The Matsu Project

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Open Cloud Consortium

What is the Matsu Project?

Matsu is an open source project for processing satellite imagery to support earth sciences researchers using a community science cloud.

Matsu is a joint project between the Open Cloud Consortium and NASA's EO-1 Mission (Dan Mandl, Lead)

OSDC Console Apply Public Data Status Projects Support News/PIRE Open Science Data Cloud

OCC Project Matsu

An open source project for cloud-based processing of satellite imagery to support the earth sciences.

Project Matsu

Project Matsu is a collaboration between NASA and the Open Cloud Consortium to develop open source technology for cloud-based processing of satellite imagery to support the earth sciences. Technology developed by the collaboration include:

- The Namibia Flood Dashboard.
- MapReduced based analytics for identifying floods and CO_2 concentrations.
- Using elastic infrastructure-as-a-service to create Level 1 images each day.
- A Hadoop-based OGC-compliant tiling service and Web MapService.

You can learn more from these five minute videos introducing some Matsu tools.

Matsu Resources

- Daily Namibia Flood Dashboard
- Hadoop-supported Web Map Service Areas of Interest:
  - Carbon Monoxide cluster centers from volcanic eruption
  - Irrigation Patterns in the Sahara
  - Elevation
  - Water Classifier Namibia
  - Water Classifier Italian coast
- Available Matsu images

Matsu Support

- The code can be found at the OCC Github site.
- Description of Matsu Tile and WMS Services.

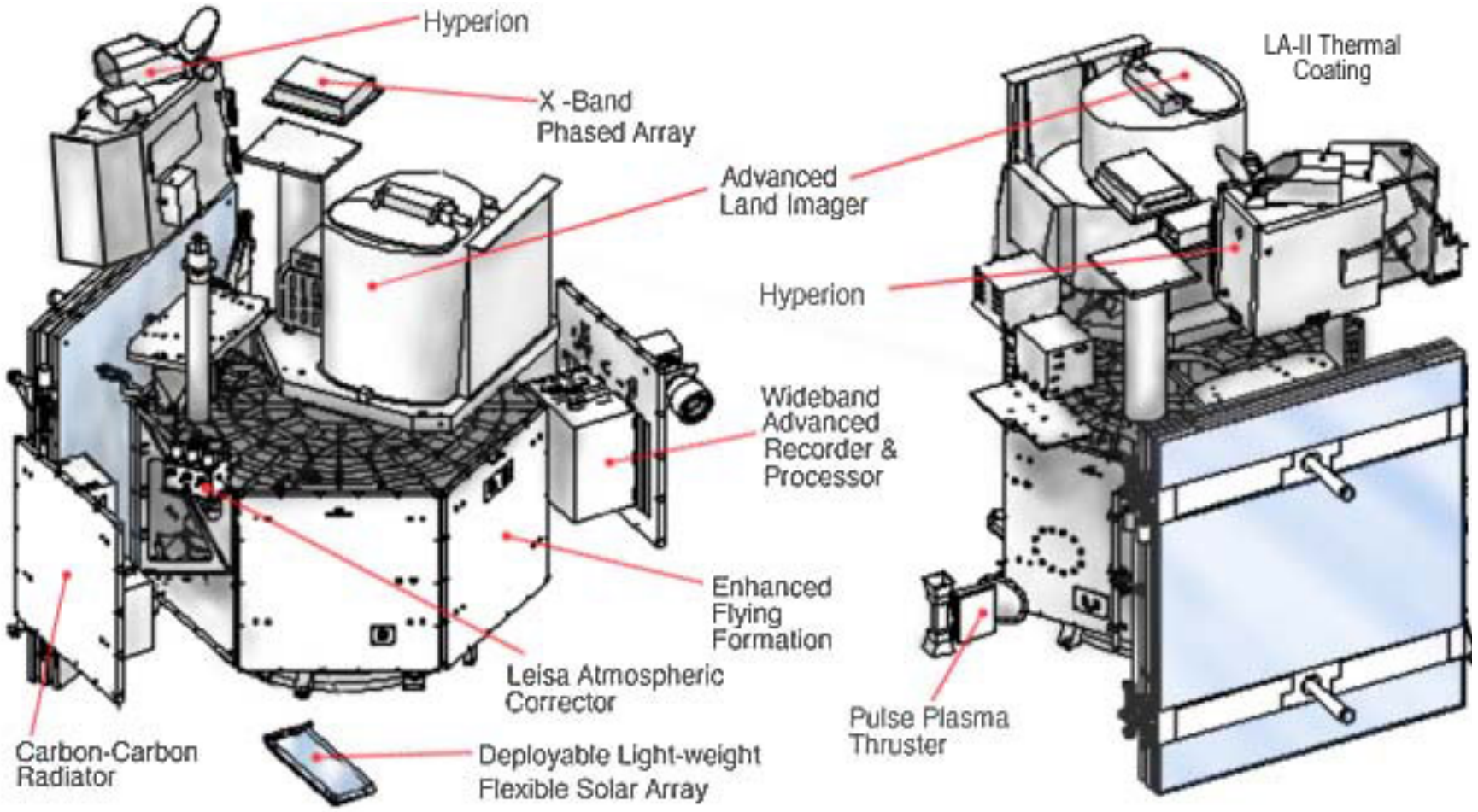
The OSDC is a resource of the Open Cloud Consortium and made possible by our sponsors.

matsu.opensciencedatacloud.org

EO-1 mission

- Approved in March 1996 and launched on November 21, 2000 from Vandenburg Air Force Base, California on a Delta 7320
- All technologies were flight-validated by December 2001
- EO-1 is now in an Extended Mission

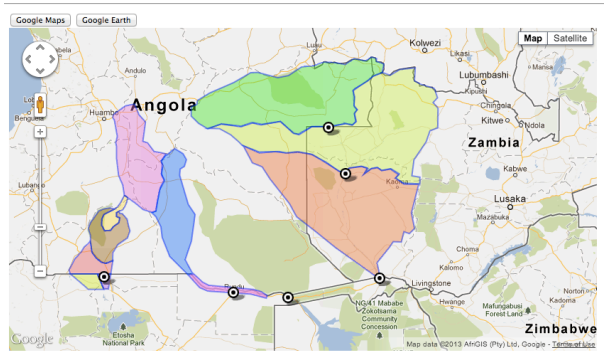
EO-1's ALI and Hyperion Instruments



Data - Instruments

- Hyperion Imaging Spectrometer
  - Designed to gather data from a given region on the Earth by viewing the surface in terms of 242 distinct 'bands' of light.
- Advanced Land Imager (ALI)
  - Used to validate and demonstrate technology for the Landsat Data Continuity Mission (LDCM)

All available L1G images (2010-now)

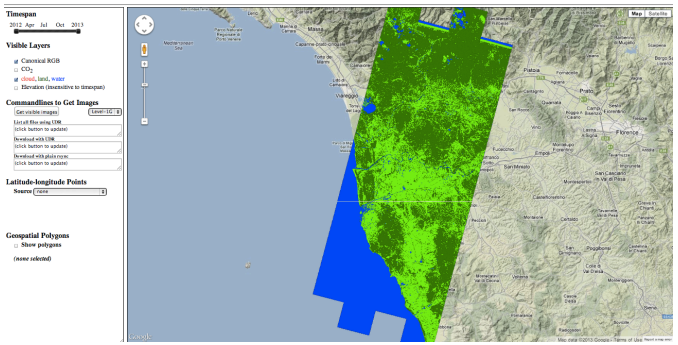


Legend:

ALI Flood Classification	Class 1 - Background:	Class 2 - Opaque Clouds:	Class 3 - Cloud Shadow:	Class 4 - Haze and Thin Clouds:	Class 5 - Clear Water:	Class 6 - Turbid Water:	Class 7 - Dry Land:

