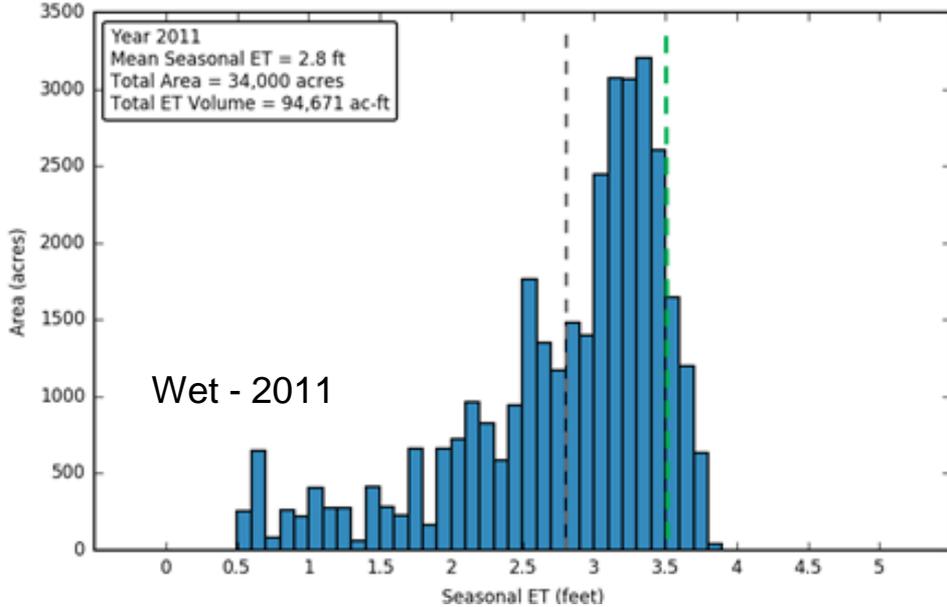
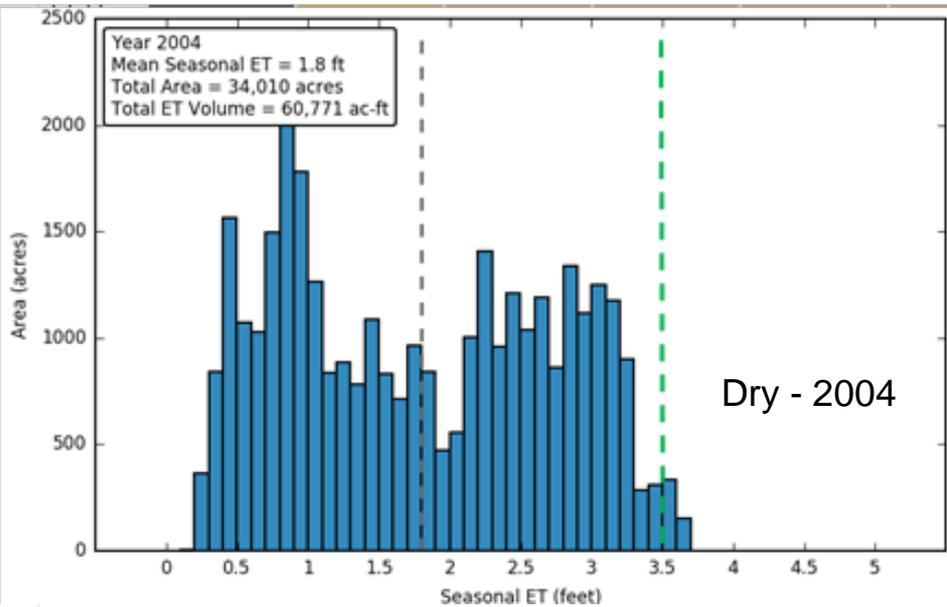
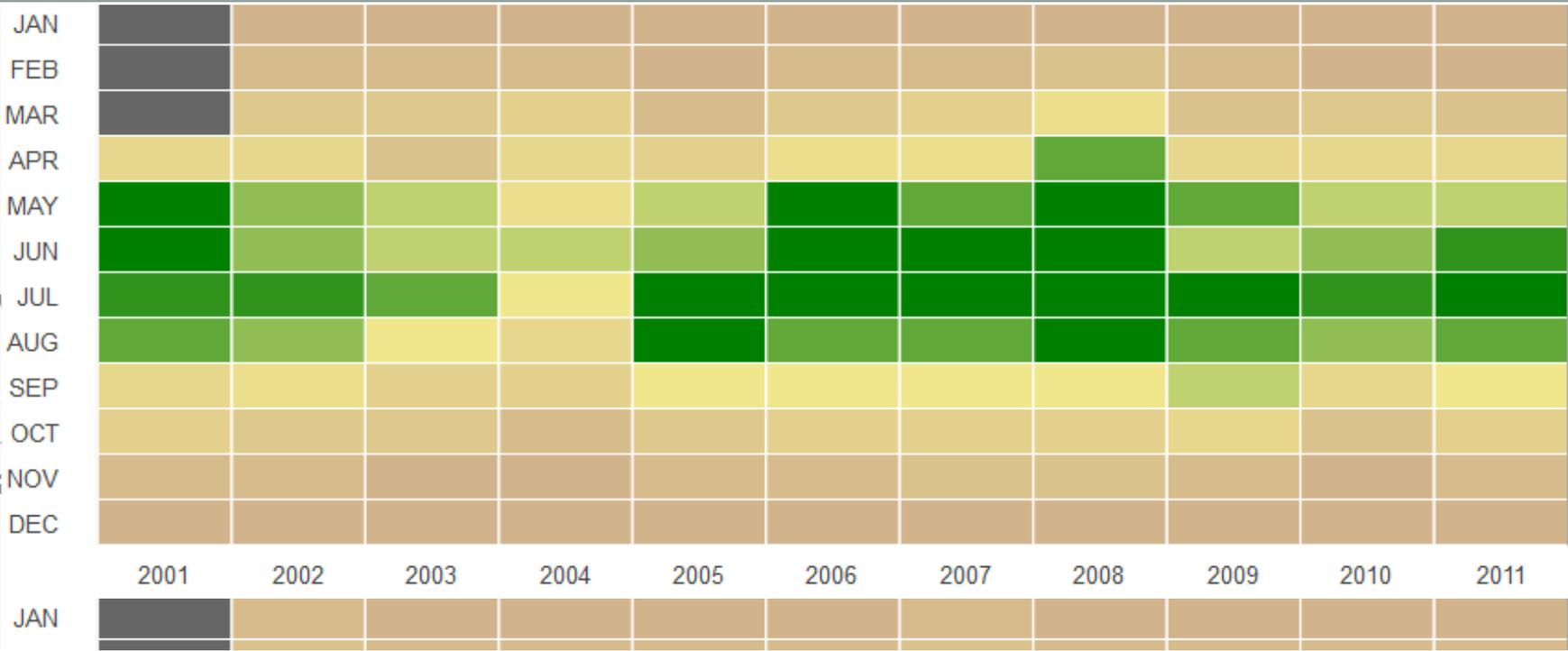
```
5 //print(et_coll);
6 //print(etr_coll);
7 //print(etr_f_coll);
8
9 function mask_nodata(image){
10   return image.updateMask(image.gt(-3.40282e+38)); }
11 et_coll = et_coll.map(mask_nodata);
12 etr_coll = etr_coll.map(mask_nodata);
13 etrf_coll = etrf_coll.map(mask_nodata);
14
15 var ETof_PALETTE = 'F5F5DC, D2B48C, 40E0D0, 80FF00, 006400, 0000FF';
16 //Map.addLayer(ee.Image(et_coll.mean()), {min:0, max:300, palette:ETof_PALETTE}, 'ET');
17 //Map.addLayer(ee.Image(etr_coll.mean()), {min:0, max:300, palette:ETof_PALETTE}, 'ETr');
18 Map.addLayer(ee.Image(etr_f_coll.mean()), {min:0, max:1.1, palette:ETof_PALETTE}, 'ETrF');
19 Map.centerObject(etr_f_coll, 7);
20
21
22 // Join two collections on system index
23 function joinCollections(imagecollection1, imagecollection2) {
24   var filterTimeEq = ee.Filter.equals({
25     leftField: 'system:index',
26     rightField: 'system:index'
27   });
28   var joined = ee.Join.inner().apply(
29     imagecollection1, imagecollection2, filterTimeEq);
30   return joined.map(function(feature) {
```