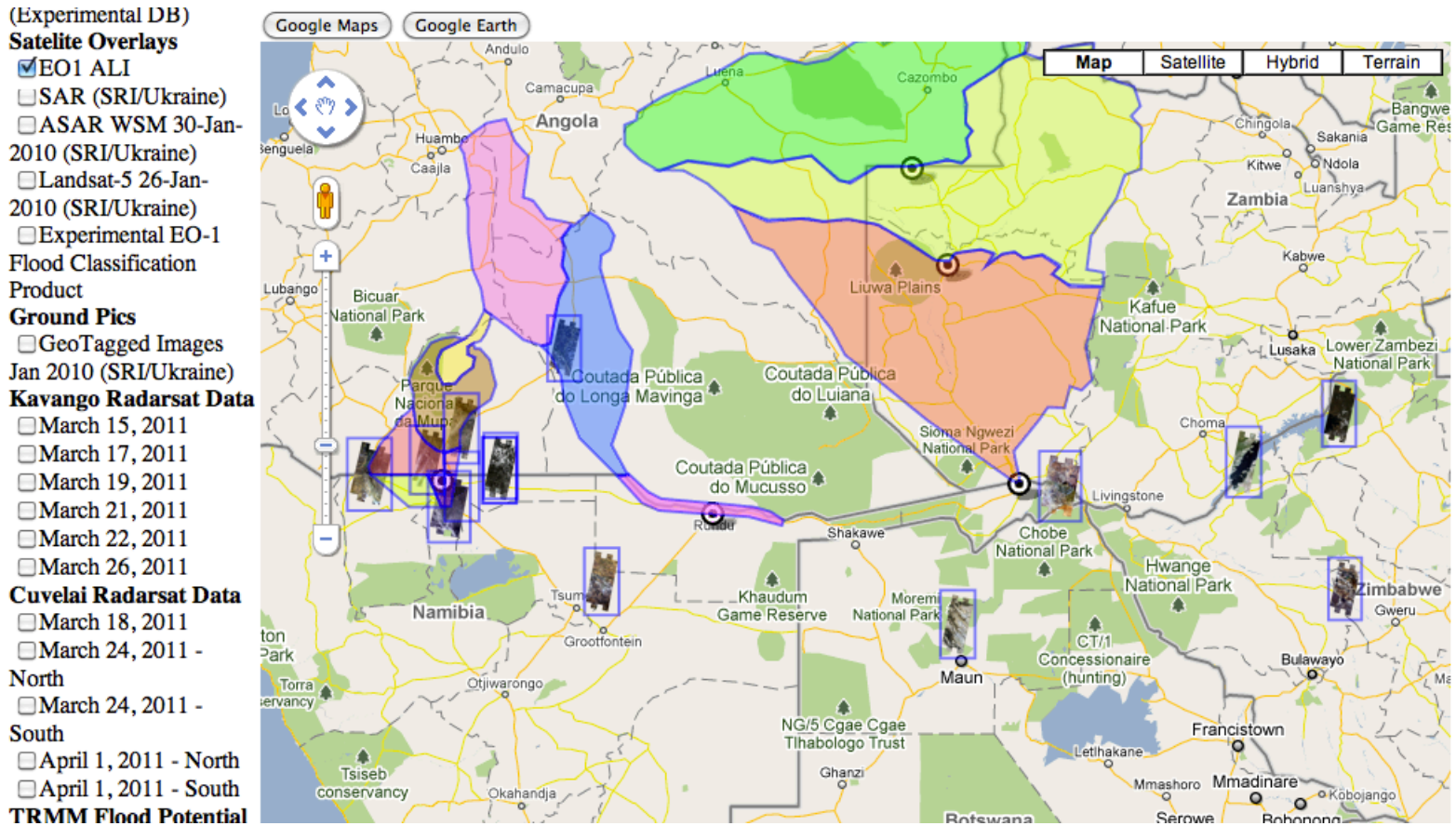
1. Open Science Data Cloud (OSDC) stores Level 0 data from EO-1 and uses an OpenStack-based cloud to create Level 1 data.

2. OSDC also provides OpenStack resources for the Nambia Flood Dashboard developed by Dan Mandl's team.



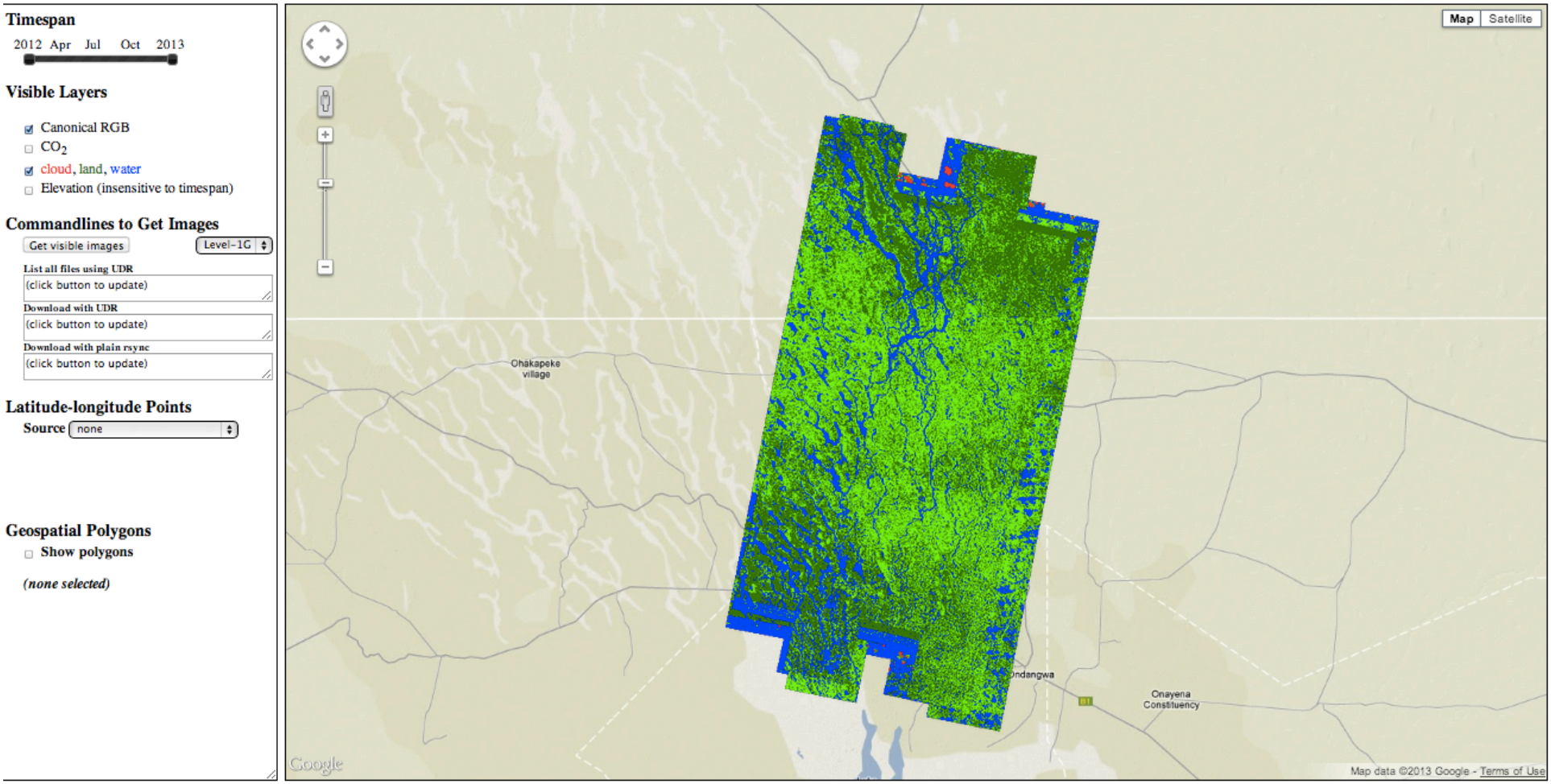
3. Project Matsu uses a Hadoop/Accumulo system to run analytics nightly and to create tiles with OGC-compliant WMTS.

NASA's Matsu Mashup

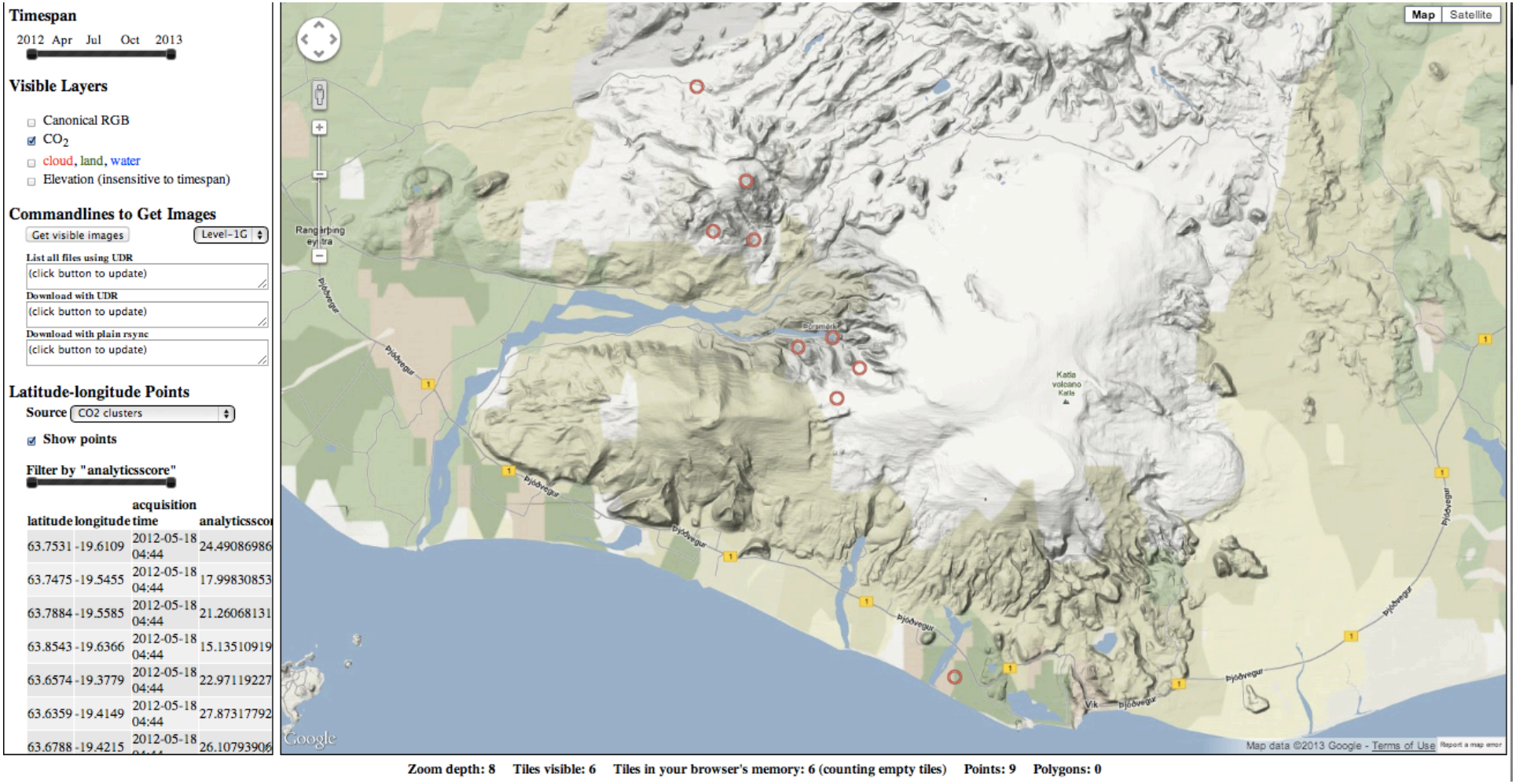


OSDC Satellites

- EO-1 (2012)
- Landsat7 – GLS 2000 (2013)
- MODIS (2013)
- TBD (2014)
- TBD (2015)

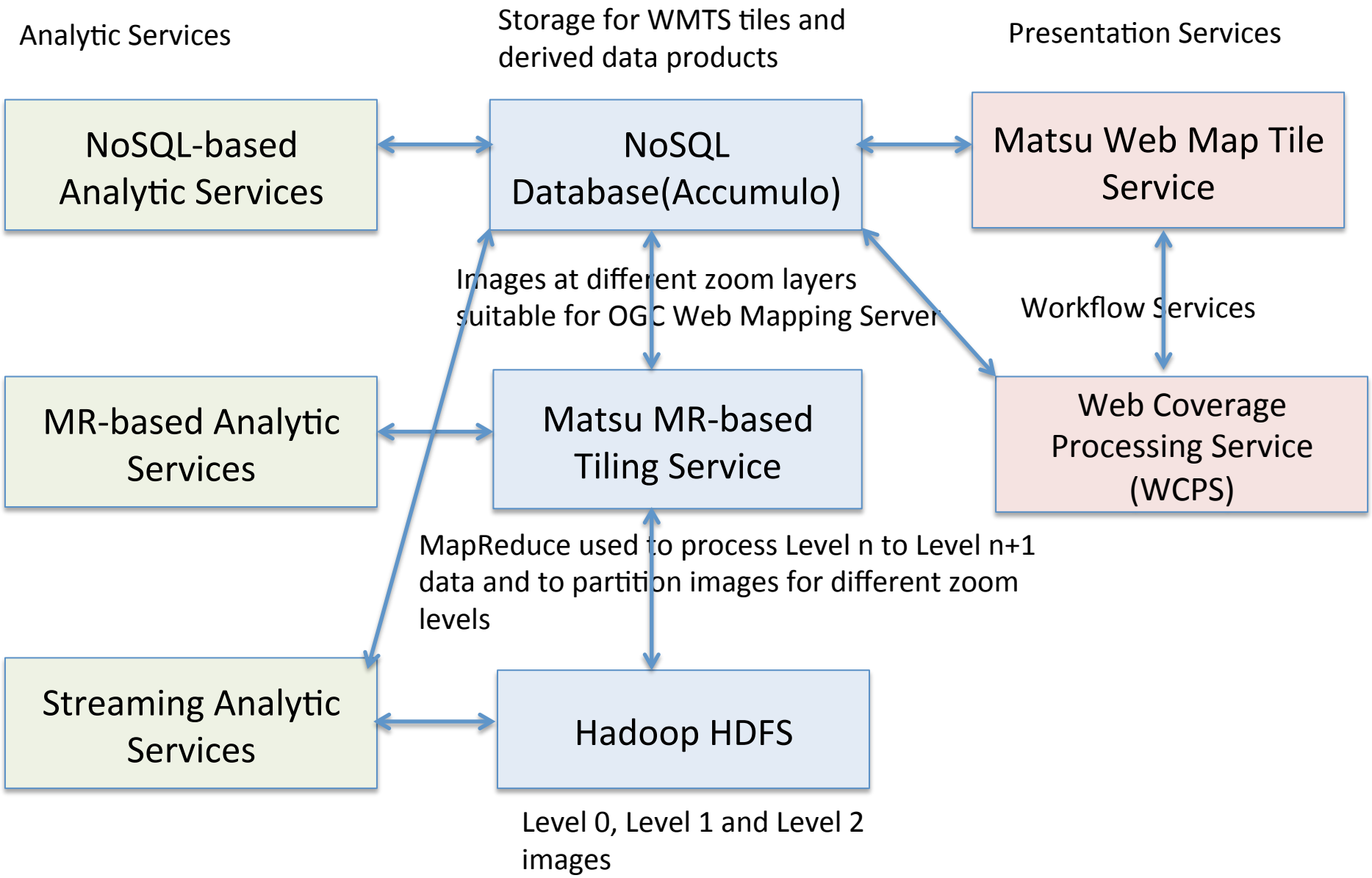


Matsu Web Map Tile Service



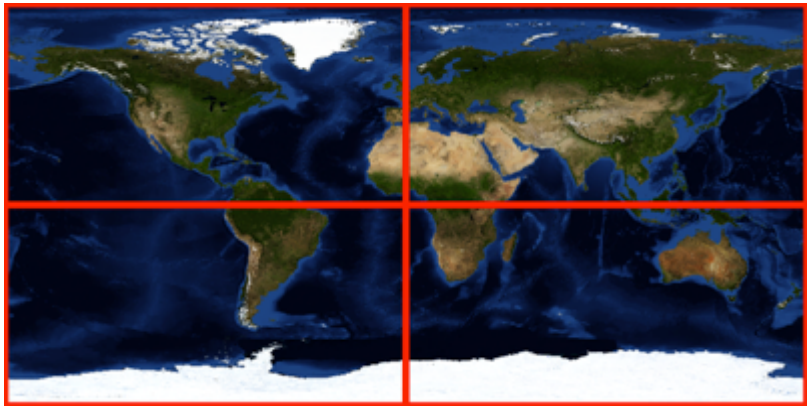
It is easy to layer analytics over the Web Map Tile Service (WMTS). Here is one identifying CO_2