The console on the right shows the title "ET and Reference ET" and a line graph. The y-axis is labeled "ET (mm)" and ranges from 0 to 400. The x-axis shows dates from Jan 2011 to Jan 2015. Two lines are plotted: a blue line for "ET" and a red line for "ETr". Both lines show a strong seasonal cycle, with peaks around 300 mm and troughs near 0 mm. The "ETr" line generally follows the "ET" line but with slightly higher peaks and lower troughs.

At the bottom, the map shows a satellite view of a rural area with a red location pin. The interface includes standard map controls like zoom in (+) and zoom out (-) buttons, and a "Layers" panel on the right.

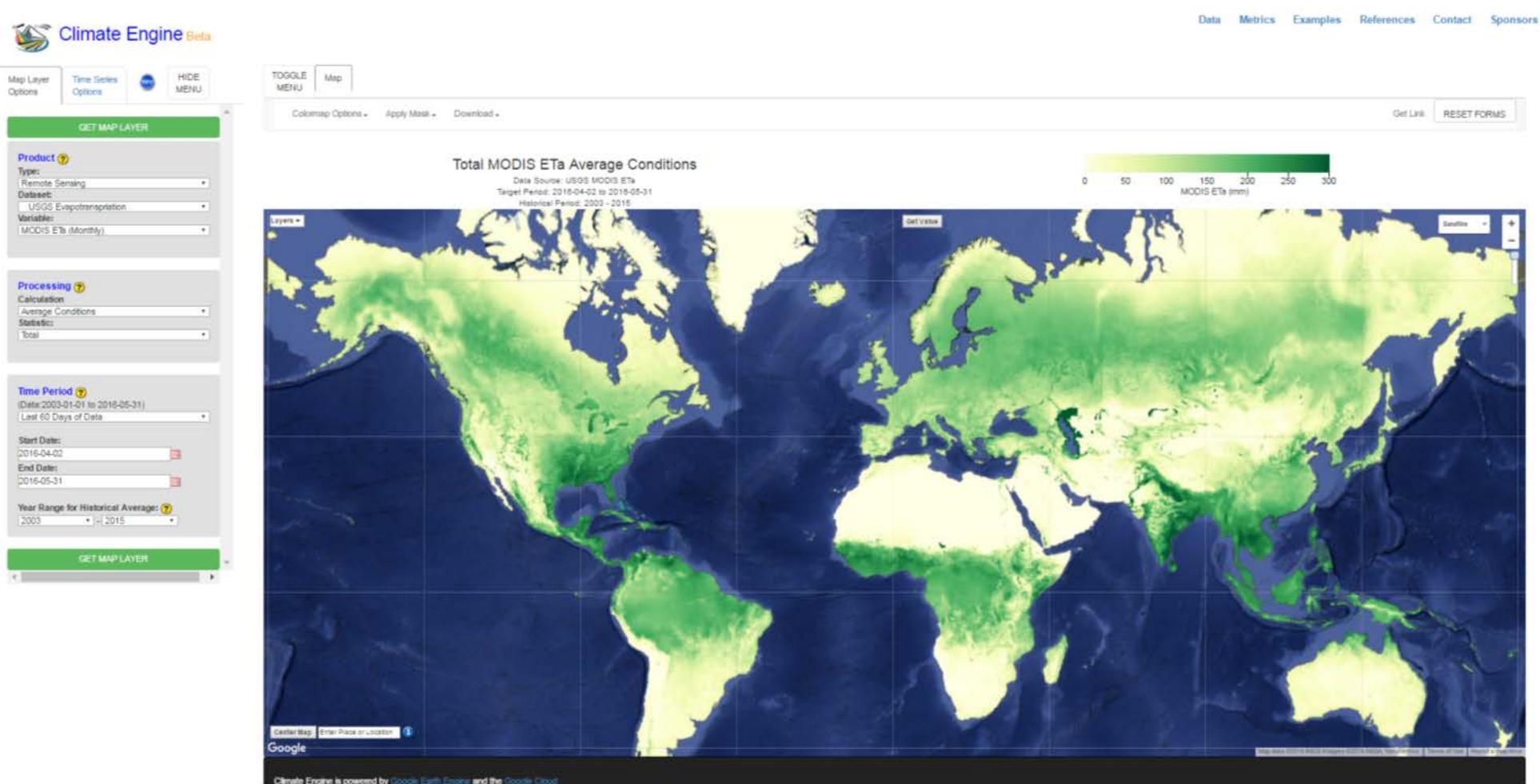
ClimateEngine.org to host and post-post Process ET Data





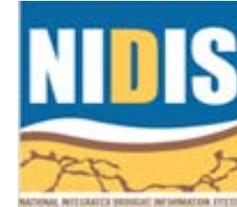
Larger Scale ET Mapping – Coming Soon..