Matsu Hadoop Architecture

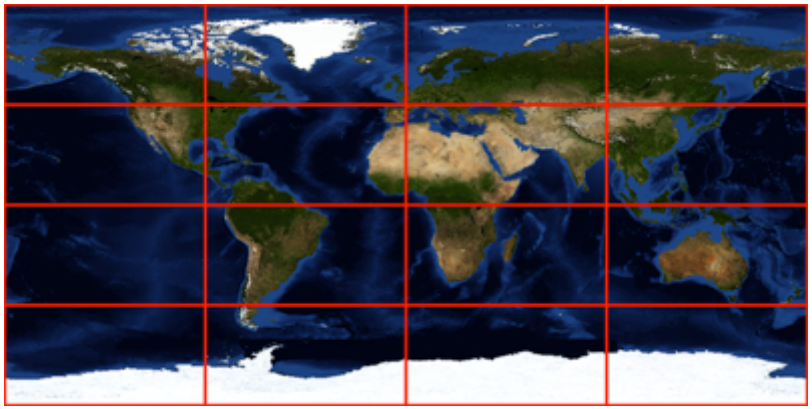


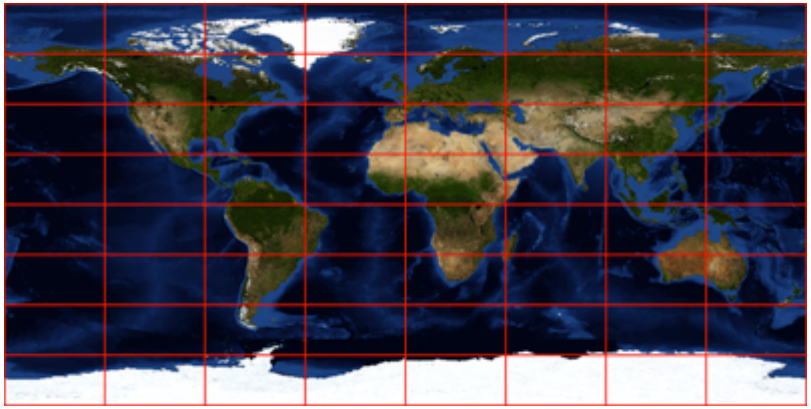
Zoom Levels

Zoom Level 1: 4 images

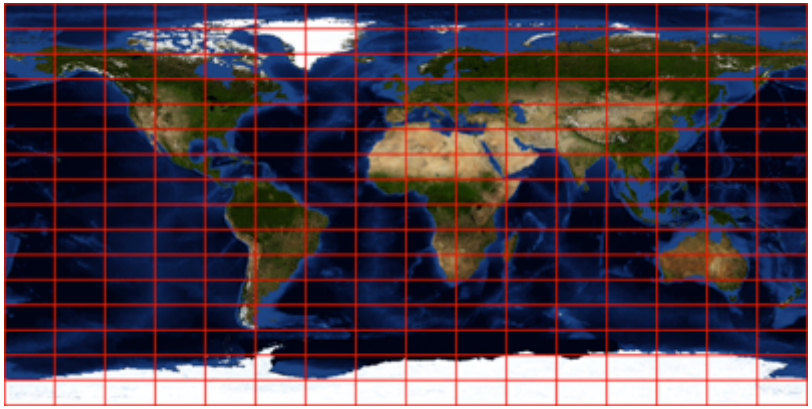


Zoom Level 2: 16 images





Zoom Level 3: 64 images



Zoom Level 4: 256 images

Build Tile Cache: Map

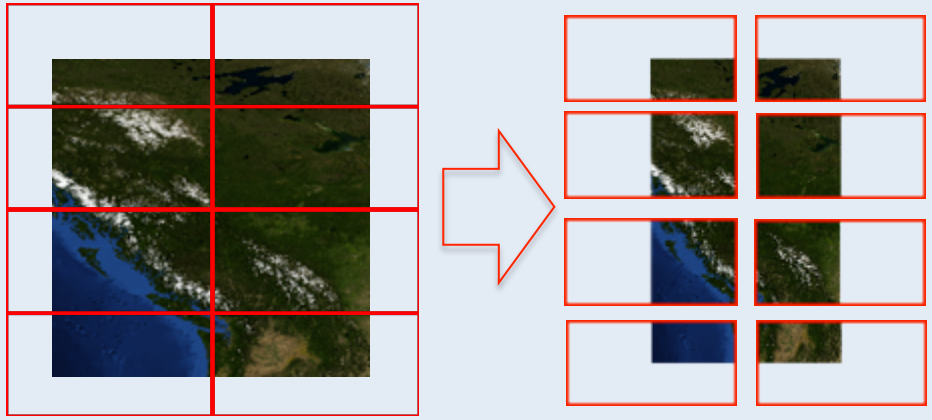
Mapper Input Key: Bounding Box

(minx = -135.0 miny = 45.0 maxx = -112.5 maxy = 67.5)

Mapper Input Value:

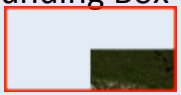
Step 1: Input to Mapper

Mapper resizes and/or cuts up the original image into pieces to output Bounding Boxes

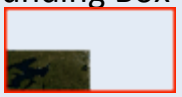


Step 2: Processing in Mapper

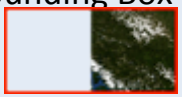
Mapper Output Key: Bounding Box
Mapper Output Value:



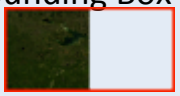
Mapper Output Key: Bounding Box
Mapper Output Value:



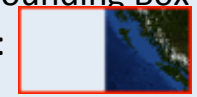
Mapper Output Key: Bounding Box
Mapper Output Value:



Mapper Output Key: Bounding Box
Mapper Output Value:



Mapper Output Key: Bounding Box
Mapper Output Value:



Mapper Output Key: Bounding Box
Mapper Output Value:

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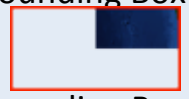
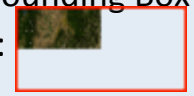
Mapper Output Value:



Mapper Output Key: Bounding Box
Mapper Output Value:



Step 3: Mapper Output

Build Tile Cache: Reduce

Reducer Key Input: Bounding Box
(minx = -45.0 miny = -2.8125 maxx = -43.59375 maxy = -2.109375)
Reducer Value Input:

...

Step 1: Input to Reducer

Assemble Images based on bounding box

Step 2: Reducer Output

- Reducer assembles tiles at each zoom level
- Tiles written to Accumulo (a NoSQL database)

Map Phase

- Map
  - Read in images by Bands, Date, and Region
  - Fix a zoom level for sending to reducers
    - Based on number of reducers and processing power, ***not on*** the zoom you want for display
  - Emit as <key>, <value>
    - Key = <Bounding Box at Fixed Zoom Level>
    - Value = <Bounding Bounding Box at Smallest Zoom Level, Bands, Projection, Timestamp, Image Bytes>

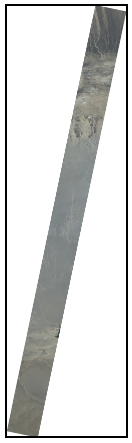
Reduce Phase

- All bytes for bands and satellite strips in this bounding box are mapped to the same reducer
- The key can be identified by the Lat/Long of the upper right corner of the box

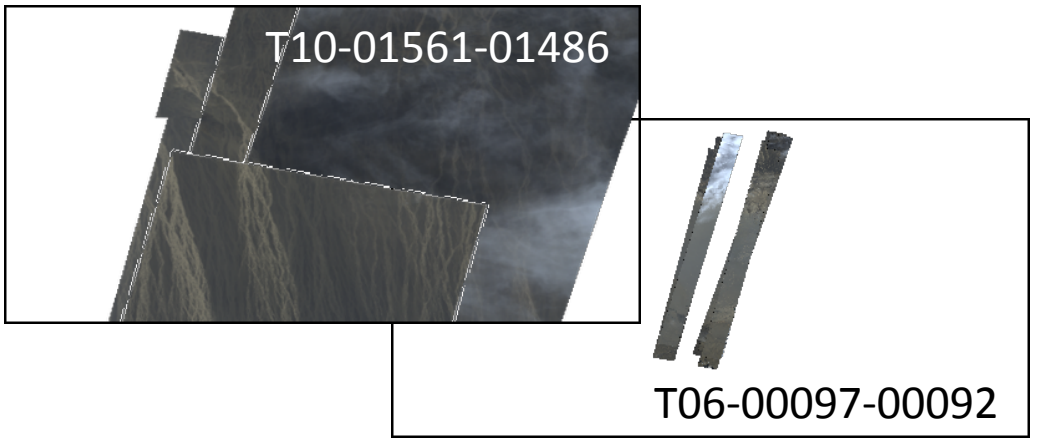
Level 1 Images - Details

location in Google Maps

L1R



L1G



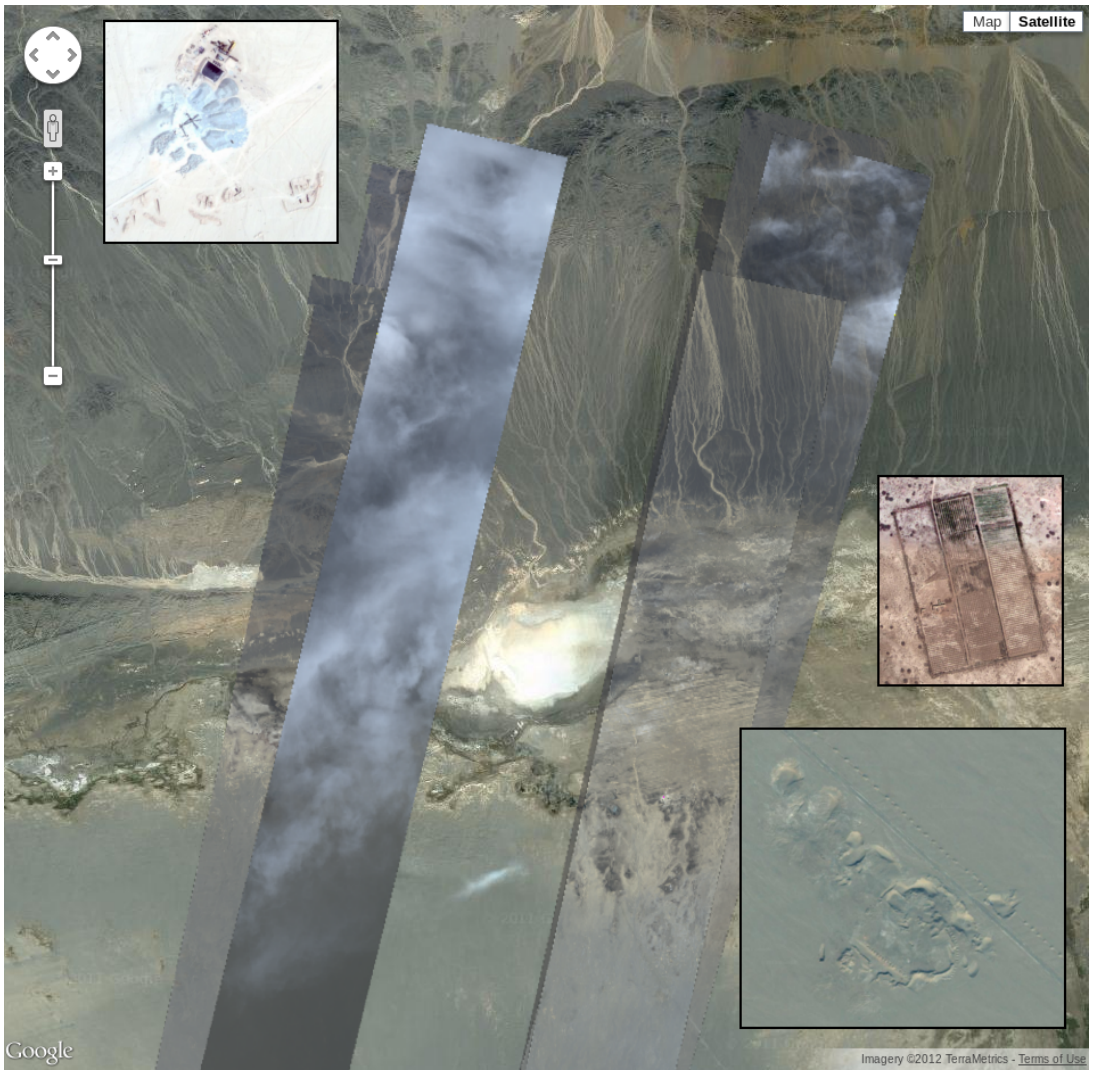
Level-2 tiles made in Map-Reduce, prepared for WMS

- Satellite track images (L1R) are rotated and geolocated (L1G) by NASA
- We overlay L1G images into Level-2 dyadic tiles in Map-Reduce

Some example images

Gobi Desert

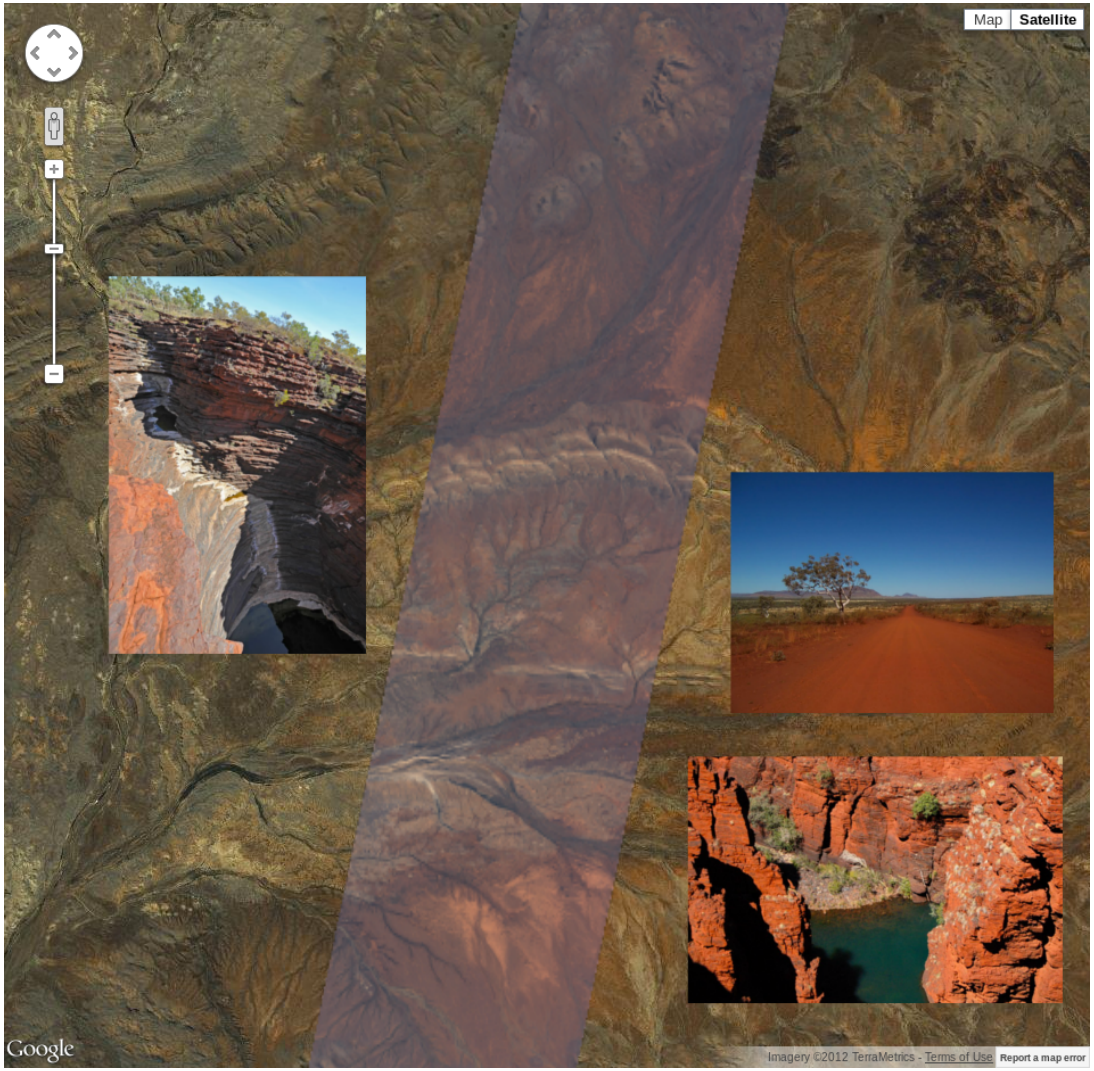
- same as previous page
- contains some strange structures that are too small to spatially resolve with Hyperion, but they might have interesting spectral features



Some example images

Karijini, Australia

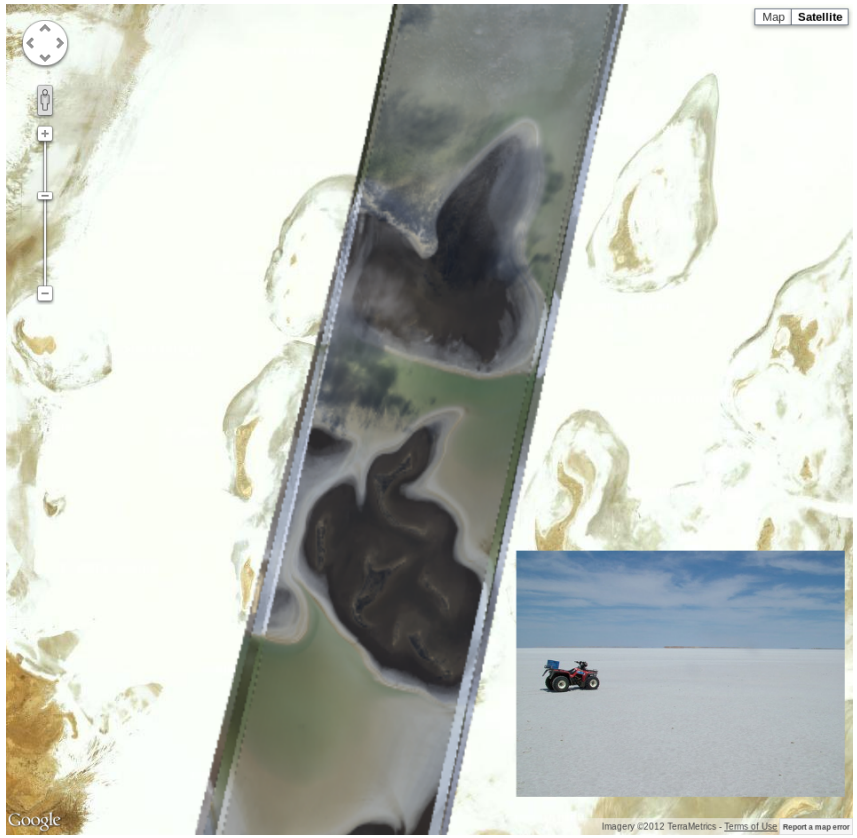
- lots of colorful minerals
- should have a very rich spectrum