MODIS based USGS ET products loaded to asset manager and accessed through ClimateEngine.org to perform statistical calculations and summaries (i.e. ET and % Difference From Average mapping and time series).. More ET models/products hopefully on the way.. pending funding

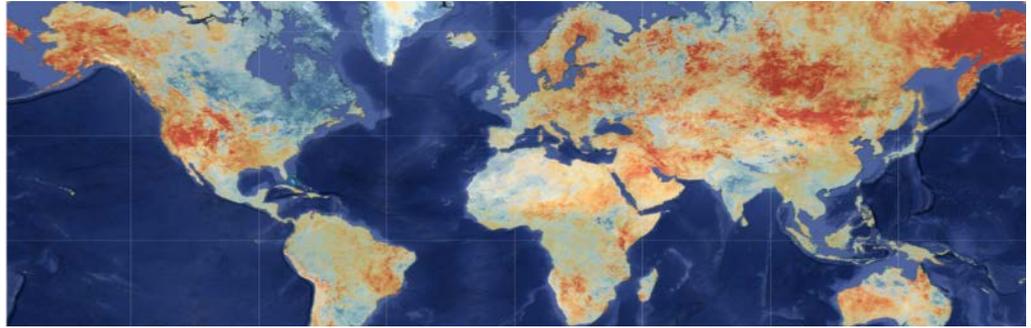


A few impacts of ClimateEngine.org and FEWS NET Apps.

- National Integrated Drought Information System (NIDIS) supporting application and will soon host ClimateEngine.org on Drought.gov for regional and place-based drought monitoring
- Bureau of Land Management and Forest Service supporting application for baseline assessments and operational monitoring of rangelands and groundwater dependent ecosystems
- USAID and FEWS NET African field scientists starting to use FEWS NET app. for crop failure monitoring
- Water resource agencies using ClimateEngine.org for drought, groundwater dependent ecosystem, and water right abandonment
- Being used by several NGOs to perform water resource and ecosystem monitoring related to climate and water development



Summary



- Cloud computing with remote sensing and climate data is amazing!
- Creating never imagined opportunities for advanced drought monitoring with climate and remote sensing data at all scales
- ClimateEngine.org allows for on-demand processing of common climate/drought/vegetation metrics with a simple web connection
- Allows for scientists and non-scientists to perform advanced monitoring
- Download answers instead of archives!

Contact Information:

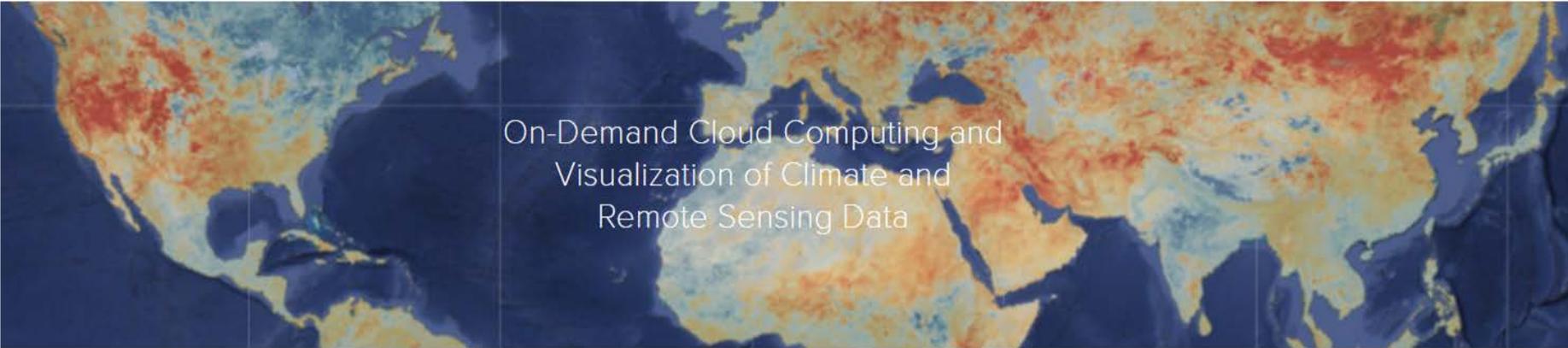
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John Abatzoglou (U Idaho) jabatzoglou@uidaho.edu

Demo of ClimateEngine.org

CLIMATE ENGINE

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On-Demand Cloud Computing and
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Analyze and interact with climate and land-surface environmental monitoring datasets in real-time to improve decision making related to drought, water sustainability, agricultural productivity, wildfire, and ecological health.

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Drought Monitoring



Agriculture & Ecosystems



Wildfire



University
of Idaho



Google