Some example images

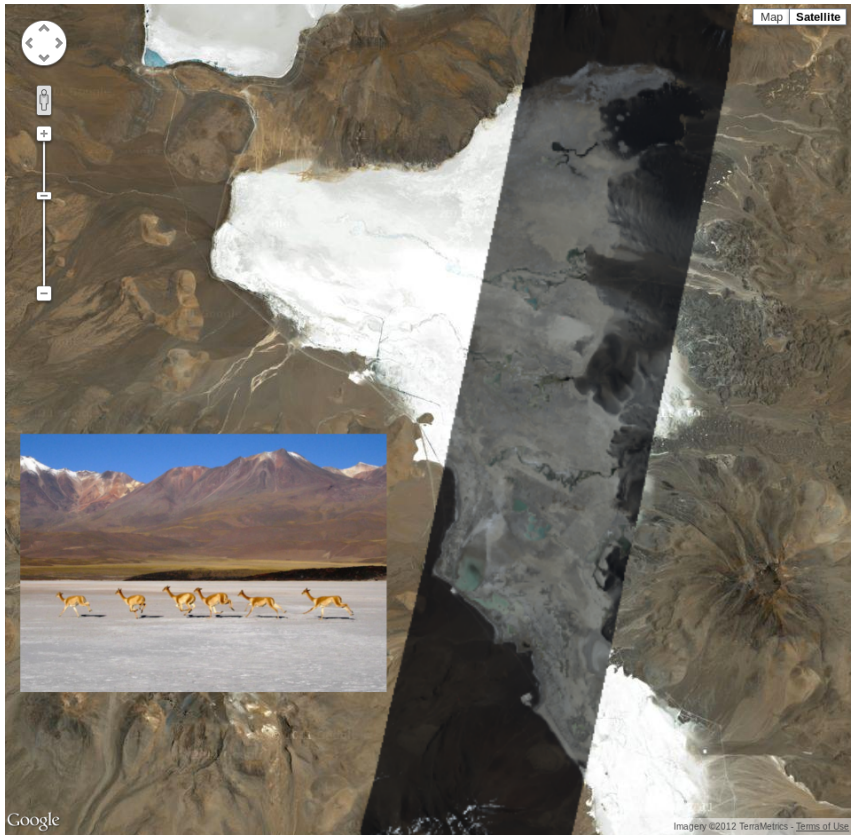
Lake Frome, Australia

- salt bed is a standard calibration target



Atacama Desert, Chile

- salt bed in the driest part of the world



Algebraic combination of spectral bands to make a more sensitive image

- CO_2 has three absorbtion lines within Hyperion's spectral range

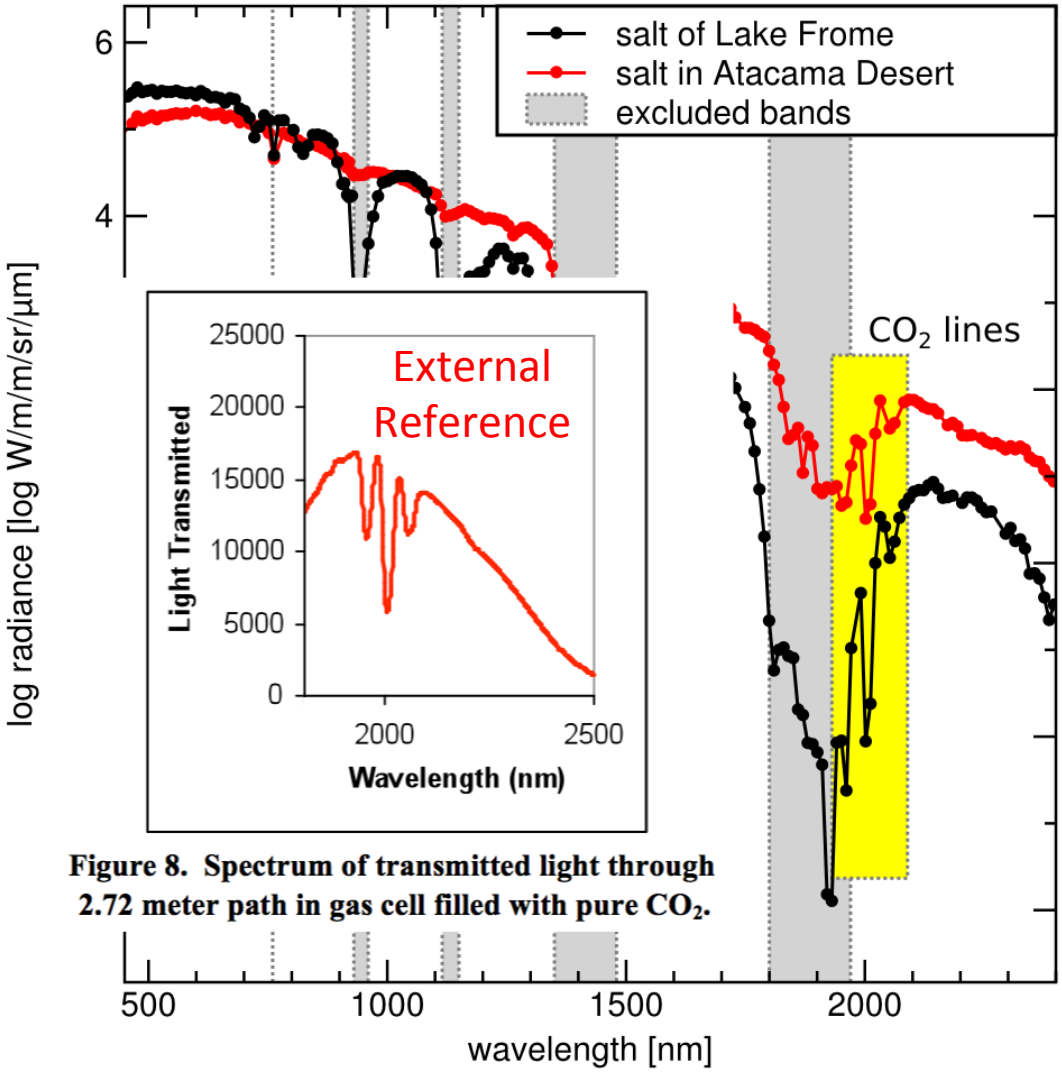
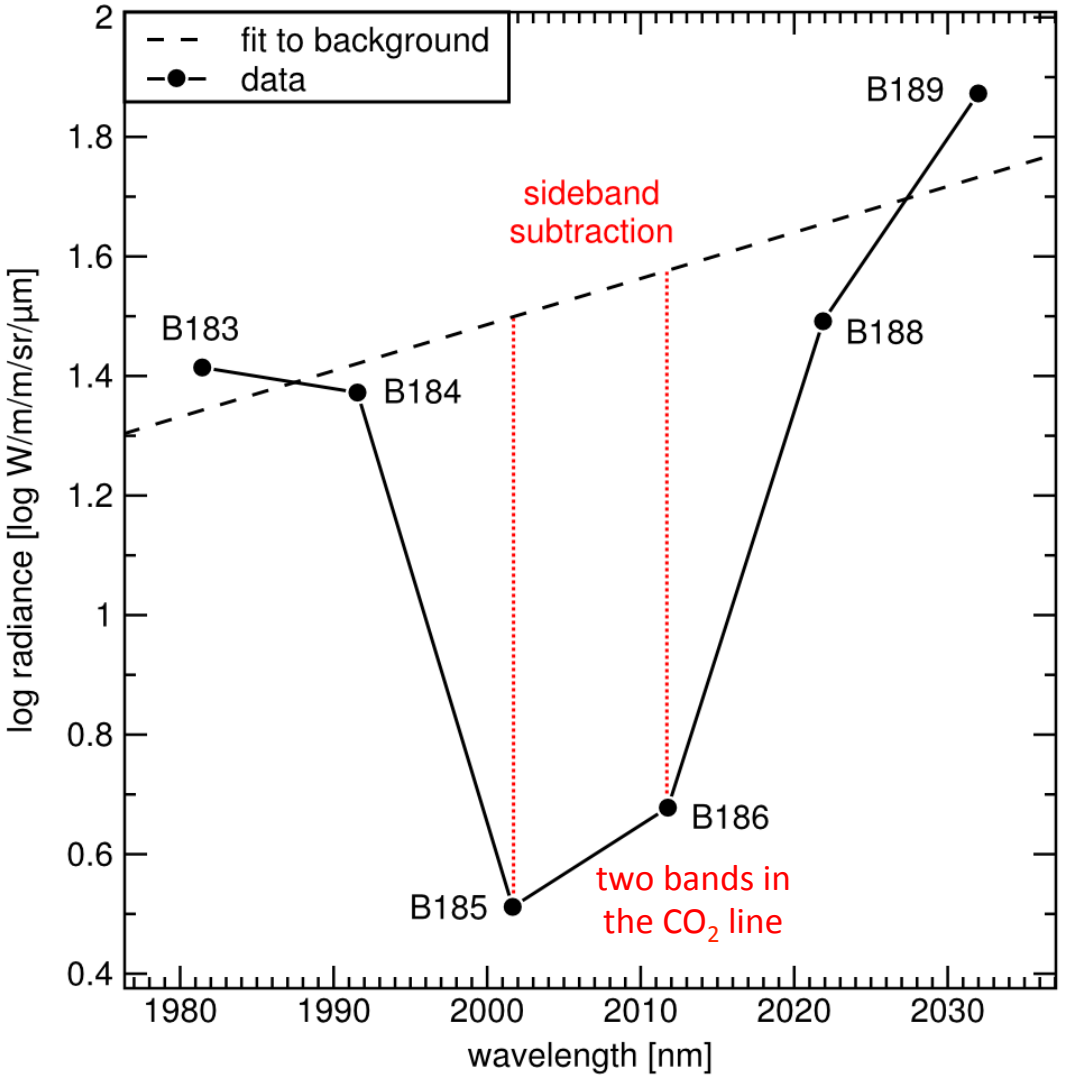


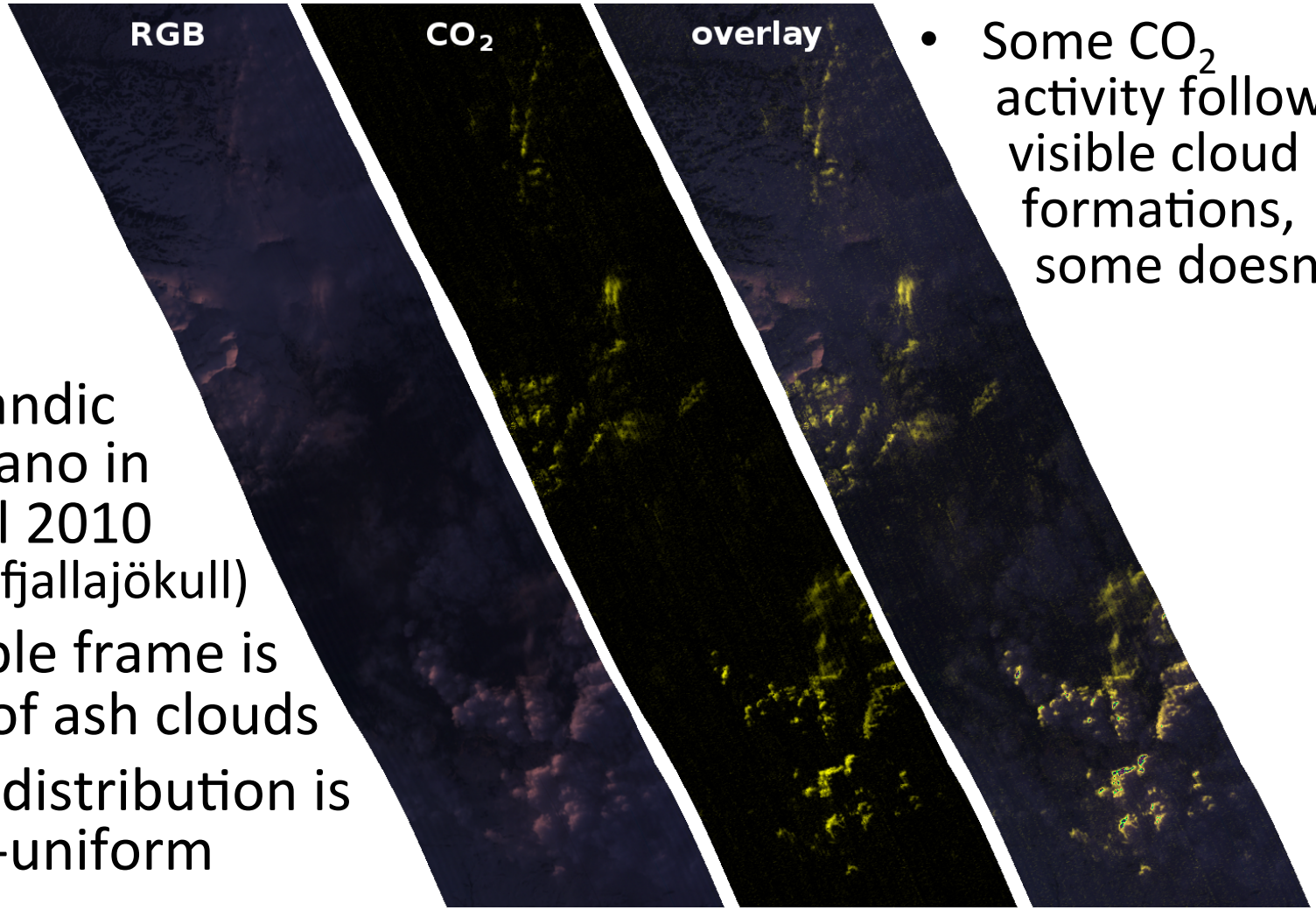
Figure 8. Spectrum of transmitted light through 2.72 meter path in gas cell filled with pure CO_2.

Algebraic combination of spectral bands to make a more sensitive image

- CO_2 has three absorbtion lines within Hyperion's spectral range
- Sideband subtraction technique extracts a pure sample of data in a peak by fitting nearby datapoints to a curve and subtracting peak values from the curve
- In this case, we invert the subtraction because it's an anti-peak



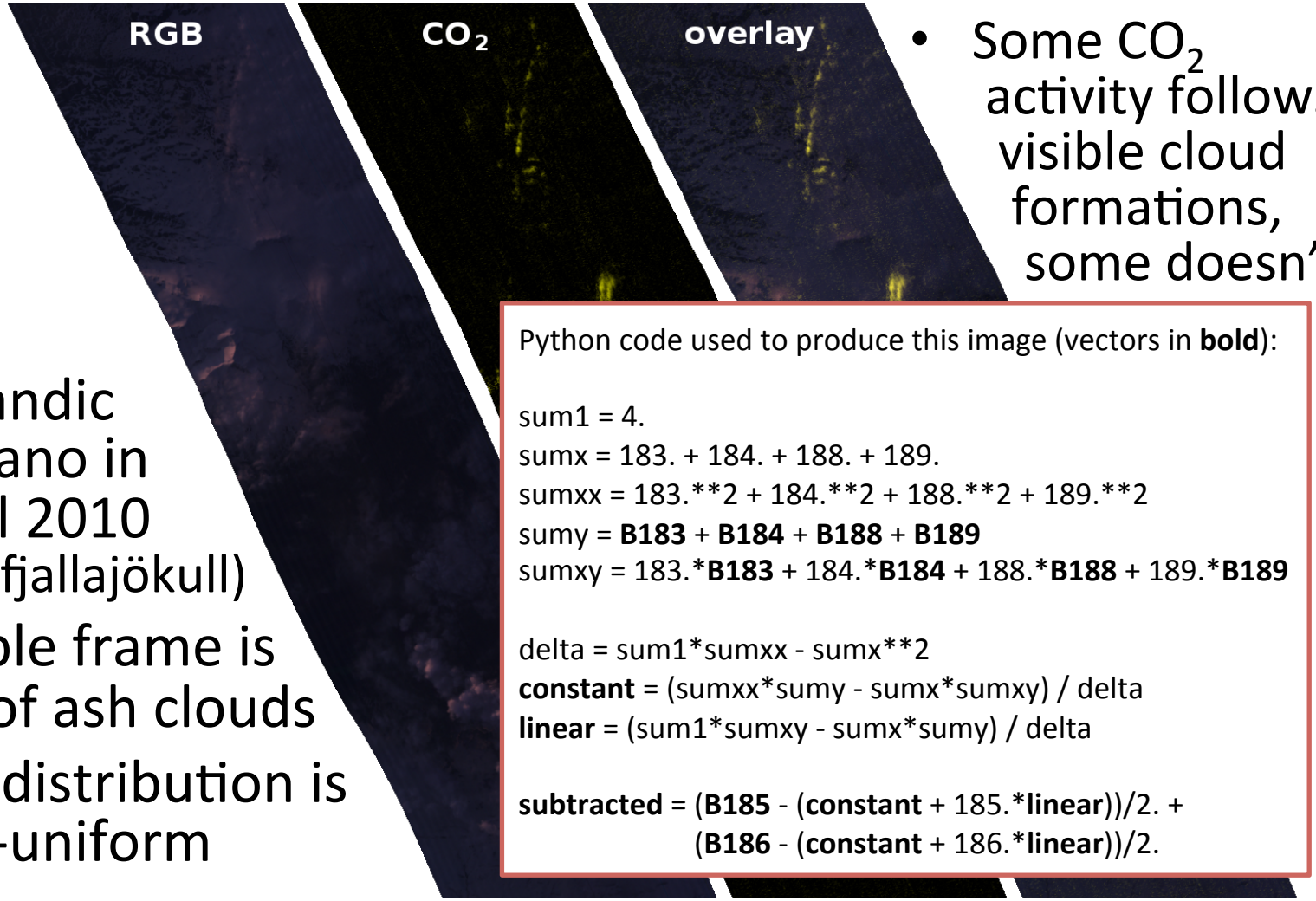
Algebraic combination of spectral bands to make a more sensitive image



- Some CO_2 activity follows visible cloud formations, some doesn't

- Icelandic volcano in April 2010 (Eyjafjallajökull)
- Visible frame is full of ash clouds
- CO_2 distribution is non-uniform

Algebraic combination of spectral bands to make a more sensitive image



- Some CO_2 activity follows visible cloud formations, some doesn't

- Icelandic volcano in April 2010 (Eyjafjallajökull)
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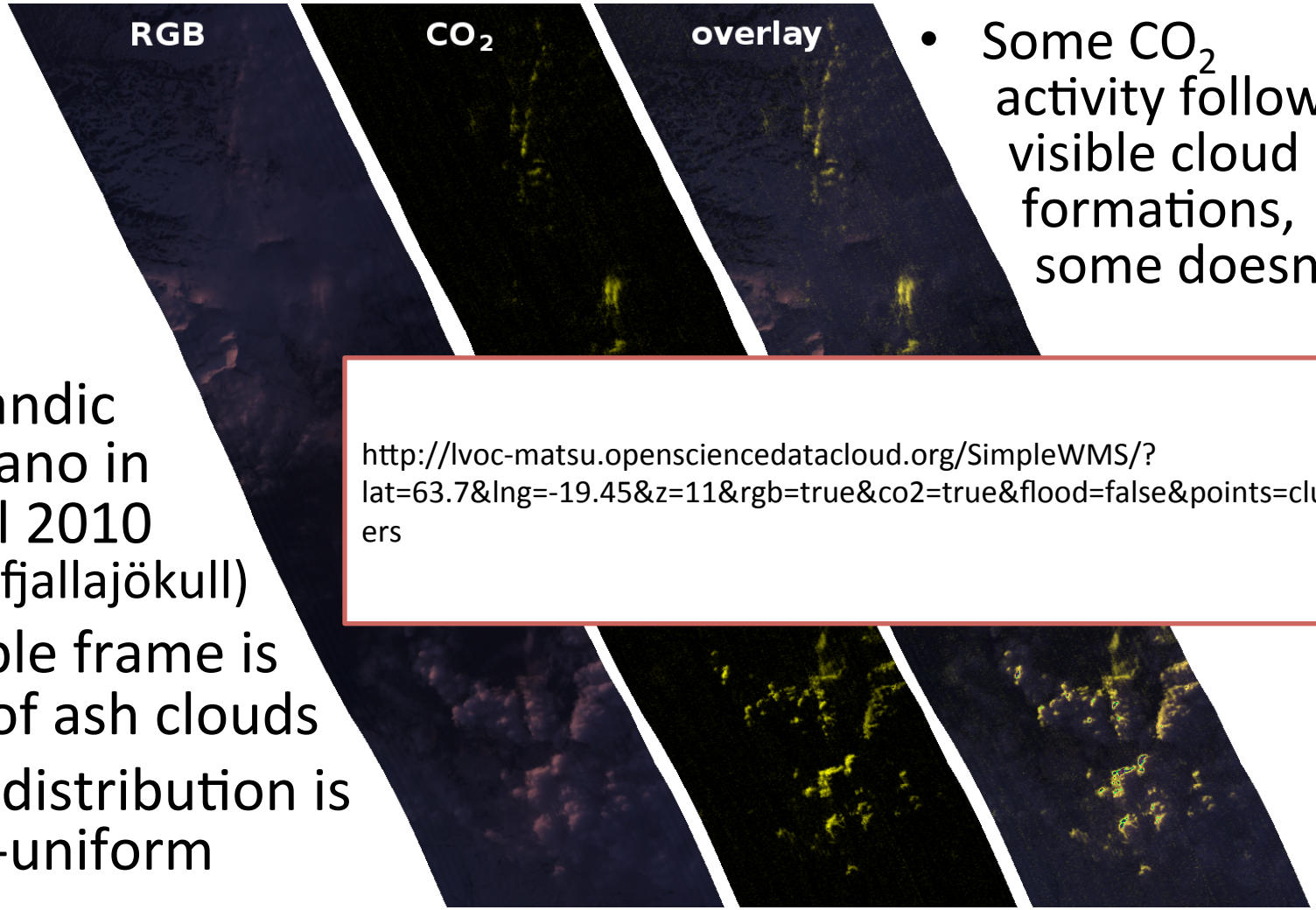
Python code used to produce this image (vectors in **bold**):

```
sum1 = 4.
sumx = 183. + 184. + 188. + 189.
sumxx = 183.**2 + 184.**2 + 188.**2 + 189.**2
sumy = B183 + B184 + B188 + B189
sumxy = 183.*B183 + 184.*B184 + 188.*B188 + 189.*B189

delta = sum1*sumxx - sumx**2
constant = (sumxx*sumy - sumx*sumxy) / delta
linear = (sum1*sumxy - sumx*sumy) / delta

subtracted = (B185 - (constant + 185.*linear))/2. +
             (B186 - (constant + 186.*linear))/2.
```

Algebraic combination of spectral bands to make a more sensitive image



- Some CO_2 activity follows visible cloud formations, some doesn't

- Icelandic volcano in April 2010 (Eyjafjallajökull)
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http://lvoc-matsu.opensciencedatacloud.org/SimpleWMS/?lat=63.7&lng=-19.45&z=11&rgb=true&co2=true&flood=false&points=clusters

Questions

For More Information

- Project Matsu is managed and operated by the Open Cloud Consortium (www.opencloudconsortium.org).
- Project Matsu is supported in part by grants from Gordon and Betty Moore Foundation and the National Science Foundation (Grants OISE - 1129076 and CISE 1127316).
- For more information about Project Matsu, please see the Project Matsu website: matsu.opensciencedatacloud.org
- The Project Director is Robert Grossman, who can be reached at

robert.grossman@uchicago.edu

Here is some detail of how we process EO-1 satellite imagery data using Hadoop in Project Matsu…

Step 1 – Storage & Archiving

From Space to Goddard to the OSDC

1. Transmit data from NASA's EO-1 Satellite to NASA ground stations and then to NASA Goddard
2. At Goddard, align data, perform radiometric corrections and generate Level 0 images (16-bit radiance values)
3. Transmit Level 0 data from NASA Goddard to the OCC's Open Science Data Cloud (OSDC)
4. Store images in a distributed, fault tolerate, file system

Step 2 – Creating Level 1 Images

Building Level 1 Images on the OSDC

1. Each day, the new Level 0 images stored on the OSDC are processed
2. Within the OSDC, NASA launches Virtual Machines (VMs) specifically built to render Level 1 images from Level 0 data.
   - Each Level 1 band is saved as a distinct image
3. Level 1 bands are written to storage facility in the OSCD for long-term public access

Step 3 – Tiling

Matsu Processing

1. Build Web Mapping Tile Service Tiles from Level 1 images using MapReduce
2. Store tiles in Accumulo
   - Index them so that they are accessible via Web Mapping Service
3. Run Analytics on Level 1 images
   - Move results of the analytics to Accumulo

Tiling - Detail

- Use MapReduce to build Web Tiles
  1. Each day, the Level 1 images created by NASA and stored on the OSDC are processed
  2. The Date and Bands (to create a visible image) are specified
  3. Run MapReduce Job
     1. Map – FILL-IN
     2. Partition – FILL-IN
     3. Reduce – FILL-IN

Tile Details, cont'd

- Images are handles as byte streams
- Divide (chunk) the Level 1 images into manageable sizes.
- Dyadic decomposition
  - Divide each image into 4 equal size pieces
  - For each additional zoom, subdivide each piece into 4 equal size pieces
- Tag each chunked images with the bounding box, date, time, dyadic level and bands.
- Convert the bytes into PNG files

Processing the Data

- Reduce
  - Once all images are received for a Bounding Box, sort by the most granular zoom level
  - Process that Zoom Level
  - Once a zoom level in is completed, combine images and scale the build the next zoom level

Accumulo Storage

- Images are stored by Bounding Box
  - -180.0_-90.0_180.0_90.0
- Column family
  - The tile style, zoom, and projection
- Column qualifier
  - Dimensions (width and height, 512 x 256)
- Value
  - the corresponding PNG image in raw bytes

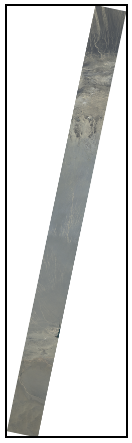
Serve to WMTS

- The WMTS query:
  - Bounding Box
  - Date
  - Layer name as a string
    - Haiti
  - Style name as a string
    - The bands used to build the Level 1 image or an alias: “B058:B023:B015” or “agricultural”
- Not supported
  - Map Project could be used, but for now, we only support a single projection

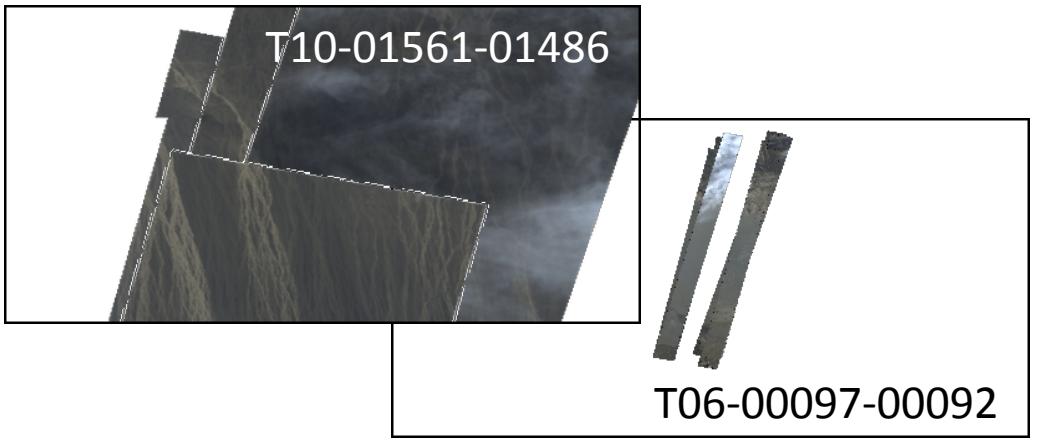
Images: stages of processing

image locations (viewed in Google Maps)

L1R



L1G



Level-2 tiles made in Map-Reduce, prepared for WMS

- Satellite track images (L1R) are rotated and geolocated (L1G) by NASA
- We overlay L1G images into Level-2 dyadic tiles using Map-Reduce